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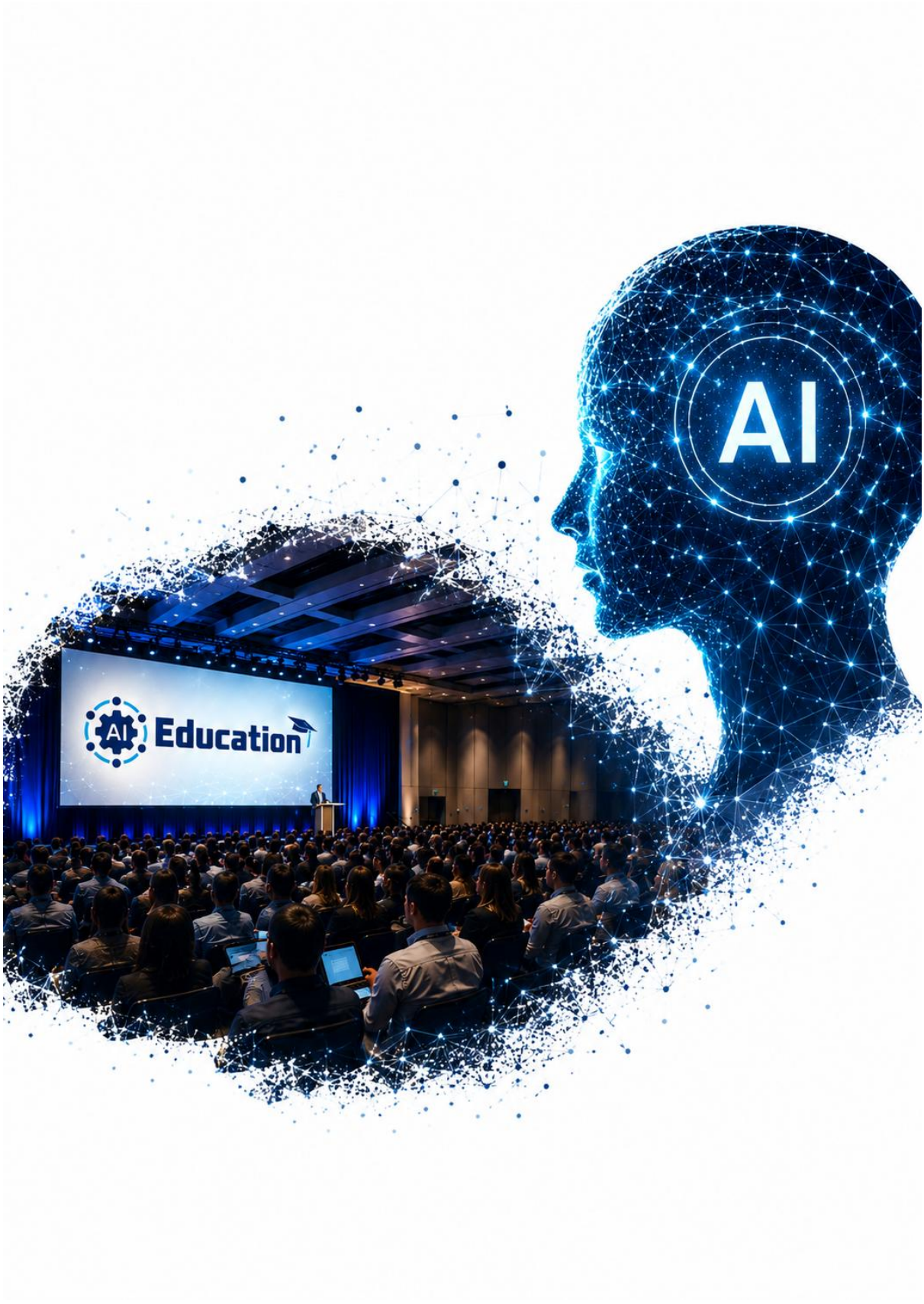
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Message from the Conference Chairs

Dear Colleagues and Friends,

On behalf of the Organizing and Scientific Committees, it is our distinct privilege to present the official conference proceedings of the 2025 International Conference on Artificial Intelligence in Education (AI-Education 2025), held on December 12 and 13, 2025, at the Thessaloniki campus of the International Hellenic University (IHU), Greece.

AI-Education 2025 has successfully concluded, marking a critical milestone in academic dialogue around the integration of intelligent agents, multi-modal systems, and machine learning models within contemporary classrooms. This volume serves as a comprehensive record of the rich scholarly contributions, innovative methodologies, and rigorous ethical debates presented over the course of the event. Rather than a prospective look, these proceedings represent a reflective synthesis of research that has already been tested, debated, and refined by our academic community.

The core theme of the conference, 'Human vs Artificial: Learning and Thriving in a Digital Age,' provided a vibrant framework for exploration. Throughout the parallel technical sessions, researchers scrutinized how AI can serve as a catalyst for educational justice, a collaborative companion in specialized disciplines, and an automated grading and assessment mechanism to reduce teacher workloads. At the same time, substantial attention was dedicated to the socio-ethical alignment of human creativity and the philosophical, legal, and systemic challenges associated with automated pedagogical mediation.

We extend our deepest gratitude to the keynote speakers, the institutional co-organizers, our sponsors, and the media partners whose generous support rendered this event possible. Most importantly, we thank the authors and presenters whose high-quality papers constitute the core of this volume. It is our hope that the insights preserved herein will continue to inspire transformative pedagogical frameworks, equitable digital infrastructures, and responsible technological governance in education world-wide.

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Analysis and Implementation of the UNESCO AI Competency Framework: A Case Study of a Multimodal Teacher Training Program

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Abstract— The UNESCO AI Competency Framework for Teachers (2024) defines five competency areas (Human-centred mindset, Ethics of AI, AI foundations and applications, AI pedagogy, AI for professional development) across three progression levels (Acquire-Deepen-Create). Despite its recognition as a global standard, AI competency frameworks for teachers remain rare globally (only seven countries by 2022), while documented implementation models of the UNESCO framework are absent. Key challenges include translating theoretical descriptions into concrete educational activities, integrating multiple educational theories without cognitive overload, and ensuring progressive competency development. This work analyzes these challenges and presents an implementation case study through a design-based research approach.

The research question explores how the UNESCO framework can be translated into a functional educational program that integrates educational theory without cognitive burden. Through an iterative design process spanning 7 + 2 cycles, a program was developed in two versions (Greek and English) with 110 participants in total. The methodology was based on systematic alignment of each module with the five areas and three levels of the framework, applying TPACK for the holistic approach to technology-pedagogy-content, UDL for accessibility, and Bloom's Taxonomy for cognitive complexity, through an "invisible theory" strategy that embeds pedagogical principles without academic terminology.

The implementation analysis reveals specific design decisions for each area: For Human-centred mindset, five transversal pedagogical pillars were developed (critical thinking, ethical use, personalization, collaboration, assessment). For Ethics of AI, a dedicated module was combined with embedded ethical dilemmas presented through audio scenarios featuring virtual educators expressing concerns before expert solutions. For AI foundations, progressive complexity was applied from basic concepts (Acquire) to LLMs and prompt engineering (Deepen) to content creation (Create), with the development of EduPrompt Studio as a tool that implements automatic integration of educational theories into prompt generation. For AI pedagogy, UDL applications and differentiation were incorporated. For Professional development, an ecosystem was created with Teacher Toolbox, forums, and self-reflection. The implementation leveraged multimodal means—AI-generated podcasts with dialogical approach, virtual exhibitions on the ArtSteps platform for visualization of ethical dilemmas, H5P interactive exercises—to support different learning styles. Strategic partnerships with

six international platforms (Brisk, Genially, Twee, Redmenta, Eduaide, Almanack) provided premium access (3-12 months) for immediate practical application of professional tools, ensuring the transition from theory to practice.

The case study identifies three critical factors for successful implementation: explicit alignment with progression levels in each activity, strategic partnerships for practical tool application, and reusable architecture adaptable to different cultural contexts. The contribution is twofold: an analytical model for implementing the UNESCO framework and design principles for replicability in other educational systems. Future research will investigate effectiveness through systematic evaluation of participants.

Keywords— UNESCO AI Competency Framework, Teacher Professional Development, Design-Based Research, Implementation Model, Case Study

Introduction

The integration of artificial intelligence (AI) into educational practice has emerged as a critical imperative for teacher professional development. UNESCO's AI Competency Framework for Teachers (UNESCO, 2024) represents the most systematic attempt to articulate the competencies required for effective AI integration into pedagogy. The framework delineates 15 competency blocks across five key areas (Human-centred mindset, Ethics of AI, AI foundations, AI pedagogy, and Professional development) that progress through three developmental levels (Acquire, Deepen, and Create).

Despite the framework's comprehensive theoretical foundation, a significant implementation gap persists between these competency specifications and functional educational programs. The challenge lies in operationalizing these abstract competency frameworks into coherent, theory-infused educational experiences that address multiple competency areas simultaneously without creating cognitive overload. According to UNESCO (2022), only seven countries had developed national AI programs for teachers, and these primarily focused on basic digital literacy rather than comprehensive AI competency development. Furthermore, programs must embed technological knowledge within robust pedagogical frameworks, honoring established theories such as constructivism (Piaget, 1952; Vygotsky, 1978) and adult learning principles (Knowles, 1984).

This paper addresses a fundamental question: How can UNESCO's AI Competency Framework for Teachers be systematically translated into a functional educational program that integrates multiple educational theories while maintaining comprehensive coverage of all competency areas and developmental levels? We examine this question through a design-based research case study of a multimodal teacher training program implemented across seven cycles from September 2024 onwards with 110 participants. The program was designed with explicit alignment to UNESCO’s framework, operationalizing all 15 competency blocks across the three developmental levels through innovative design elements including five transversal pedagogical pillars, theory-infused prompt engineering tools, and multimedia ethics scenarios. The program embeds theoretical principles (constructivism, UDL, TPACK) into practical tools and activities through what we term "invisible theory"—the systematic incorporation of pedagogical frameworks without overwhelming participants with academic terminology (Knowles, 1984).

This case study makes three significant contributions to the field of AI in teacher education. First, it provides the first documented implementation achieving 100% coverage of UNESCO's AI Competency Framework. Second, it offers a replicable model for operationalizing competency frameworks through the integration of transversal pillars, progressive complexity structures, and theory-infused tools. Third, it demonstrates methods for embedding multiple educational theories (including constructivism, andragogy, TPACK, UDL, and Bloom's Taxonomy) into coherent learning experiences without creating theoretical overload or losing practical relevance.

The paper proceeds as follows: The Theoretical Framework section examines the UNESCO AI Competency Framework and supporting educational theories. The Methodology section describes the design-based research approach and systematic alignment procedures. The Implementation Analysis section details design decisions

for each of UNESCO's five competency areas and demonstrates how transversal pillars and integrated tools operationalize the framework. The Results and Discussion section synthesizes findings regarding comprehensive coverage, theoretical integration, and participant transformation. The Conclusion identifies implications for teacher education programs and policy makers.

Theoretical Framework

UNESCO AI Competency Framework for Teachers

The UNESCO AI Competency Framework for Teachers (UNESCO, 2024) represents the first global attempt to systematically articulate what teachers need to know and be able to do to effectively integrate AI into educational practice. The framework is structured as a two-dimensional matrix comprising five competency aspects that evolve across three progression levels, forming fifteen distinct competency blocks.

The five competency aspects represent interlinked domains of knowledge, skills, values, and attitudes:
Aspect 1: Human-centred mindset defines the values and critical attitudes teachers need to develop towards human-AI interactions, emphasizing human agency, accountability, and social responsibility. Teachers learn to evaluate AI's benefits and risks while ensuring human flourishing remains central.
Aspect 2: Ethics of AI delineates essential ethical principles, regulations, and practical rules that teachers must understand and apply. This progresses from understanding fundamental ethical principles to making safe and responsible use of AI, ultimately enabling participation in co-creating ethical guidelines for educational contexts.
Aspect 3: AI foundations and applications specifies conceptual knowledge and operational skills necessary for selecting, applying, and customizing AI tools. Teachers develop understanding of AI definitions and basic functionality, skills to evaluate tool appropriateness, and ultimately the ability to creatively adapt AI for student-centered learning environments.
Aspect 4: AI pedagogy proposes competencies for purposeful and effective AI-pedagogy integration, covering the validation and selection of appropriate tools and their integration with pedagogical methods to support course preparation, teaching, learning, and assessment.
Aspect 5: AI for professional development outlines competencies for using AI to drive lifelong professional learning, support collaborative development, and explore professional transformation.
These five aspects develop across three progression levels: **Acquire** establishes foundational knowledge enabling teachers to evaluate and use AI tools appropriately; **Deepen** develops intermediate competencies for designing meaningful pedagogical strategies integrating AI; and **Create** cultivates advanced competencies for creative configuration of AI systems and innovative educational applications.

Foundational Learning Theories

The program's theoretical foundation rests on constructivist epistemology, which posits that learners actively construct knowledge through experience and reflection rather than passively receiving information (Piaget, 1952; Vygotsky, 1978). Vygotsky's social constructivism particularly emphasizes the role of social interaction and cultural tools

in learning, directly relevant to AI integration where technology serves as a mediating artifact. This constructivist foundation manifests in the program's emphasis on hands-on practice, peer collaboration, and reflective activities.

Knowles' (1984) andragogical principles inform the program's design for adult learners. Andragogy recognizes that adults are self-directed learners who bring accumulated experience, require immediate practical application, and are motivated by relevance to their professional contexts. The program operationalizes these principles through authentic teaching scenarios, teacher-selected application contexts, and emphasis on immediately implementable strategies.

Integration Frameworks

Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) framework provides the structure for integrating AI technology with pedagogical knowledge and content expertise. Rather than treating technology as a separate domain, TPACK emphasizes the complex interplay between technology, pedagogy, and content, ensuring that AI tools serve pedagogical goals rather than becoming ends in themselves.

Universal Design for Learning (Meyer, Rose, & Gordon, 2014) principles ensure accessibility and multiple means of representation, engagement, and expression throughout the program. UDL implementation includes multimedia content formats, varied assessment approaches, and flexible pathways through learning materials.

Anderson and Krathwohl's (2001) revised Bloom's Taxonomy guides the progressive cognitive complexity across the program's three-phase structure (Acquire-Deepen-Create), moving from knowledge and comprehension through application and analysis to evaluation and creation.

Transversal Competencies

The program integrates additional theoretical frameworks as transversal competencies woven throughout all modules. Critical thinking development draws on Facione's (1990) consensus definition and Paul and Elder's (2001) framework for analytical and evaluative thinking. Collaborative learning employs Johnson and Johnson's (1999) cooperative learning principles emphasizing positive interdependence and individual accountability. Personalization and differentiation apply Tomlinson's (1999) strategies for addressing diverse learner needs through content, process, and product differentiation. Formative assessment integrates Black and Wiliam's (1998) principles of ongoing feedback and self-regulated learning. Human-centered AI design principles (Shneiderman, 2022) ensure that technology amplifies rather than replaces human capabilities, maintaining teacher agency and ethical responsibility.

These theoretical foundations do not exist as abstract justifications but are operationalized through specific program elements: the EduPrompt Studio application embeds pedagogical theories into AI prompt generation; audio ethics dilemmas present constructivist learning scenarios; Teacher Toolboxes provide differentiated resources; and structured forums enable collaborative knowledge construction. This "invisible theory" approach ensures theoretical rigor without overwhelming participants with

academic terminology, honoring andragogical principles of immediate practical application while developing deeper pedagogical understanding.

Methodology

Design-Based Research Approach

This study employs design-based research methodology (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004), an approach particularly suited to developing and refining educational innovations through iterative cycles of design, implementation, analysis, and redesign. Design-based research differs from traditional experimental research by prioritizing the development of usable knowledge through systematic refinement of interventions in authentic educational contexts. The methodology enabled continuous improvement based on participant feedback, technical challenges, and emerging insights about UNESCO framework implementation.

The program was developed in two versions to serve different educational contexts and participant needs. The Greek version comprises 400 hours of instruction organized across 8 modules delivered over 9 months, designed for comprehensive professional development within the Greek educational system. The English version comprises 110 hours organized across 12 weekly modules delivered over 12 weeks, designed for international accessibility and integration into existing teacher education programs. Both versions maintain systematic alignment with UNESCO's framework while adapting delivery format and cultural examples to their respective contexts.

Participants and Implementation Cycles

Implementation commenced in September 2024 and has progressed through seven complete cycles with 110 participating teachers from diverse educational levels and subject areas. Participants ranged from early career teachers with minimal AI experience to experienced educators seeking to integrate emerging technologies into established practice. This diversity proved valuable for program refinement, as feedback revealed different needs across experience levels and teaching contexts. Each cycle informed subsequent iterations through participant surveys, forum analysis, and examination of created artifacts.

Systematic Alignment Methodology

The core methodological innovation lies in the systematic alignment procedure mapping program elements to UNESCO's framework. Each module, activity, and resource was explicitly mapped to specific competency blocks within the five areas and three levels. This mapping occurred through a structured analysis protocol: (1) identifying the primary UNESCO competency area and level targeted by each program element; (2) determining secondary competencies addressed through transversal pillars; (3) documenting design decisions operationalizing abstract competency descriptions into concrete learning experiences; (4) verifying coverage through matrix analysis ensuring all 15 blocks received substantive treatment.

The alignment process revealed that comprehensive coverage required both dedicated modules addressing specific competencies and transversal elements threading through

multiple modules. For example, human-centered mindset development occurred through dedicated forum discussions but also through reflective prompts embedded in technical modules, ensuring this critical competency permeated the entire program rather than existing in isolation.

Data Sources and Analysis

The analysis draws on multiple data sources documenting program design and implementation. Primary sources include complete program materials (modules, activities, assessments, resources), systematic alignment matrices mapping each element to UNESCO competencies, participant-created artifacts (lesson plans, prompt collections, ethics analyses, multimedia materials), and forum discussions capturing collaborative knowledge construction. These materials enable comprehensive documentation of how theoretical frameworks translated into functional educational experiences and how participants engaged with and applied AI competencies in their teaching contexts. The present analysis focuses on the program design and UNESCO alignment rather than participant learning outcomes, establishing the foundational model before subsequent empirical evaluation of effectiveness.

DBR Methodology and Iterative Validation

The choice of Design-Based Research (DBR) methodology was essential for addressing the operational translation gap in the UNESCO framework. DBR, which focuses on developing and testing interventions in real-world settings, allowed for the systematic evolution of the program across multiple iterations. Our study spanned 7 domestic (Greek) cycles and 2 intensive (International) cycles, involving a total of 110 participants (N=110). The 7 domestic cycles provided longitudinal data crucial for refining curriculum effectiveness and sustained behavior change (leading to V1 → V2 changes in content and activities). The 2 international cycles focused on cross-context validation and scalability. Each cycle followed an iterative loop of: (1) Analysis and Design refinement (based on previous cohort outcomes); (2) Implementation and Data Collection (formative feedback, completion rates, self-efficacy surveys); and (3) Reflective Analysis to inform the next iteration. This rigorous, multi-cycle approach provides strong empirical validation for the final program model presented, elevating the study from a simple implementation report to a documented, evidence-based instructional design.

Implementation Analysis

This section details design decisions operationalizing each of UNESCO's five competency areas. The analysis demonstrates how abstract competency descriptions translated into concrete educational experiences while maintaining theoretical rigor and comprehensive framework coverage.

Aspect 1: Human-Centred Mindset Through Transversal Pillars

The human-centered mindset aspect, emphasizing human agency, accountability, and social responsibility, proved most challenging to operationalize as it represents attitudinal orientation rather than discrete skills. The solution emerged through five

transversal pedagogical pillars threading through all program modules: Critical Thinking, Ethical Use, Personalization, Collaboration, and Assessment. These pillars function as recurring lenses through which participants examine AI integration across different contexts.

Critical thinking development (drawing on Facione, 1990; Paul & Elder, 2001) occurs through structured forum discussions requiring participants to evaluate AI tool appropriateness, identify potential biases, and question automated recommendations. Ethical use appears in every module through embedded reflection prompts examining fairness, transparency, and student wellbeing implications. Personalization and collaboration pillars operationalize through differentiated activities and peer review structures. Assessment pillar integrates formative assessment principles (Black & Wiliam, 1998) ensuring AI supports rather than replaces human judgment in evaluating student learning. This pillar structure ensures human-centered values permeate technical skill development rather than existing as isolated content.

Pillar	Academic/Theoretical Anchor	Operational Function in the Program	Connection to UNESCO Aspect 1
1. Critical Thinking	Facione (1990), Paul & Elder (2001), OECD (2018)	• 5-Question Framework for AI evaluation (Virtual Exhibition). • Structured discussions questioning algorithmic recommendations.	**Human Agency & Accountability:** Training teachers to maintain skepticism and critically evaluate the "authority" of AI output.
2. Ethical Use & Responsibility	UNESCO (2021), EC (2022)	• Audio Ethics Dilemmas. • Development of School AI Policy documents (Create Level activity).	**Social Responsibility & Values:** Modeling ethical behavior and focusing on fairness, transparency, and data privacy in educational contexts.
3. Personalization & Inclusion	UDL (Meyer et al., 2014), Differentiation (Tomlinson, 1999)	• UDL Planning Templates (Teacher Toolbox). • Design of differentiated content using AI tools (e.g., Diffit.me).	**Human Flourishing:** Ensuring AI usage narrows, rather than widens, equity gaps and supports diverse learner needs.
4. Collaboration & Human Connection	Cooperative Learning (Johnson & Johnson, 1999), OECD (2023)	• Forums for peer-to-peer knowledge sharing. • Check-in/Check-out collaboration frameworks.	**Human-AI Interaction:** Positioning AI as a supportive tool that enhances human communication and teamwork, rather than replacing it.
5. Assessment & Learning Analytics	Formative Assessment (Black & Wiliam, 1998)	• Reflective Evaluation Forms after AI tasks. • Emphasis on human judgment and feedback over automated scoring.	**Accountability & Agency:** Teachers retain ultimate decision-making authority over

Pillar	Academic/Theoretical Anchor	Operational Function in the Program	Connection to UNESCO Aspect 1
			evaluation, using AI insights only to inform judgment.

Table 1. Operationalizing the Human-Centred Mindset: The 5 Transversal Pillars

The five Transversal Pillars serve as the core structural innovation designed to operationalize UNESCO's challenging **Aspect 1: Human-Centred Mindset**. This mindset, which emphasizes human agency, accountability, and social responsibility, is dispositional rather than skill-based. Rather than confining these values to a single introductory module, the pillars function as **recurring pedagogical lenses** woven throughout all program content and activities. This structural integration ensures that every technical skill developed (Aspect 3) and every pedagogical application (Aspect 4) is constantly mediated by critical, ethical, and inclusive reasoning. This mechanism successfully translates abstract competency descriptions into an actionable, research-anchored model for responsible AI integration in the classroom.

The selection of these five dimensions was deliberate, designed to directly address the most critical risks and opportunities of AI integration, forming the operational core of UNESCO's Human-centred mindset (Aspect 1). The pillars synthesize established requirements for 21st-century teaching, specifically: (a) **Critical Thinking** and **Ethical Use**, to counteract the risks of AI bias and hallucinations and align with the Human-centred mindset's focus on **accountability**; (b) **Personalization & Inclusion** (anchored in UDL principles), to ensure AI tools effectively support differentiation and **equity**; and (c) **Collaboration** and **Assessment**, to maintain the **centrality of human judgment and social learning** in the face of increased automation. This comprehensive set ensures that dispositional competencies permeate the entire program, rather than being relegated to isolated content.

Aspect 2: Ethics of AI Through Immersive Scenarios

Ethics of AI competencies developed through three complementary mechanisms addressing UNESCO's progression from understanding ethical principles to safe use to co-creating ethical guidelines. Week 2 introduced foundational ethical concepts (fairness, transparency, privacy, academic integrity) through readings and discussion. Week 3 presented Audio Ethics Dilemmas—professionally narrated scenarios featuring virtual educators expressing authentic concerns about AI implementation (e.g., automated grading bias, student data privacy, overreliance on AI suggestions). Each dilemma provided expert analysis modeling ethical reasoning frameworks rather than prescribing single solutions, honoring the complexity of ethical decision-making in educational contexts.

The Virtual Art Exhibition on the ArtSteps platform created an immersive space where participants explored visual representations of AI ethics concepts through curated artwork and interpretive text. This aesthetic approach complemented analytical discussions, engaging emotional and intuitive dimensions of ethical understanding. Weeks 8-12 required participants to develop School AI Policy documents, moving from understanding principles to co-creating institutional guidelines—directly addressing

UNESCO's Create level competency of participating in ethical rule adaptation. This progression from exposure to analysis to creation systematically developed ethical competency across all three framework levels.

The use of **Audio Ethics Dilemmas** and the **Virtual Art Exhibition** also operationalize 'invisible theory' by integrating constructivist principles. Instead of passive lectures on ethics (Cognitive Level: Acquire), these multimodal scenarios place the participant in an authentic problem space (Cognitive Level: Analyze/Apply), requiring them to actively construct ethical reasoning frameworks through reflection and social negotiation (Vygotsky's social constructivism). This ensures deep ethical understanding is built through experience, rather than rote memorization.

Aspect 3: AI Foundations Through Progressive Complexity

AI foundations developed through carefully scaffolded progression matching UNESCO's three levels. Acquire phase (Weeks 1-3) established basic AI literacy: definitions, machine learning concepts, categories of AI technologies, and initial tool exploration. Participants learned to distinguish AI capabilities from limitations and identify appropriate use cases. Deepen phase (Weeks 4-7) focused on Large Language Models and prompt engineering—conceptual understanding of how LLMs function, systematic prompt crafting strategies, and extensive practice with multiple premium tools. Week 4 introduced the podcast "Mastering Prompting" providing accessible explanations of prompt engineering principles, while structured activities developed practical skills.

The EduPrompt Studio application represents a key innovation operationalizing the Create level. This custom-built tool automatically integrates educational theories (TPACK, UDL, Bloom's Taxonomy) into AI prompt generation. Rather than requiring participants to manually incorporate theoretical frameworks, EduPrompt Studio embeds pedagogical principles into prompt templates and generates theory-informed outputs. This mechanism embodies the 'invisible theory' approach, where the tool's architecture manages the cognitive complexity of synthesizing multiple theoretical demands, allowing the teacher to focus on the content and pedagogical outcome (TPACK integration) rather than the academic framework itself. This aligns with andragogical principles of reducing extraneous cognitive load to focus working memory on essential learning. Weeks 8-10 emphasized multimedia content creation (images, video, audio, presentations) using AI tools, moving from tool consumption to creative production—the hallmark of UNESCO's Create level.

Aspect 4: AI Pedagogy Through UDL Integration

AI pedagogy competencies integrated Universal Design for Learning principles throughout the program, demonstrating how AI tools can support multiple means of representation, engagement, and expression (Meyer, Rose, & Gordon, 2014). Week 5 explicitly introduced UDL concepts alongside AI applications, while Week 7 provided extensive Teacher Toolboxes containing UDL Planning Templates, Student Needs Matrices, and differentiation guides. These resources translated abstract pedagogical frameworks into immediately applicable classroom tools.

Weeks 9-10 focused on creating diverse learning materials addressing varied learner needs: visual storytelling tools (Canva), gamified learning experiences (Genially, Kahoot), and multimodal content. The six premium platform partnerships (Brisk, Genially, Twee, Redmenta, Eduaide, Almanack) provided 3-12 months of professional access, enabling authentic exploration beyond free-tier limitations. Week 11 culminated in final projects requiring participants to design AI-enhanced lessons integrating 2-3 tools while demonstrating pedagogical reasoning through submitted rationales. This progression from understanding AI pedagogy principles to designing comprehensive learning experiences systematically developed competencies across UNESCO's three levels.

Aspect 5: Professional Development Through Collaborative Ecosystems

Professional development competencies emerged through the program's collaborative infrastructure rather than isolated modules. Twelve discussion forums created sustained peer interaction, with early forums (Weeks 1-4) building community and later forums (Weeks 8-12) facilitating sophisticated knowledge sharing about creative tool combinations and pedagogical innovations. These forums operationalized collaborative learning principles (Johnson & Johnson, 1999) while developing professional learning competencies.

Teacher Toolboxes provided extensive resources supporting continued professional development beyond program completion: prompt engineering blueprints, activity templates, policy frameworks, assessment rubrics, and curated tool collections. These resources acknowledged that professional development extends beyond formal training into ongoing practice. The premium partnerships ecosystem enabled participants to experiment with professional-grade tools unavailable in typical school budgets, developing evaluation skills for institutional adoption decisions. Week 12's synthesis activities required participants to reflect on professional transformation, articulating how AI integration changed their pedagogical thinking and practice—moving from skill acquisition to identity development as AI-capable educators. This progression addresses UNESCO's vision of teachers as agents of educational transformation rather than mere tool users.

Discussion

Achieving Comprehensive Framework Coverage

The systematic alignment analysis demonstrates that comprehensive coverage of all 15 UNESCO competency blocks is achievable through deliberate design decisions rather than happening organically. Three key insights emerged from this implementation. First, complete coverage requires both dedicated modules and transversal elements. Human-centered mindset and ethics cannot be confined to single weeks but must permeate the entire program through recurring structures like the transversal pillars. Second, progression across UNESCO's three levels requires explicit scaffolding. The AI foundations sequence from basic literacy to prompt engineering to creative production exemplifies systematic complexity building. Third, theoretical integration without cognitive overload is possible through invisible theory approaches, where pedagogical frameworks operate through program structure rather than explicit academic content.

The implementation revealed tensions between comprehensive coverage and practical constraints. Achieving depth across all five aspects within 110 hours required strategic prioritization—more time on foundational concepts and prompt engineering (high applicability) than advanced customization (lower immediate need for most teachers). The 400-hour Greek version's additional time enabled deeper exploration, suggesting coverage comprehensiveness trades against program duration. This raises important questions about optimal program length for different teacher populations and contexts.

Innovative Operationalization Mechanisms

Several program elements represent novel approaches to UNESCO framework operationalization. The transversal pillars mechanism addresses a persistent challenge in competency-based education: how to develop dispositional orientations alongside technical skills. Rather than treating human-centered mindset as separate content, the pillars ensure every technical skill development activity includes critical, ethical, collaborative, and evaluative dimensions. This structural integration prevents the common pattern where values receive lip service in introductory modules but disappear during technical training.

The Audio Ethics Dilemmas represent another innovation, leveraging narrative and voice to engage emotional dimensions of ethical reasoning. Professional narration featuring authentic educator concerns creates psychological proximity unavailable in text-based case studies. The approach acknowledges that ethical competency requires not just analytical frameworks but empathetic understanding of stakeholder perspectives and comfort with ambiguity—elements difficult to develop through purely cognitive methods.

EduPrompt Studio's automatic theory integration demonstrates how technology can reduce cognitive load while maintaining pedagogical rigor. Rather than requiring participants to manually incorporate TPACK and UDL principles into every prompt, the application embeds this integration structurally. This aligns with andragogical principles of reducing extraneous cognitive load to focus working memory on essential learning, while simultaneously developing deeper theoretical understanding through repeated exposure to well-structured examples. The approach suggests possibilities for intelligent systems supporting professional learning without deskilling teachers.

Implications for UNESCO Framework Implementation

This implementation model offers several contributions to the nascent field of UNESCO AI competency framework operationalization. First, it provides existence proof that comprehensive 15-block coverage is achievable, countering assumptions that full implementation requires years-long programs. The English version's 110 hours suggests feasibility for integration into existing teacher education programs without requiring separate extended courses. Second, the systematic alignment methodology offers a replicable process other program developers can adapt. The four-step protocol (identifying primary competencies, determining secondary competencies, documenting design decisions, verifying coverage through matrix analysis) provides concrete guidance beyond UNESCO's framework descriptions.

Third, the model demonstrates how established educational theories (constructivism, andragogy, TPACK, UDL, Bloom's Taxonomy) can inform AI competency development rather than being displaced by AI-specific frameworks. The invisible theory approach suggests pathways for integrating AI literacy into existing pedagogical knowledge rather than treating AI as entirely separate domain. This integration may support broader adoption by positioning AI competency as evolution of existing practice rather than wholesale replacement.

Limitations and Future Directions

Several limitations constrain generalizability and suggest future research directions. First, this analysis documents program design and UNESCO alignment without evaluating participant learning outcomes. While the implementation achieves comprehensive framework coverage by design, empirical validation of whether participants actually develop claimed competencies remains essential. Future research should employ pre-post assessments, analyze participant artifacts against competency rubrics, and examine longer-term impacts on classroom practice.

Second, both program versions serve self-selected teachers already interested in AI integration, potentially limiting applicability to mandatory professional development contexts with resistant or skeptical participants. The design assumptions about participant motivation and baseline digital literacy may not transfer to all teaching populations. Third, heavy reliance on premium platform partnerships, while providing authentic professional tool access, creates sustainability challenges for institutions without similar arrangements. The model requires adaptation for contexts lacking such resources.

Fourth, the rapid evolution of AI technologies creates ongoing challenges for curriculum currency. Content about specific tools ages quickly, suggesting the importance of focusing on transferable principles and critical evaluation frameworks rather than tool-specific procedures. Finally, cultural and linguistic factors in UNESCO framework operationalization deserve deeper investigation. While this implementation developed both Greek and English versions, systematic comparison of cultural adaptations and their effectiveness would inform international scaling efforts. Future research should examine how UNESCO competencies manifest differently across educational contexts, cultures, and languages.

Conclusion

This study addressed a critical gap in AI competency framework implementation by documenting how UNESCO's abstract competency descriptions can translate into functional teacher education programs. Through systematic design decisions informed by established educational theories, the program achieved comprehensive coverage of all 15 competency blocks across five areas and three progression levels—representing the first documented implementation model achieving complete framework alignment.

Three key innovations emerged from this implementation. The transversal pillars mechanism demonstrates how dispositional competencies like human-centered mindset can permeate technical training rather than existing as isolated content. The invisible theory approach shows how pedagogical frameworks can inform program design

without overwhelming participants with academic terminology, honoring andragogical principles while maintaining theoretical rigor. The integration of immersive elements (audio ethics dilemmas, virtual exhibitions) and practical tools (EduPrompt Studio, Teacher Toolboxes, premium partnerships) created authentic learning experiences unavailable through traditional professional development formats.

The systematic alignment methodology offers a replicable process for other educators and institutions seeking to operationalize the UNESCO framework in their contexts. While this implementation serves specific populations and contexts, the underlying principles—comprehensive competency mapping, progressive complexity scaffolding, theory integration through program structure, and balanced attention to technical skills and ethical dispositions—transfer across educational settings.

As AI technologies continue evolving and educational systems worldwide grapple with integration challenges, systematic approaches to teacher competency development become increasingly critical. This work demonstrates that comprehensive framework implementation is achievable through deliberate design, providing both conceptual guidance and practical exemplars for the field. Future research examining participant learning outcomes, longitudinal classroom impacts, and cross-cultural adaptations will build on this foundation, advancing from documentation of what is possible to empirical validation of what is effective in developing AI-capable teachers who can guide students toward human flourishing in an AI-integrated world.

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Psychoanalyzing Sakis: From Tool to Interlocutor – Ethical Issues, Social Challenges and Educational Potentials of Artificial Intelligence

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Abstract— The rapid development and integration of artificial intelligence into the field of education is substantially reshaping the way the learning process, access to knowledge, and pedagogical interaction are approached. Contemporary artificial intelligence systems, and particularly language models, no longer function exclusively as technological tools for information provision, but emerge as dialogical interlocutors capable of participating in processes of interpretation, reflection, and meaning production. This shift raises critical pedagogical and philosophical questions concerning the role of the teacher, the nature of learning, and the boundaries of human and non-human intelligence.

The present paper proposes a conceptual and pedagogical framework for the utilization of artificial intelligence in education, inspired by the spirit and philosophy of the book *Psychoanalyzing Sakis*. A central axis of this approach is the understanding of artificial intelligence not only as a tool supporting learning, but as a dialogical agent that can contribute to the cultivation of students' critical thinking, reflection, and metacognition. The theoretical framework draws on contemporary pedagogical, philosophical, and educational perspectives on dialogue and learning, highlighting the importance of active participation and a multi-perspectival approach to knowledge.

At the level of educational practice, the paper presents the design rationale of worksheets that focus on different types of learning interaction, such as the formulation of secondary (inquiry-based) questions, the juxtaposition of multiple perspectives, the critical exploration of arguments, and the creative representation of knowledge. The proposed pedagogical applications do not aim to replace the teacher, but to support and enrich the teaching process, with the teacher maintaining a central role as a pedagogical mediator. Overall, the paper argues that the pedagogical utilization of artificial intelligence can contribute to the formation of a learning environment that enhances dialogue, critical thinking, and creativity, offering an open and extensible framework for further educational research and application.

Keywords— Artificial intelligence in education, dialogic learning, critical thinking, reflection, worksheets

Introduction

The rapid entry of artificial intelligence into the field of education has substantially transformed the way the learning process, access to knowledge, and the relationship between students and digital tools are conceptualized (Luckin et al., 2016; Holmes et al., 2019). Contemporary artificial intelligence systems no longer function exclusively as means of information retrieval, but emerge as dialogical interlocutors capable of participating in processes of interpretation, discourse production, and reflection. This shift raises critical pedagogical questions regarding the role of the teacher, the nature of learning, and the boundaries between human and non-human intelligence (Selwyn, 2019).

Despite the growing interest in the use of artificial intelligence in educational practice, the relevant literature often focuses either on technical applications or on instrumental uses, without sufficiently incorporating the reflective, philosophical, and linguistic character of the learning experience (Biesta, 2017; Williamson, 2017). As a result, a gap is identified in the development of pedagogical frameworks that approach artificial intelligence not only as a means, but also as a stimulus for dialogue, critical thinking, and students' self-awareness.

The book *Psychoanalyzing Sakis* constitutes a dialogical and reflective endeavor in which artificial intelligence is not presented as a tool for information provision, but as an interlocutor in an open dialogue with humans. The work constructs a field of inquiry in which artificial intelligence functions as a stimulus for reflection on fundamental questions concerning knowledge, meaning, and human understanding. The form and spirit of the book render it suitable not as an instructional manual, but as a pedagogical stimulus that can be utilized in education for the cultivation of dialogue, reflection, and students' critical thinking.

Within this context, the present paper seeks to propose a conceptual and pedagogical framework for approaching artificial intelligence in education, inspired by the spirit and philosophy of the book *Psychoanalyzing Sakis*. The paper combines theoretical reflection with indicative applications in school practice, through the presentation of worksheets that aim to cultivate dialogue, reflection, and students' critical engagement with artificial intelligence. The structure of the paper follows a mixed approach, in which the conceptual framework serves as a foundation for the development of pedagogical applications.

Theoretical and Conceptual Framework

Aim of the section

This section establishes the conceptual background of the paper and clarifies the manner in which artificial intelligence is approached not exclusively as a technological tool, but as a dialogical agent within the educational environment, while at the same time highlighting broader pedagogical dimensions related to dialogue, reflection, and critical learning. The theoretical framework functions as a bridge between philosophical inquiry and pedagogical application (Biesta, 2017; Selwyn, 2019).

From tool to interlocutor

Traditional educational technology is usually approached as a means of supporting learning: a tool for information retrieval, content organization, or process automation. However, contemporary artificial intelligence systems, particularly language models, shift this relationship, as they introduce the possibility of dialogue, questioning, reformulation, and meaning-making (Luckin et al., 2016; Holmes et al., 2019). Interaction ceases to be unidirectional and acquires conversational characteristics, a fact that affects the way students think, formulate questions, and engage in reflection (Williamson, 2017).

Dialogue, reflection, and learning

The concept of dialogue constitutes a central axis in numerous pedagogical and philosophical approaches. Dialogue is not understood merely as an exchange of information, but as a process of meaning construction, questioning, self-correction, and understanding of the self and the other (Freire, 1970; Wegerif, 2013). Within this framework, artificial intelligence can function as a "mirror of thought," prompting students to reconsider their positions, articulate arguments, and discern the limits of their knowledge (Mercer & Littleton, 2007).

Extension of the pedagogical dimensions of dialogue

Beyond dialogue as a core pedagogical axis, the approach emerging from the present conceptual framework highlights a set of complementary pedagogical practices that strengthen students' critical thinking and reflection. Particular importance is attributed to the formulation of secondary questions, namely questions built upon answers that have already been provided, as well as to the juxtaposition of different perspectives on the same issue (King, 1992; Facione, 2015). The possibility of submitting the same question to different interlocutors—scientists, philosophers, or representatives of different worldviews—enables students to perceive the multi-perspectival nature of knowledge and the relativity of interpretations. At the same time, practices such as the creative representation of knowledge through narrative or theatrical forms and the critical exploration of erroneous or illogical arguments contribute to awareness of the limits, potentials, and responsibilities of both the human and the artificial interlocutor (Bruner, 1996; Selwyn, 2019). These pedagogical dimensions are not exhausted by the examples presented, but constitute an open framework within which additional forms of educational utilization of artificial intelligence may dynamically emerge.

Pedagogical and ethical implications

Recognizing artificial intelligence as an interlocutor simultaneously raises pedagogical and ethical issues. The role of the teacher is transformed from a transmitter of knowledge into a mediator and guarantor of the pedagogical process (Biesta, 2017). At the same time, it becomes necessary to cultivate students' critical stance toward the responses of artificial intelligence, so as to avoid uncritical acceptance and to strengthen responsibility, autonomy, and awareness of its limitations (Floridi et al., 2018).

Connection with educational practice

This conceptual framework does not remain at a theoretical level, but serves as a basis for the development of pedagogical applications. Approaching artificial intelligence as an interlocutor enables the design of worksheets that focus on dialogue, interpretation, metacognition, and creative thinking (Wegerif, 2013; Holmes et al., 2019). These applications aim not to replace the teacher, but to broaden learning experiences and support students' active participation.

Pedagogical Applications and Worksheet Structure

Aim of the section

This section describes the pedagogical framework and the design rationale of worksheets that emerge from the theoretical background of the paper. The aim is not the detailed presentation of specific activities, but the clarification of the basic principles, the types of interaction, and the learning objectives that can support the pedagogical utilization of artificial intelligence in educational practice.

Basic design principles

The design of the worksheets is grounded in principles that enhance active learning, critical thinking, and reflection. Artificial intelligence is approached as a dialogical interlocutor rather than as an authority providing ready-made answers. A decisive role is played by the guidance of the teacher, who sets the framework, defines the boundaries, and encourages the exploration and evaluation of responses.

Types of learning interactions

Within this framework, worksheets can be organized around different types of interaction, such as:

- the formulation of secondary questions, in which students construct new questions based on the answers they receive,
- the juxtaposition of multiple perspectives, through the submission of the same question to different interlocutors or cognitive frameworks,
- the critical exploration of arguments, including the examination of erroneous or contradictory positions,
- the creative representation of knowledge, in the form of narrative or theatrical dialogues,
- the production of visual representations of scientific or conceptual processes, utilizing artificial intelligence tools.

Learning objectives

The above types of activities aim at cultivating metacognition, argumentative competence, source evaluation skills, and awareness of the limitations of artificial intelligence. At the same time, they enhance the originality of questions and the quality of dialogue as central learning outcomes.

Open and extensible framework

The proposed design framework is not exhausted by the above categories, but remains open to further pedagogical approaches that may dynamically emerge through teaching practice. This flexibility allows the adaptation of worksheets to different subject areas, age groups, and educational contexts.

Conclusion

The present paper sought to approach artificial intelligence within the educational context not exclusively as a technological tool, but as a dialogical agent that can contribute meaningfully to the learning process. Through the integration of philosophical, pedagogical, and instructional perspectives, the importance of dialogue, reflection, and critical thinking was highlighted as central axes of the pedagogical utilization of artificial intelligence.

The theoretical and conceptual framework demonstrated that interaction with artificial intelligence systems can function as a stimulus for deepening knowledge, reformulating questions, and becoming aware of the limits of both human and non-human intelligence. The shift from a one-dimensional instrumental use toward a dialogical and reflective approach enhances the role of the student, transforming them from a passive recipient of information into an active participant in the learning process.

At the same time, the presentation of the worksheet design rationale highlighted the potential for developing pedagogical applications that focus on meaning-making, a multi-perspectival approach to knowledge, and the creative representation of concepts. The proposed activities do not aim to replace the teacher, but to support and enrich teaching practice, with the teacher maintaining a central role as a pedagogical mediator.

Within the framework of the proposed approach, artificial intelligence functions not only as a dialogical interlocutor, but also as a mirror of thought, through which students are given the opportunity to reconsider their positions, the way they formulate their questions, and the logic of the responses they receive. At the same time, the creative and, in certain cases, playful dimension of the proposed activities contributes to reducing anxiety and enhancing students' active engagement, without negating the reflective and critical character of the learning process.

Overall, the paper argues that the pedagogical utilization of artificial intelligence can contribute to the formation of a learning environment that enhances students' critical thinking, reflection, and creativity. The proposed framework remains open and extensible, offering opportunities for further exploration and adaptation to different educational contexts and subject areas.

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Artificial Intelligence as a Tool for Equity: Addressing Diverse Learning Profiles in Primary Classrooms

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Abstract – The growing presence of Artificial Intelligence (AI) in education creates new pathways that contribute to inclusion and equity in the learning spaces of today's globalised and diversified world. By supporting personalized learning, multimodal engagement practices and responsive feedback, AI can function supportively in bridging achievement gaps and empowering all learners to participate meaningfully in the learning process. This paper aims to explore the way AI-driven instructional practices can mitigate varied learning profiles within the context of English as a Foreign Language (EFL) education in primary schools. The present study is based on classroom experiences from a sixth-grade English class in Northern Greece, characterized by students mixed competence levels ranging from those with dyslexia and those with autism spectrum characteristics. To ensure accessibility and active engagement for every learner, teaching practices incorporated AI-based applications, interactive digital resources and cooperative tasks. Therefore, instruction was not uniform but differentiated. To this end, AI-enhanced platforms were employed into lessons in an attempt to facilitate reading comprehension, improving students' writing fluency and creative expression of ideas through multiple modes- visual, auditory and written. Such technologies offered immediate feedback, language assistance and alternate modes of representation – such as visual and auditory adjustments – that benefitted neurotypical and neurodiverse students alike. Dyslexic students benefitted from speech-enabled technologies and multimodal feedback whereas autism spectrum learners displayed improvement in focus and engagement through AI-mediated activities. More advanced learners integrated AI to expand their vocabulary repertoire and engage in creative text production. Qualitative evidence from classroom observations revealed an increase in engagement, confidence and task persistence, particularly among students who had previously struggled to participate actively. Implications of this practice-orientated research are discussed in connection with recent research on AI-supported inclusion and personalized learning (Holmes et al.,2023; Kohnke & Zou, 2022; Firat, 2023; UNESCO, 2022). Findings pinpoint the significance of teachers' pedagogical judgment, ethical awareness and adaptability skills when introducing AI into daily school practice. Indeed, while AI technologies may seem promising as far as access and engagement are concerned, equity is achieved only when moderated by a well-informed inclusive design. The paper concludes that if properly and ethically combined, AI is equipped with the potential to function as an agent of educational inclusion. Through adjusting feedback, multimodal learning pathways and utilization of differentiation practices and strategies, AI can enable students with varying learning profiles to access the curriculum on equal terms. The study also highlights the necessity of teacher training, ethical guidance, and supportive school policies in an attempt to ensure responsible use of AI.

Keywords— artificial intelligence, equity, EFL, dyslexia, autism

1. Introduction

Artificial Intelligence (AI) is increasingly recognised as a force capable of transforming contemporary education, that is reshaping how learning is accessed, experienced, and supported across a wide range of educational contexts. International policy reports and research studies suggest that AI technologies, when thoughtfully integrated, have the potential to enhance learner engagement, personalise instruction, and reduce barriers to participation, particularly for students who struggle within traditional instructional models (OECD, 2021; UNESCO, 2022; Zawacki-Richter et al., 2019). Rather than replacing teachers, AI tools are increasingly viewed as supportive pedagogical resources that can augment instructional practices and facilitate more inclusive learning environments (Luckin et al., 2016; Holmes et al., 2023).

These affordances are particularly evident in primary education, where learners demonstrate substantial variability in cognitive development, language exposure, learning pace, and socio-emotional needs. Research on inclusive pedagogy emphasises that equity in education does not imply uniformity of instruction, but rather the provision of multiple pathways through which learners can access, engage with, and demonstrate understanding of curricular content (Florian & Black-Hawkins, 2011; Tomlinson, 2017). In this regard, AI-supported learning environments offer promising opportunities to operationalise differentiation and universal design principles in everyday classroom practice (Meyer et al., 2014; Rose et al., 2006).

The relevance of AI-mediated support is particularly evident in English as a Foreign Language (EFL) classrooms. Young EFL learners often differ markedly in linguistic proficiency, processing speed, working memory capacity, and confidence in language use, especially in contexts where exposure to English is limited to the school setting (Butler, 2015; Pinter, 2017). In inclusive classrooms, these differences are further compounded by the presence of learners with dyslexia, attention-related difficulties, and autism spectrum characteristics. Studies in EFL and special education contexts indicate that such learners frequently encounter challenges related to decoding, comprehension, task organisation, and sensory overload, which may hinder their active participation in language learning activities (Ganschow & Sparks, 2016; Kormos & Smith, 2012; O'Brien, 2019).

In Greece, as in many European educational systems, inclusive education policies promote the participation of learners with diverse learning profiles in mainstream classrooms (European Agency for Special Needs and Inclusive Education, 2018). However, research suggests that teachers often face practical difficulties in implementing inclusive practices within linguistically heterogeneous EFL classrooms, particularly when relying on standardised materials and whole-class instruction (Avramidis & Norwich, 2002;Vlachou et al., 2016). Traditional "one-size-fits-all" approaches may inadvertently marginalise neurodiverse learners, leading to reduced engagement, limited learner autonomy, and unequal access to learning opportunities (Slee, 2018; Tomlinson & Moon, 2013).

Within this context, AI-enhanced learning environments have been increasingly discussed as tools capable of supporting differentiated instruction, adaptive feedback, and multimodal accessibility (Holmes et al., 2023; Zawacki-Richter et al., 2019). Features such as text-to-speech, speech-to-text, visual supports, adjustable pacing, and

interactive digital tasks align closely with principles of Universal Design for Learning and have been shown to support learners with language-based learning difficulties and neurodevelopmental differences (Al-Azawei et al., 2016; Kapp et al., 2020). When embedded within sound pedagogical frameworks, AI tools may enhance learner autonomy, motivation, and self-regulation, while enabling teachers to respond more flexibly to learner diversity (Ifenthaler & Schumacher, 2016; Luckin et al., 2016).

Against this backdrop, the present study seeks to contribute to the growing body of empirical research on AI-supported inclusive practices by examining the implementation of AI-mediated instruction in a sixth-grade primary EFL classroom in Northern Greece. The classroom included learners with dyslexia and autism spectrum characteristics, alongside peers with varied levels of English language proficiency. Adopting a practice-based qualitative research design, the study explores the educational, social, and motivational effects of AI-supported learning tasks, with particular emphasis on accessibility, learner engagement, and perceptions of equity within the learning process.

2. Literature Review

2.1 AI supported inclusion in Language Education

Recent studies have examined Artificial Intelligence (AI) as having the potential to function as a catalyst for more inclusive educational practices. Within this framework, equity in education is not equal to uniformity of instructional practices in the classroom but as provision of fair opportunities enabling learners to achieve their full potential, regardless of their background, learning profile, or needs (OECD,2018; UNESCO,2017). Indeed, AI is often viewed as a technology capable of supporting this vision by offering personalised pathways and removing barriers to participation. Systematic reviews of AI implementation in education show that AI technologies enable teachers and students to adjust task difficulty, provide immediate feedback and support individual learning differences, thereby taking into consideration their learning styles, preferences and needs (Zawacki-Richter et al.,2019; Chen et al, 2020). However, it is also cautioned that the educational benefit is evident in the way the AI-supported lesson is designed and implemented (Holmes, Bialik& Fadel, 2023; Luckin et al, 2016).

From an inclusion perspective, AI technologies are closely connected with the Universal for Learning (UDL) principles, as they are based on offering multiple means of representation and engagement in an attempt to cater to each learner's needs (CAST,2018). According to Rose et al. (2016) and Meyer et al (2014) AI-mediated feedback and tasks operationalise these principles and enable multimodality of input and adjusting pace and difficulty giving learners with varied language levels, working memory capacity and preferred modes of learning the ability to engage in learning.

As far as the field of Foreign Language Learning is concerned, AI-supported tools have been associated with a number of benefits. More precisely, research in computer-assisted language learning suggests that AI technologies providing feedback and interactive tasks to students can contribute to increased learner experimentation with language as they create low-risk environments in which errors are not considered failures but an attempt to learn (Golonka et al, 2014; Fryer et al. , 2017). The creation of such settings is particularly important as anxiety and fear of negative grading have

been shown to block participation and expression (Horwitz et al., 1986; Dewaele & McIntyre, 2014). In addition, the provision of immediate and personalized feedback supports and promotes self-correction while increasing the quantity and quality of language exposure (Long, 1996;Swain 2005).Indeed, in foreign language settings where exposure to the target language is limited, these capabilities are valuable. Studies on young language learners indicate that AI technologies create tasks that can in a way compensate for restricted input (Butler, 2015). Therefore, AI implementation in pedagogical tasks can effectively support both receptive and productive skills, while increasing students' autonomy and engagement (Kohnke & Zou, 2022).

2.2 AI and Dyslexia in EFL contexts

Dyslexia as a term is associated with persistent difficulties in spelling, and decoding often linked to phonological processing differences and demands on working memory during literacy tasks (Snowling ,2019; Shaywitz, 2013). In EFL settings, these difficulties are easily noticeable because learners must cope with unfamiliar phoneme-grapheme correspondences, new words and additional grammatical phenomena often with limited classroom instruction (Kormos &Smith, 2012). Additionally, a finding that appears consistently across dyslexia and foreign language learning research, is that the mode of access to content seems to be causing problems not only the language content itself. In situations where reading requires significant effort, learners must concentrate mainly on recognizing words instead of focusing on more complex mental processing (Snowling & Hulme, 2012). This is the reason why dyslexic learners seem to 'know' words and grammar but struggle to demonstrate understanding through textbook-reading writing activities (Kormos &Smith, 2012; Sparks, 2016).

Within this framework, Rello et al. (2017) and McArthur (2009) suggest that features such as text to speech can support comprehension by reducing decoding barriers while speech to text can support written output by minimizing transcription demands. Most importantly, other studies pinpoint that technology benefits are strongest when they are related with instructional scaffolding and strategy training (Snowling , 2019; Lyon, Shaywitz & Shaywitz, 2003). Recent studies on AI implementation for dyslexic learners advocate that accessibility should not be treated as a static feature. More specifically, Lombardo Pontillo and Oliva (2015) pinpoint that AI can significantly contribute to Universal Design for Learning by providing flexible pathways, that is adapting content, pacing, final products, while emphasizing that teacher's role is fundamental to ensure that AI promotes autonomy and obeys curricular objectives.

2.3 AI and Autism Spectrum Learners in EFL contexts

Autism spectrum disorder (ASD) is associated with differences in social interactions together with restricted or repetitive patterns of behavior (American Psychiatric Association, 2013). By implementing technology and more specifically AI tools in education autistic learners can be effectively supported as they are provided with structures characterized with predictability, guidance during every step, adjusted pace to their strengths and weaknesses and a variety of input modes (Kotsi, 2025). This point is particularly relevant in the case of Foreign Language Learning. More specifically, a recent systematic review of technological tools implemented in a foreign language setting with autistic students indicated that in the case of vocabulary the use of such tools can facilitate vocabulary learning (Urrea et al., 2024). However, the authors

pinpoint the fact that the outcomes may vary depending on learner's learning preferences, characteristics and prior knowledge.

Furthermore, Jiang et al's (2022) systematic review of technology use with ESL/EFL students who are at risk or have disabilities indicated that technology can function in an assistive way by providing access and engagement but whether or not they prove effective it depends on the teacher who selects them. In the same vein, Sancosti (2015) pinpoints the effectiveness of such tools in equipping ASD students with a range of skills. Furthermore, Mohamed's qualitative study on using AI to teach English to multilingual autistic children suggests that these students are benefitted as far as engagement and confidence are concerned despite the constraints associated with their implementation.

Overall, the literature supports that AI tools benefit autistic learners by providing structured support, pacing, multimodal routes to into language tasks and increasing engagement. However, limitations and ethical issues need to be taken into consideration as AI tools have been accused of introducing inaccuracies and violating privacy (Khoshtaria, Matin, Rinella, & Polizzi, 2025).

3. Methodology

3.1 Research Design

The present study adopts a practice-based, qualitative methodology, focusing on classroom evidence rather than on experimentation and testing. The aim was to explore how AI-supported instructional practices function in a primary school classroom. For this purpose data sources included:

- systematic classroom observation notes,
- teacher reflection logs,
- samples of student work,
- recurring patterns in learner responses to AI tasks.

In addition to the use of observation notes and reflection logs, a teacher-rated perceived impact scale (1–5) was used to contribute to qualitative impressions across key learning domains such as engagement, accessibility, confidence, focus and task persistence. This scale was used as a descriptive tool in an attempt to visualise observed patterns rather than to provide a numerical measurement of student performance.

3.2 Context and Participants

The research took place in a sixth-grade classroom at a public primary school in Northern Greece during regular English as a Foreign Language (EFL) lessons. The class profile included 3 learners with dyslexia, 2 learners with autism spectrum characteristics, and 15 learners across A1–B1 EFL proficiency levels (N = 20). All learners were taught within the same classroom and followed the same core curriculum. Differences in learning profiles were taken into consideration and differentiation instructional practices were implemented rather than parallel instruction.

Instructional content was based on the official English language curriculum provided by the Greek Ministry of Education and the approved sixth-grade English textbook used in public primary schools. To support instructional planning and differentiation, learner's English language proficiency levels and learning preferences were identified at the beginning of the school year using classroom-based diagnostic activities. Language proficiency was explored through curriculum-aligned tasks while learning preferences were examined using a learning style survey based on Cohen, Oxford and CHI (2001). This action enabled the adaptation and transformation of the instructional content through the use of AI-supported tools in an attempt to enhance accessibility and engagement. This included transforming written textbook material into multimodal resources, scaffolded tasks and uploading it on Moodle platform. Therefore, students accessed AI – enhanced material through a structured digital learning environment and tasks were selected according their profile (e.g. dyslexic, autistic, A1 level student, A2 level student, B1 and B2 according to the CEFR).

3.3 AI Tools

In the present research AI tools employed are presented not in terms of specific brand names but they fall into categories and function they served:

Type of AI Tool	Primary Function
Text-to-speech	Reading support, decoding assistance
Speech-to-text	Writing support, fluency
Generative AI	Vocabulary building, writing scaffolds
Multimodal content creation tools	Creative expression
Adaptive feedback systems	Tailored corrections

3.4 Ethical Safeguards

Ethical safeguards were strictly observed throughout the study. No personal or sensitive data were collected, stored or analysed. Observations in classroom focused strictly on learning behaviours and instructional interactions. Parental consent was obtained prior to the study and approval was granted by the school head teacher, in accordance with school policies and ethical guidelines for educational research. The teacher-researcher remained attentive to issues of equity, inclusion and responsible AI use.

4. Findings

4.1 Overview of Observed Learning Improvements

Classroom observations and teacher reflections showed a range of positive learning-associated developments. These developments were not the same for all learners but they reflected differences in learning profiles, language levels and modes of engagement. Table 1, below, presents a summary the main observed gains witnessed in each learner group.

Learner Group	Observed Gains
Dyslexic learners	Better reading comprehension; reduced decoding effort; improved fluency
Autistic learners	Stronger focus; clearer task progression; reduced anxiety; higher task completion

Advanced learners	Increased vocabulary; creative writing confidence
Whole class	More engagement; higher confidence; collaborative interaction

Table 1. Summary of Observed Learning Improvements

These patterns appeared consistently across multiple lessons and were supported by observation notes, learner work samples and teacher logs.

4.2 Thematic Findings

Qualitative analysis of classroom data provided information regarding four interrelated themes that show how learners respond to AI-supported instructional practices.

Theme 1: Increased Engagement

A significant finding was a noticeable increase in learner engagement during AI-enhanced activities. Students' attention was easily sustained through interactive AI tasks and AI feedback. Learners who had previously shown reluctance to participate , after the implementation of AI-supported instruction participated more frequently and engaged more actively in individual and group tasks.
This increased engagement was especially evident during activities that allowed students to participate according to their own pace. At the same time the availability of AI guidance reduced hesitation and encouraged students to deal with tasks without fear of failure.

Theme 2: Accessibility Through Multimodal Input

AI-supported adaptation of textbook content into multimodal formats played a key role in enhancing accessibility. Learners were able to access the same instructional content through different modes, depending on their needs , learning preferences and differences. More specifically, dyslexic learners benefitted from text to speech features, which reduced decoding demands and allowed them to focus more comprehension. At the same time scaffolding and segmented instructions further supported task comprehension and completion. Observations showed that these learners were benefitted as they showed greater confidence while participating in reading-related tasks.

Theme 3: Emotional and Cognitive Independence

Another topic concerned learners' growing sense of independence and emotional security during learning activities. AI-supported tools enabled learners to check answers, revise output, and receive feedback without the teacher intervening during the process. This situation appeared to reduce anxiety associated with making mistakes, particularly for learners who showed hesitation to participate in traditional classroom situations. Additionally, teacher's reflections showed that students relied on self-correction strategies, revisiting prompts or trying to work out responses before seeking teacher's help. This pattern shows that students gradually developed their self-regulation and had their confidence boosted.

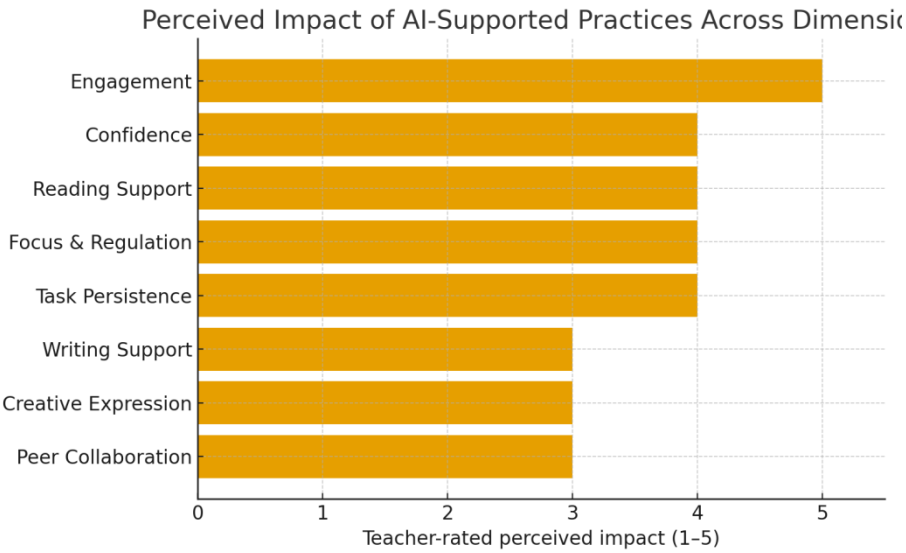
Theme 4: Structured Support for Autism Spectrum Learners

Learners with autism spectrum characteristics demonstrated improved focus and task persistence when activities were designed with clear, predictable structures. AI-supported tasks that were based on step by step instructions and consistent layouts were connected with longer periods of sustained engagement. Data showed that these learners were more likely to complete tasks on their own and without further assistance. Simultaneously, reduced ambiguity and predictable task flows appeared to minimize cognitive overload while providing emotional regulation.

4.3 Descriptive Graph of Observed Improvements

To illustrate the relative strength of the improvements observed in the classroom, a teacher-rated perceived impact scale (1–5) was used to summarise qualitative observations across key learning dimensions. This scale does not represent measured student performance but rather reflects systematic, practice-based judgments regarding how learners responded to AI-supported instructional activities.

As illustrated in Figure 1, engagement received the highest perceived impact rating, followed by confidence, reading support, focus and regulation, and task persistence. These domains showed the most visible improvements during AI-enhanced lessons. Writing support, creative expression, and peer collaboration demonstrated moderate but meaningful gains. Overall, the pattern indicates that AI-supported activities contributed most strongly to motivational and regulatory dimensions of learning, while also providing valuable—but more gradual—support in literacy development and creative language use. These findings align with the qualitative nature of the study and highlight the role of AI as a supportive instructional mediator rather than a determinant of learning outcomes.



5. Discussion

5.1 Alignment with Existing Research

The findings of the present study are consistent with existing research showing that AI-supported instruction can improve the way students engage with learning. In line with

previous studies in computer-assisted language learning and AI technologies in education the most noticeable changes were observed in students' engagement, confidence , task focus and ability to manage learning tasks rather than in test-related outcomes (Golonka et al, , 2014; Richter et al. 2019; Holmes et al, 2023). Furthermore, the increased levels of learner engagement align with research suggesting that AI-mediated tasks can create low-risk, friendly and supportive environments that encourage participation and reduce anxiety and fear of failure (Kohnke &Zou, 2022). To be more precise, in the present study, learners who had shown reluctance to engage in whole-class activities were more eager to participate during AI-supported tasks. Importantly, the findings do not suggest uniform benefits for all learners in the same way. Instead, they highlight that AI-supported practices were experienced differently depending on learners' individual profiles, including language proficiency level and neurodiversity-related characteristics. This observation aligns with research emphasizing that the educational impact of AI and digital technologies is shaped by learner characteristics, instructional content and pedagogical design rather than by technology itself (Zawacki-Richter at al., 2019; Holmes et al. , 2023; OECD, 2021).

5.2 AI-supported Accessibility and Dyslexic learners

The observed improvements in reading comprehension and task fluency among dyslexic learners are consistent with research showing that assistive and AI-supported technologies can reduce decoding demands and support access to written language (Kormos&Smith, 2012; Rello et al., 2017; Firat, 2023). In the present study the text to speech and scaffolded multimodal recources enabled dyslexic students to focus more on meaning and comprehension and less on mechanical decoding. These findings support the argument that accessibility –oriented AI use does not undermine literacy development but can instead mediate access to the curriculum, allowing learners to participate meaningfully alongside peers. At the same time, the gradual nature of observed gains in writing and creative language use aligns with the literature's caution that technological support must be complemented by structured instruction and guided practice (Snowling, 2019; MacArthur, 2019).

5.3 Structured AI support and Learners with Autism Spectrum Characteristics

For learners with autism spectrum characteristics, the findings highlight the importance of integrating structure, predictability and clarity as far as the instructional design is concerned. To be more precise, the increased focus and task persistence observed during AI-supported activities aligns with previous research discovering that autistic learners benefit from environments that reduce ambiguity and provide guidance (Odom et al., 2015;Parsons and Cobb, 2011).

AI-supported tasks that were characterized with consistency in terms of format and were based on visual sequences appeared to support emotional regulation and reduce cognitive overload, facilitating more stable participation. These outcomes align with qualitative findings presented by Mohamed (2025) and suggesting that AI technologies can prove beneficial with autistic learners when they are carefully adapted and implemented by teachers.

5.4 Learner Autonomy and Self-regulation

Across learner groups, AI-supported activities appear to foster increased impendence and confidence particularly through opportunities for self correction and private feedback. This finding aligns with research suggesting that technology-mediated environments can support self-regulated learning by allowing learners to monitor progress, revise responses and control pacing (Tai&Chen, 2020).

In the present study, the learners' growing reliance on self correction rather than immediate teacher feedback suggests a shift toward greater learner autonomy. From an inclusive education perspective, this is particularly significant as autonomy and confidence are key components of equitable participation in learning (Florian & Black-Hawkins, 2011). However, the findings highlight the continued importance of teacher guidance in supporting learners to use AI technologies strategically rather than dependently.

5.5 Limitations and Implications for future research

While the findings offer valuable insights into AI-supported inclusive practices, several limitations must be acknowledged. The study was conducted in a single classroom with a small number of learners, and findings are based on qualitative observations rather than measured learning outcomes. Therefore, results cannot be generalised beyond the specific context studied. Future research could build on this study by combining qualitative classroom-based approaches with longitudinal or mixed-methods designs, examining how AI-supported differentiation influences language development over time. Further investigation is also needed into how teachers are trained to integrate AI technologies ethically and effectively, particularly in inclusive primary education settings.

6. Conclusion

The present study examined the role of AI-supported instructional practices in promoting equity and inclusion within a sixth grade primary EFL classroom characterised by diverse learning profiles. Drawing on classroom-based qualitative evidence, the findings suggest that AI, when integrated into everyday teaching practice, can enhance learner engagement, accessibility, and participation without disrupting shared curricular goals.

The use of AI-supported tools enabled learners to access textbook content through multiple pathways , supporting students with dyslexia through reduced decoding demands and multimodal input , while offering learners with autism spectrum characteristics greater structure , predictability, and opportunities for sustained focus. At the same time, more advanced learners benefited from opportunities for extended language use and creative expression. These outcomes indicate that AI may function as a flexible pedagogical resource that supports differentiated instruction and learner autonomy in inclusive primary EFL contexts.

Importantly, the study reinforces the view that AI does not function as an autonomous solution for inclusion. Rather, its educational value depends on careful pedagogical design, curriculum alignment and teacher mediation. The adaptation of official textbook materials the organisation tasks within a Moodle learning environment, and the intentional selection of AI-supported activities were central to ensuring that

technology enhanced rather than complicated, the learning process. From an equity perspective, this approach highlights the distinction between providing identical instruction and offering fair access to learning through responsive and differentiated practices.

The findings should be interpreted in light of certain limitations. The study was conducted within a single classroom and relied on qualitative, practice-based evidence rather than standardised measures of achievement. Nevertheless, these constraints reflect the study's focus on authentic classroom practice and underline the need for further research employing longitudinal and mixed-methods design across diverse educational contexts.

Overall, he study concludes that AI holds potential as a tool for educational equity when embedded within inclusive pedagogical frameworks. By supporting multimodal access, adaptive feedback and differentiated learning pathways, AI can help primary EFL learners with diverse needs engage with the curriculum on more equal terms. Future research and teacher professional development should therefore focus not only on technological innovation, but also on ethical guidance, pedagogical training and supportive school policies to ensure responsible and effective AI integration in inclusive classrooms.

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AI4LessonDesign: A MOOC for Instructional Design in Foreign Language Education

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract – The rapid development of Artificial Intelligence (AI) and its integration into educational practice create both new challenges and significant opportunities for teachers' professional development. This paper presents a Massive Open Online Course (MOOC) focusing on instructional design in foreign language education through the use of Generative AI tools. The development of the MOOC is grounded in research data that explored the attitudes and perceptions of Greek teachers regarding the use of AI tools in instructional design, as well as their training needs in this specific field.

The research findings indicated that, although teachers demonstrate a highly positive attitude toward AI and acknowledge its benefits for personalized learning, time efficiency, and the creation of rich learning materials, the frequency of their actual use of AI tools remains low to moderate. Furthermore, the analysis of self-assessment data suggests that teachers express a strong need for further support in understanding and applying the principles of instructional design. Although several participants had attended general MOOCs related to AI, the majority expressed strong interest and a positive intention to participate in a future, targeted professional development program. In addition, the research highlighted teachers' needs for practical guidance, pedagogical integration, and a deeper understanding of the ethical dimensions of AI use in educational practice.

Based on these findings, the development of a MOOC exclusively oriented toward instructional design through the use of Generative AI tools was considered necessary, in order to address the identified training gaps and bridge the divide between teachers' positive attitudes toward AI and its meaningful pedagogical application in the classroom. The MOOC was designed to support foreign language teachers at all educational levels in strengthening their instructional design skills, familiarizing themselves with digital tools, and integrating AI across all stages of teaching — from lesson planning to the development of learning scenarios, worksheets, and instructional activities.

The MOOC is structured into thematic modules covering lesson planning, formulation of learning objectives, development of lesson plans and learning scenarios, construction of worksheets, and the practical use of generative AI tools such as ChatGPT, MagicSchool, Diffit, Twee, Chalkie, and Curipod. The course content is enriched with interactive activities, quizzes, discussion fora, assessment rubrics, and visualized material, while the final assignment is based on the application of AI tools in an authentic teaching context. The instructional design methodology of the MOOC is grounded in the principles of blended learning, active participation, and self-regulated

professional development, with AI functioning as a collaborative partner for teachers in instructional planning and pedagogical innovation.

This paper highlights the role of AI as a tool for pedagogical design and professional empowerment of foreign language teachers. By linking research findings with practical implementation, the MOOC serves as a model of professional development intervention that promotes the development of instructional design competencies, pedagogically grounded use of AI, and critical understanding of its possibilities and limitations. The proposed model may also be adapted to other subject areas, contributing to the development of a culture of innovation and responsible AI use in education.

Keywords — Artificial Intelligence, Instructional Design, Foreign Languages, MOOC

Introduction

The rapid advancement of Artificial Intelligence (AI) is redefining the ways in which learning processes are designed, implemented, and evaluated, influencing both instructional practice and the role of the teacher. Particularly in the field of foreign language education, generative AI tools offer new possibilities for differentiated instruction, personalized learning, and the development of rich educational materials (Villar Onrubia et al., 2025). At the same time, the integration of AI into teaching practice highlights the need for pedagogically grounded use, which goes beyond mere technical familiarization and requires systematic instructional design (EDEH, 2023; OECD, 2025, 2025b).

Within this context, a research study was conducted with the aim of investigating the attitudes, perceptions, and professional development needs of Greek teachers of English (PE06) regarding the use of AI tools in instructional design. The study was based on two questionnaires and involved a total of 96 primary and secondary education teachers, responding to the international need for empirical evidence concerning teachers' attitudes toward AI (European Commission, 2022).

The findings of the study indicate that teachers maintain a clearly positive attitude toward AI, recognizing its contribution to personalized learning, time efficiency, and the creation of rich learning materials—results that are consistent with relevant international studies (Villar Onrubia et al., 2025). Despite this positive stance, the frequency of AI tool use in educational practice remains low to moderate, suggesting difficulties in transitioning from the recognition of AI's potential to its meaningful pedagogical integration. At the same time, the research data reveal that teachers express a strong need for further support and deeper engagement with both the theoretical framework and the practical applications of instructional design, underscoring the importance of professional development in this area (Cukurova et al., 2024).

Of particular significance is the finding that only a limited number of teachers have so far participated in structured professional development programs focusing exclusively on the use of AI for lesson creation and instructional planning. The majority of participants expressed strong interest in attending such a program and evaluated its potential usefulness as very high, confirming the role of Massive Open Online Courses (MOOCs) as flexible and accessible environments for professional learning (University of Helsinki, 2023). Open-ended responses further highlighted teachers' needs for practical guidance, pedagogical integration of AI tools, and a deeper understanding of ethical issues related to their use in education—concerns that are strongly reflected in contemporary literature on AI in education.

These findings therefore reveal a substantial professional development gap: although teachers appear positive and receptive toward the use of AI, a structured training framework supporting the transformation of this positive attitude into systematic and pedagogically grounded practice is largely absent. Consequently, the need for a MOOC exclusively oriented toward instructional design through the use of AI tools emerges as an immediate and evidence-based response to the research data, aligned with contemporary approaches to teacher professional development (Cukurova et al., 2024).

The present paper draws on these research findings as a starting point for the design and development of a MOOC that aims to bridge the gap between positive attitudes toward AI and its meaningful pedagogical application. In doing so, it seeks to support the professional empowerment of foreign language teachers and facilitate the transition from technological familiarization to pedagogically grounded instructional design.

Theoretical Framework

The design of the Massive Open Online Course (MOOC) was grounded in pedagogical principles that support active learning, self-regulated professional development, and the systematic connection between theory and educational practice—elements considered critical for effective adult teacher education (Giannoulas, 2023). A central objective was the creation of a professional development environment that does not focus solely on technical familiarization with AI tools, but rather emphasizes their pedagogically grounded use within the context of instructional design in foreign language education, in line with contemporary approaches in educational technology (Peachey & Crichton, 2024; Sofos et al., 2023).

The MOOC was designed according to the principles of active and experiential learning, encouraging participants to engage meaningfully in the design process, experiment with different AI tools, and reflect on their own teaching practice—a process that promotes deeper understanding and facilitates the transfer of knowledge into practice (Dimitriadis, 2015). At the same time, the logic of self-regulated learning was adopted, allowing teachers to manage their study time, pace, and sequence of modules—an element particularly important for professional development programs addressed to adult educators with demanding professional responsibilities (Borg & Al-Busaidi, 2012).

The course structure follows the principles of blended learning, combining asynchronous theoretical material, application examples, interactive activities, and practical tasks—an approach associated with increased engagement and effectiveness in teachers' professional learning (Tomlinson & Whitaker, 2013). The thematic modules were organized progressively, starting from fundamental concepts of instructional design and gradually leading to the development of complete lesson plans, learning scenarios, and worksheets. In this way, participants are supported in systematically constructing their knowledge and skills while linking theory to the real needs of their teaching practice.

Artificial Intelligence is integrated into the MOOC as a supportive and collaborative instructional design tool rather than as an end in itself, in accordance with contemporary perspectives that emphasize the complementary role of AI in teaching and learning (EDEH, 2023; UNESCO, 2025). Generative AI tools are employed at specific stages of the learning process, aiming to enhance creativity, support differentiation of instructional materials, and improve the overall quality of instructional design, particularly in foreign language education. Participants become familiar with ways of using AI for the formulation and reformulation of learning objectives, the creation of instructional activities, the adaptation of materials to different learner levels, and reflection on the effectiveness of their design decisions.

Particular emphasis is placed on the critical and responsible use of AI, with explicit references to issues of ethics, reliability of generated outputs, and pedagogical appropriateness—topics strongly highlighted in contemporary literature on AI in education (OECD, 2025a, 2025b; UNESCO, 2021, 2022). Within this framework, AI is approached as a catalyst for pedagogical reflection and teacher empowerment, rather than as a mechanistic solution or a substitute for professional teaching judgment.

The instructional design of the MOOC incorporates multiple forms of learning activities and assessment that support active participation and continuous learning. Self-assessment quizzes, interactive exercises, online forum discussions, and assessment rubrics function complementarily, guiding participants toward the gradual improvement of their instructional designs. The final assignment is based on the application of AI in an authentic teaching context, strengthening knowledge transfer to practice and positioning assessment as a learning and reflective process, in line with principles of formative assessment (Petropoulou et al., 2015).

MOOC Design

The MOOC was organized into distinct thematic modules that follow the logic of instructional design and support the gradual and systematic development of knowledge and skills. The modules cover key stages of the teaching process, including lesson planning, formulation of learning objectives, development of learning scenarios and worksheets, as well as the pedagogically grounded use of generative Artificial Intelligence tools. This structure enables participants to approach instructional design as a coherent and integrated process, within which AI is embedded functionally rather than fragmentarily.

The learning activities of the MOOC were designed to promote active engagement and the progressive transfer of knowledge into educational practice. Each module includes a combination of theoretical content, application examples, and activities that invite participants to immediately apply what they study within the context of their own teaching subject. The selection of activities is based on the principle that teacher professional development is more effective when it is connected to authentic teaching situations and real classroom needs.

Particular emphasis is placed on reflective activities, in which participants are encouraged to evaluate the ways in which Artificial Intelligence can support, enhance, or reshape their instructional design. Through guided tasks, participants experiment with generative AI tools, examine the produced outputs, and adapt them according to pedagogical criteria and the specific characteristics of their learners. In this way, AI is integrated as a tool that supports instructional thinking rather than as an automated solution.

Assessment within the MOOC has a formative orientation and aims to support participants' learning trajectories. It includes self-assessment activities, short quizzes, and feedback through assessment rubrics, which guide participants toward the gradual improvement of their instructional designs. Assessment is organically embedded within the learning process and functions as a mechanism for reflection and continuous self-improvement.

A central component of assessment is the final assignment of the MOOC, which is based on the application of AI within an authentic teaching context. Participants are required to design a complete lesson plan or learning scenario, justify their instructional choices, and implement it in their classroom, thereby highlighting the role of AI in instructional design. The final assignment serves as a synthesis of the knowledge and skills developed throughout the course and as a means of transferring professional development into practice.

The MOOC is initially planned to be implemented in a pilot phase, with the aim of collecting participant feedback and improving the content, learning activities, and assessment tools. Following the completion of the pilot phase, the program will be offered free of charge to foreign language teachers through the Center for Lifelong Learning (KEDIVIM) of Aristotle University of Thessaloniki, contributing to the dissemination of knowledge and the strengthening of professional development within the educational community.

Discussion – Conclusions

The present paper highlights the importance of targeted and pedagogically grounded professional development for foreign language teachers in the era of Artificial Intelligence. The preceding research data demonstrated that, despite teachers' positive attitudes toward AI, its use in instructional practice remains limited and fragmented. This situation is not associated with a lack of interest or willingness on the part of teachers, but rather with the absence of structured professional development frameworks that link AI use to fundamental principles of instructional design and pedagogical practice.

Within this context, the proposed MOOC seeks to shift the focus from technology itself to the teacher and the ways in which teaching is designed, implemented, and reflected upon. Artificial Intelligence is not presented as a ready-made solution or as a mechanism for automating instruction, but as a collaborative means of supporting instructional thinking, creativity, and differentiation. This approach strengthens the pedagogical role of the teacher and contributes to the development of a more critical and responsible stance toward the use of AI in education.

The selection of the MOOC format as a professional development medium responds to contemporary teachers' needs for flexible, accessible, and self-regulated learning environments. At the same time, it enables the formation of a community of practice in which participants can exchange experiences, concerns, and good practices.

Particular pedagogical value is attributed to the emphasis on formative assessment and reflection, elements that enhance teachers' professional self-awareness and support the continuous improvement of their practice. Through the final assignment, participants are invited to reconsider the role of AI within their own teaching contexts, highlighting both its possibilities and its limitations.

Regarding future perspectives, the MOOC is planned to be implemented initially on a pilot basis, with the aim of collecting feedback and further improving the course content, learning activities, and assessment tools. The pilot implementation will allow for the evaluation of the program's effectiveness and the exploration of its impact on

participants' instructional design practices. The MOOC may function as a replicable and adaptable professional development framework, not only for foreign language education but also for other subject areas, supporting the systematic and meaningful integration of AI in education.

Overall, this paper contributes to the ongoing discussion on teacher professional development in the age of Artificial Intelligence by proposing a model that bridges research and educational practice and promotes a pedagogically responsible use of AI technologies.

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Evaluation of Conversational Artificial Intelligence Agents for Automated Grading in Education

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Abstract – This work focuses on evaluating the performance of three popular AI conversational agents (Gemini 2.5 Pro, ChatGPT 4.1, and Claude 3.7 Sonnet) as automated grading systems on a dataset containing short answers to questions from the subject area of Data Structures (Computer Science). The performance analysis was based on four main research questions: 1) How accurate is the evaluation of an AI-based automated grading system compared to the grading performed by expert human evaluators, 2) Is there a correlation between the length of the response (number of words) and the performance of AI-based automated grading systems, 3) Is there a correlation between the score of the response (as determined by expert human evaluators) and the performance of AI-based automated grading systems, 4) How confident can we be in the results provided by each system. Specifically, what variation exists in the outcomes when we repeat our experiments. Through these research questions, the study aims to provide a clearer understanding of the advantages and limitations of the three systems in their application within the educational system.

The survey results show that ChatGPT 4.1 had the highest accuracy in automatic scoring, with a lower Root Mean Square Error (RMSE) compared to Claude 3.7 Sonnet and Gemini 2.5 Pro. Specifically, ChatGPT showed an RMSE of 0.82, followed by Claude with 1.02 and finally Gemini with 1.07. The statistical analysis for the whole dataset shows that the three agents had a relatively high and almost identical correlation coefficient with the grade of the expert raters, revealing the possibility of imitating human behavior in terms of scoring and at the same time indicating perhaps a common factor in the scoring process. However, there were significant differences in the performance of the three agents depending on the type of question. These differences suggest that each of the systems has distinct strengths and weaknesses depending on the content and structure of the question. Furthermore, extended research is needed to prove/or disprove the correlation (if any) between the number of words/or the score of the response (by expert human evaluators) with the error produced by the automated systems.

The results of the present work are a first indication that each of the three AI systems may be suitable for use as an automatic grading system, which could be exploited in the future to ensure maximum accuracy in examination procedures or to simplify procedures involving courses with many students (so-called massive online open courses - MOOCs). Correlation analysis indicates that the three conversational agents could be safely used in specific automatic grading applications. More research is needed in the direction of system parameterization and also in the improvement of prompts

(prompt engineering) to increase the accuracy and decrease the variability of the responses of these systems.

Keywords— Automated short answer grading systems, AI chatbots, AI in education

Introduction

Educational methods that involve active learning are proving to be very effective in promoting logical thinking and active participation (Drini, 2018). At the same time, technological advancements aim to provide new tools to educators for the invention and implementation of new teaching methods. Nowadays, society is experiencing the transition to the new era of artificial intelligence (AI), with the development of highly advanced conversational agents (AI chatbots) (Jalil, Rafi, LaToza, Moran, & Lam, 2023). It is therefore obvious that there are many challenges ahead of us regarding the role of artificial intelligence in the coming years, particularly in education.

In one of their recent studies, Tack and Piech (2022) sought to find an evaluation framework that answers the question ”how good is a conversational artificial intelli gence agent as a teacher?” In their paper, they present two AI chatbots (versions of ChatGPT and Blender) and compare their pedagogical ability with that of a teacher. Their results show that conversational artificial intelligence agents perform worse in several pedagogical dimensions, particularly in providing assistance to the learner. However, this research indirectly highlights another important question: ”How could artificial intelligence applications be developed to function as educational assistants?”. The research by Tack and Piech (2022) shows that an AI conversational agent without any supervision cannot replace the teacher in their role. However, the question that follows is: ”What utility does an AI conversational agent have in the educational system?” To answer this question, it seems necessary to first examine the benefits and impacts caused by the introduction of artificial intelligence in education. AI chatbots represent a significant advancement in the field of artificial intelligence, as they belong to a category of models known as ”Large Language Models” which have proven to be very effective in understanding natural language (Kasneci et al., 2023). Therefore, it seems logical that there can undoubtedly be immense benefits if they are successfully integrated into the educational system. However, there are also many challenges.

For example, Shahriar and Hayawi (2023) refer to issues of privacy and ethics in the use of artificial intelligence technology in society. Therefore, the educator must be careful in how they use these models. Specifically, the educator must understand their technology and their limitations. Kasneci et al. (2023) emphasize the importance of a clear strategy and approach with a focus on critical thinking and fact-checking. Indeed, artificial intelligence should not be used as a prophet and authority, but with healthy skepticism. For example, Frieder et al. (2023) refer to the limited mathematical ability of these models. Specifically, they demonstrated that ”the mathematical abilities of ChatGPT are significantly lower than those of an average mathematics graduate.” Since the use of AI chatbots in education can be justified, the next research question is ”how can an artificial intelligence application be integrated into the educational system?” An AI chatbot is a conversational agent that receives queries from users and provides answers to these questions in the form of a typical conversation. Therefore, it seems that before a clear pedagogical approach can be formulated, it is necessary to first understand how questions can be phrased to achieve the educational goal. This is a field of growing interest (White et al., 2023), called ”Prompt Engineering.” (prompt engineering). Recent research by Vemprala, Bonatti, Bucker, and Kapoor (2024) suggests a strategy that combines principles from prompt engineering, enabling ChatGPT to lead to the resolution of complex robotic tasks. Research in the field of prompt engineering has already expanded into education with works such as those of

Lee, Latif, Wu, Liu, and Zhai (2024), which evaluate different versions of ChatGPT using various prompts and present results on an innovative prompt engineering technique referred to as ”Chain of thought.” (CoT). The definition of this technique can be found in the work of Wei et al. (2022), where it is described as ”a sequence of intermediate reasoning steps expressed in natural language, leading to the final result.”

This paper focuses on the research field of automatic grading of written assignments by conversational artificial intelligence agents. Automatic grading can solve problems related to the daily parameters of teachers and students. Automated grading systems have been developed based on two categories of written assignments. Specifically, there are 1) systems developed for automated essay scoring (Automated Essay Scoring-AES) and 2) systems for automated short answer grading. (Automated Short Answer Grading-ASAG). Automated Short Answer Grading (ASAG) focuses on ”the evaluation of short answers in natural language to objective questions using computational methods.” (Burrows, Gurevych, & Stein, 2015). The main difference between AES and ASAG systems is that the latter deal with short answers that are usually graded in relation to a reference answer, while the former concern the evaluation of longer answers, where grading is based on the quality of the writing in terms of spelling, grammar, and coherence, and focuses less on the content information itself (Haller, Aldea, Seifert, & Strisciuglio, 2022). Another frequently observed difference concerns the differentiation of the sciences referenced in the two types of responses. The tasks related to AES systems cover persuasive, narrative, and source-dependent text comprehension, which pertains to the theoretical sciences (e.g., literature, philology, etc.), while the tasks related to ASAG systems tend to originate from the sciences, mathematics, and generally the positive sciences (Riordan, Horbach, Cahill, Zesch, & Lee, 2017).

In this paper, we evaluate the performance of three popular artificial intelligence conversational agents in the automatic scoring of short answers. (ASAG). It was observed by Del Gobbo, Guarino, Cafarelli, and Grilli (2023) that this research field lacks a standardized and well-defined approach for comparing the performance of the proposed methodologies. Specifically, it is noted that researchers typically use different datasets and performance metrics to evaluate their methods and often do not share the code or software for reproducing their tests. In the following sections, we focus on the literature review to document the progress in the field of ASAG, its future prospects, and ultimately to precisely define the contribution of the present work to this field.

The datasets that exist and can be used to evaluate the performance of new automatic assessment systems are limited in number (Del Gobbo et al., 2023). After conducting the literature review, we identified 4 datasets which we list below.

1. ASAP-SAS (Hamner, Morgan, lynnvandev, Shermis, & Ark, 2012). The dataset is the SAS dataset from the Kaggle competition (https://www.kaggle.com/competitions/asap-sas/data). The Hewlett Foundation: Short Answer Scoring Develop a scoring algorithm for student-written short-answer responses.) The description of the dataset is as follows: The SAS dataset consists of 17,043 total responses across 10 topics covering various subjects, which were given to 8th and 10th-grade students (depending on the topic). Each response was graded by two human raters. Along with the graded data, complete grading tables are included that contain grading instructions and score ranges tailored to each stimulus.

2. Dataset ScientBank (subset of SRA Dataset)(Dzikovska et al., 2013). The SciEntBank dataset consists of 10,000 student responses to 192 questions covering 16 scientific topics from 3rd to 6th grade. The answers are labeled with the tags a) Correct, Incorrect, b) Correct, Contradictory, Incorrect, and c) Correct, Partially Correct, Contradictory, Irrelevant. The dataset is divided into two subsets: a) training set and b) test set.
3.CU-NLP dataset (Tulu, Ozkaya, & Orhan, 2021). The CU-NLP dataset was created from the final exams of the Natural Language Processing course at C¸ ukurova University in 2019. This exam included two open-ended questions, to which 86 students provided answers. The reference answers for each question were compiled by the course instructor, and the final scores for each student response were normalized on a scale from 0 to 1. (https://ceng.cu.edu.tr/uorhan/CuNLP.htm).
4.Mohler dataset (Mohler, Bunescu, & Mihalcea, 2011). This dataset is based on the work of an undergraduate course on data structures at the University of Texas and was released in 2009. In 2011, the authors released an extended dataset. Each response is graded by two independent evaluators, and the average of their scores is considered the final grade.

We are now focusing on research related to the Mohler dataset (Mohler et al., 2011), which we are also using in this work. Many studies have already used this dataset and analyzed its characteristics. Recent research by Xie, Niu, Xue, and Guan (2024) observed that better results are achieved on the Mohler dataset when the automatic system is left without specific parameter tuning (fine tuning). They considered this to be due to the fact that in the Mohler dataset, the questions are relatively simple and short, and therefore the prior knowledge that the system has is sufficient to perform the grading adequately. Other recent works have used the Mohler dataset for the evaluation of automated grading systems. Specifically, in the work of Kaya and Cicekli (2024), an analysis and comparison of several automatic evaluation systems on the Mohler dataset was conducted. The authors of this paper argued that the Pearson correlation coefficient between the scores given by the raters and the score of each system indicates the system's ability to mimic human judgment and evaluation. In this particular study, the authors proposed their own system (with a correlation coefficient of 0.747 and a performance measure of the Root Mean Square Error (RMSE) of 0.856). For the other systems evaluated in their study, it was found that the RMSE values ranged between 0.732 and 1.050

(Contribution). The conclusions drawn from the literature review are presented below.
1. The research on the evaluation of automated grading systems is still in its early stages. Especially regarding conversational artificial intelligence agents, where there are mainly some initial results for ChatGPT.
2. According to what we know, there is no work that compares the three conversational agents ChatGPT, Gemini, and Claude (in any of their versions) and evaluates their performance as automated grading systems.
3. There are conclusions that need to be verified with more research. For example, Chang and Ginter (2024) recorded a negative correlation between the length of the responses and the performance of the model they used (in versions of ChatGPT). The same observation is present in Grevisse (2024), where the correlation between the length of the response and the model's performance is relatively weak (small linear correlation coefficient). Also, in the master's thesis by Nilsson and Tuvstedt (2023), a difference was observed in the system's performance (ChatGPT version) in relation to

the answer's score. It was also observed that the system tends to favor the rating, especially in responses that failed (favorable evaluation of responses that were rated by experts with a non-passable grade).
4. Grevisse (2024) argues that there is a possibility of model bias when the information about the scores from expert evaluators is provided in the prompts.
5. Fine-tuning the model is sometimes not necessary (Grevisse, 2024; Xie et al., 2024).
6. It is reported that ChatGPT is quite reliable with repeated prompts or prompts with minimal differences (the model gives fairly similar results with the same prompts (Grevisse, 2024; Jukiewicz, 2024).

In this paper, we investigate some of the aforementioned positions (addressing the research questions we pose in the next chapter of the Methodology) in order to either verify or challenge them. Specifically, the present work aims to contribute to the research on the usefulness of artificial intelligence conversational agents and their comparison. At the same time, this work also addresses questions regarding the performance of automatic grading systems in relation to a) the adequacy of the response (the score it received from expert graders), and b) the length of the response. The repeatability of the produced results for the conversational agents is also investigated. The experimental design includes a) prompts that do not reveal to the conversational agent the scores of the expert raters and b) no specific system parameterization is performed, as the platform used is the one mentioned for the average user.

(Dataset). To evaluate the systems under consideration in the scoring of short answers, we used the Mohler dataset from the work of Mohler et al. (2011). This dataset was selected for the present work due to the proximity of the scientific field of the questions (computer science) to the scientific field of specialization of the author of the master's thesis. The dataset contains answers to assignments from introductory computer science courses provided by a class of undergraduate students. These assignments were given as part of a Data Structures course at the University of North Texas. For each assignment, the students' answers were collected through an online learning environment. The students submitted answers to 80 questions distributed across ten assignments and two exams. The dataset consists of a total of 2273 responses. The answers were independently graded by two raters, using a scale from 0 (completely incorrect) to 5 (excellent answer). Both raters were graduate students from the computer science department; one (grader1) was the teaching assistant assigned to the Data Structures course, while the other (grader2) is one of the authors of the article under review. We also consider (as do the creators of the dataset) the average score of the two graders as the gold standard, with which we compare the evaluation of the systems under examination (Gemini 2.5 Pro, ChatGPT 4.1, Claude 3.7 Sonnet). We created appropriate prompts in the systems under examination to provide us with 1) the score that each system calculates as corresponding to the student's answer and 2) to justify that score.

(Prompt Engineering technique). For the creation of the prompts used in this work, we were inspired by ideas mentioned in Wang and Ormerod (2024). The prompts used by the authors of the article were created by the Claude Anthropic prompt design application. From their analysis, it appears that the Claude Anthropic prompt generation application produces more effective prompts than prompts that follow general rules, or those generated by the DSPy program (Khattab et al., 2024). Specifically, Wang and Ormerod (2024) showed that the prompts produced by Claude Anthropic are

approximately 10% more effective than those produced by DSPy. Similar prompt templates can also be used in the present work, with minor content variations.

Specifically, in the systems under examination, the following prompt template was used: “You are an expert grader tasked with evaluating answers to a given question. The assignments were administered as part of a Data Structures course at the University of North Texas. Your goal is to carefully analyze the provided information and grade each answer to [0...5] scale (refine your grading criteria to include grades with increments of 0.25.). Follow these steps: 1. Read the question X.Y carefully: [Question X.Y]. Now, consider the reference answer, which is the gold standard for correctness: [Reference Answer X.Y]. Now, examine the answers that need to be evaluated: [Students’ Answers for X.Y] 4. Analyze the new answers by comparing it to the reference answer. Consider the following criteria: a. Is the new answer a complete paraphrase of the reference answer that correctly answers the question? b. Is the new answer partially correct, irrelevant to the question, or out of the domain? c. Does the new answer explicitly contradict the reference answer? 5. Based on your analysis, choose a grade from [0...5] scale (refine your grading criteria to include grades with increments of 0.25.). 6. Provide your judgment using the following format: [Insert your chosen judgment here: your grade] Important notes: - provide any explanations or additional text apart from the grade itself. - Focus solely on the content and meaning of the answers, not on minor differences in wording or style. Provide your judgment in such a format that each students answer (students answer, your grade, your feedback) is in different line.”

(Research questions). In this paper, we focus on the following four (4) research questions: RQ1. How accurate is the evaluation of an automatic artificial intelligence grading system compared to the grading by expert raters? RQ2. Is there a correlation between the length of the response (number of words) and the performance of automatic artificial intelligence grading systems in terms of accurate grading? RQ3. Is there a correlation between the score of the response (as expressed by expert raters) and the performance of automated artificial intelligence grading systems in terms of accurate scoring? RQ4. How confident are we in the results provided by each system? what variation exists in the results we obtain if we repeat our experiments?

Conclusion

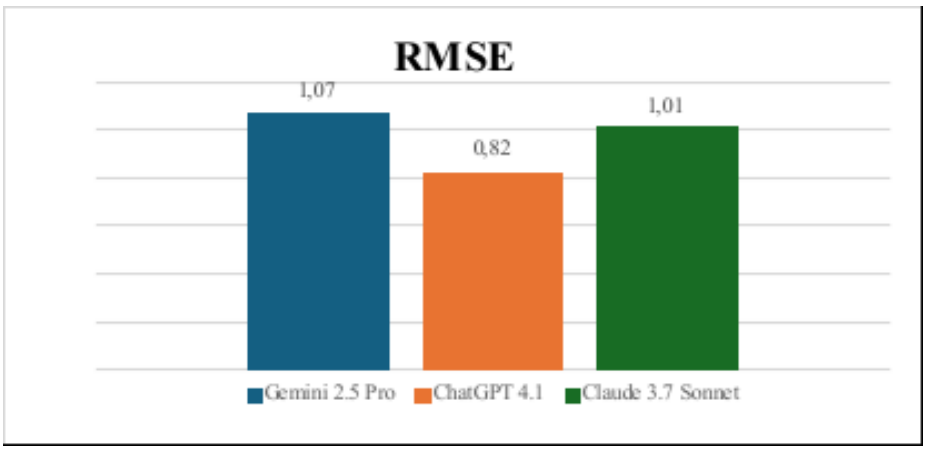


Figure 1. The RMSE as calculated for the Mohler dataset for the three systems under consideration.

(Results-RQ1 How accurate is the evaluation of an artificial intelligence automatic grading system compared to the grading by expert raters?) To answer this question, we use the root mean square error (RMSE). The RMSE was calculated for all three systems (Fig. 1). Specifically, for Gemini 2.5 Pro it is 1.07, for ChatGPT it is 0.82, and for Claude 3.7 Sonnet it is 1.01. A smaller RMSE means better performance for the respective system. So we can say that ChatGPT had the best performance in the set of responses we selected. Immediately after is Claude 3.7 Sonnet, and third is Gemini 2.5 Pro. In Figure 1, we present the RMSE analysis per question for all three systems. Fig. 1 The RMSE as calculated for the Mohler dataset for the three systems under consideration. The correlation coefficient between the average score of the raters and each system is also 0.73, 0.70, 0.72 for Gemini 2.5 Pro, ChatGPT 4.1, and Claude 3.7 Sonnet respectively, which encourages us to use these systems (Kaya and Cicekli (2024) considered a linear correlation value of 0.747 very good for their system). In Fig. 2, we present in detail the performance of each system per question, where we calculate the RMSE for each system and for each question.

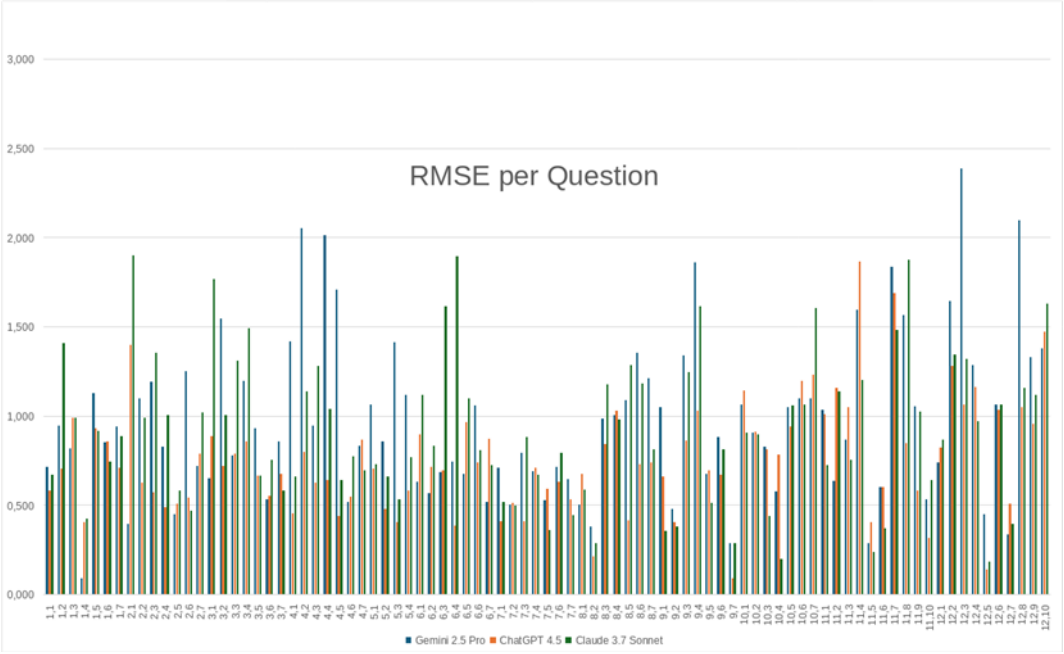


Figure 2. Histogram showing RMSE calculated per question for the systems under consideration (rounded to three decimal places).

At the same time, we present in Fig. 3, the histogram in which we distinguish the differences in absolute value of the grade of each system with the raters (for example, in category 0, we have the complete match of the grade of the system with the raters, in category 0.5 we have a difference in absolute value of 0.5, etc.). We find for Gemini 2.5 Pro, ChatGPT 4.1, Claude 3.7 Sonnet a) complete matching at 43%, 50% and 43% respectively, and b) we observe that there are no answers that are scored completely wrong (difference 5). It is interesting to notice that all the systems seem to be stricter than the human experts. Specifically, for a random answer Gemini 2.5 Pro is expected to grade the response 0.46, ChatGPT 0.16, and Claude 3.7 Sonnet 0.51 less than the human evaluators.

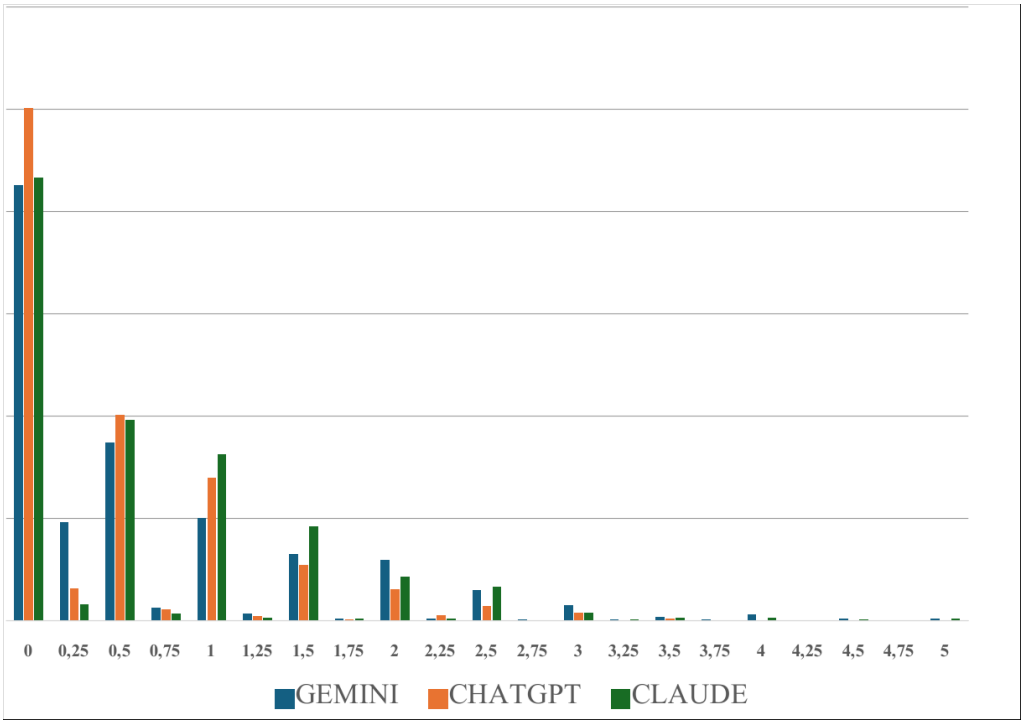


Figure 3. Histogram showing the frequencies at which the deviation values of the system grade from the expert grades occur. Orange corresponds to Gemini 2.5 Pro, blue corresponds to ChatGPT 4.1 and green corresponds to Claude 3.7 Sonnet.

(Results-RQ2 Is there a correlation between response length and the performance of AI systems in terms of correct scoring?) Our analysis is carried out in two directions expressed by two sub-questions. In subquestion a) we calculate whether increasing the number of characters in an answer is associated with better/ or worse performance of the system under consideration. The independent variable defined is the number of words, and the dependent variable is the absolute value of the difference between the mean score of the judges and the score of the system. Subquestion (b) examines whether or not the system tends to favour in degree the longer answers. Again, the independent variable is defined as the number of words, and the dependent variable is the value of the difference between the mean score of the judges minus the score of the system. For both subquestions (a, and b) we calculate the correlation coefficient to test whether there is a linear relationship between the two variables. We observe a small correlation coefficient (absolute value up to 0.05) for both subquestions for all three systems, which means that the strength of the linear correlation is very weak (we verify results of similar studies). We note in sub-question a: All three systems are observed to favor responses of a larger number of words.

(Results- RQ3: Is there a correlation between the answer score (as expressed by the human experts), and the performance of AI systems in terms of correct scoring?). Our analysis is also conducted on this question in two directions expressed by two sub-questions. In subquestion a) we calculate whether an increase in the judges' score for an answer is associated with better/ or worse performance of the system under consideration. The independent variable defined is the mean score of the judges, and the dependent variable is the absolute value of the difference between the mean score of the judges and the score of the system in question. Subquestion (b) examines whether or not the system tends to favor, or not, responses as the score of the response by the

humsn experts increases. Again, the independent variable is defined as the mean score of the judges, and the dependent variable is the value of the difference between the mean score of the judges minus the score of the system in question. For both subquestions (a, and b) we calculate the correlation coefficient.

We observe correlation coefficient values (absolute value from 0.004 to 0.280) for both subquestions for all three systems, which means that the strength of the linear correlation is quite different from system to system and between subquestions. In particular, in subquestion (a) all three systems perform better for greater human experts scores. Subquestion b) Gemini 2.5 Pro, and Claude 3.7 Sonnet tend to favor responses that have better scores by human experts (chatGPT 4.1 tends to favor the opposite direction).

(Results- RQ4: How confident are we about the results each system gives us; what variation is there in the results we get if we repeat our experiments?). We selected question 1.1 to test the repeatability of the results for each system. Specifically, 1) we asked each system 10 times to rate the 29 responses to question 1.1 (" What is the role of a prototype program in problem solving?"), 2) we calculated the standard deviation for each response (with the 10 samples of the 10 replicates), 3) we created appropriate charts in which to have the results for the standard deviations calculated for the 29 responses (median standard deviation for the 29 responses, quartiles-quartiles, maximum and minimum standard deviation values).

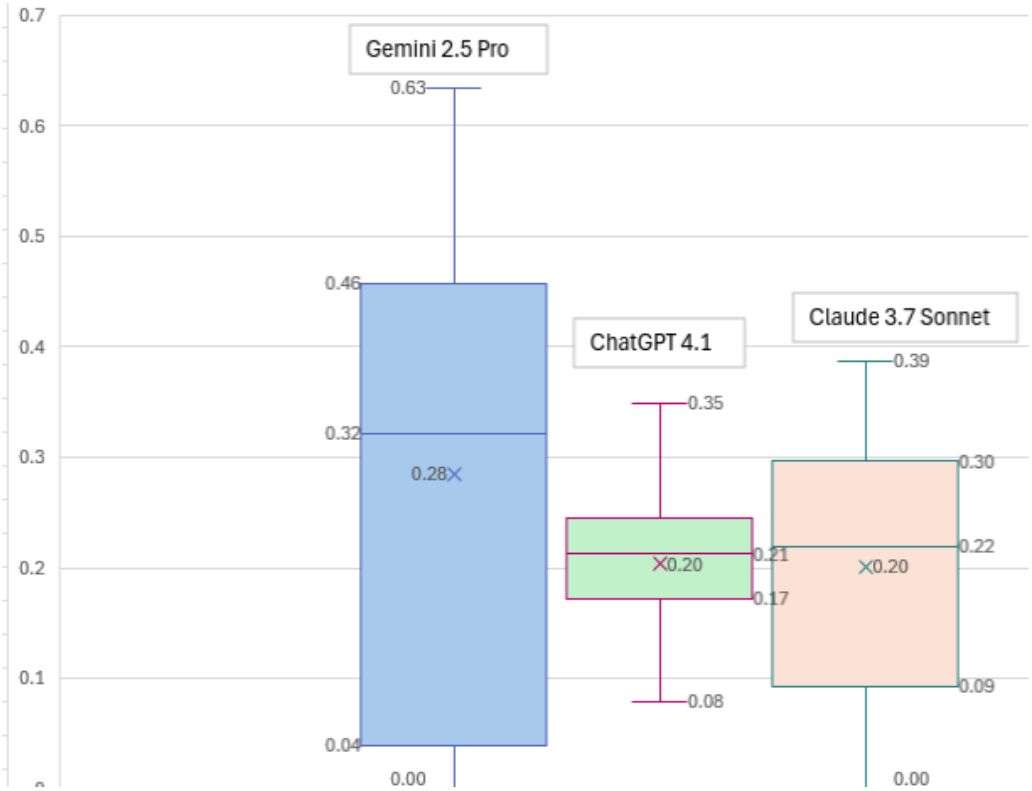


Figure 4. Repeatability for the three systems Gemini 2.5 Pro (pale blue), ChatGPT 4.1 (pale orange) and Claude 3.7 Sonnet (pale green) for question 1.1. We repeat the same prompt 10 times for the answers to question 1.1 in different sessions and find the distribution of scores.

Regarding repeatability across sessions we compare the three systems and find that the medians are 0.28, 0.20 and 0.20 for Gemini 2.5 Pro, ChatGPT 4.1, Claude 3.7 Sonnet respectively. For Gemini 2.5 Pro we have the maximum of the divergence with 0.63 and the minimum of the divergence with 0.04. ChatGPT 4.1, Claude 3.7 Sonnet seem to show quite similar pattern of behavior regarding the repeatability of results across sessions. We want to point out at this point that due to the fact that we used the platform for the average user, we did not change the parameters of the systems. We therefore consider that the experiments were performed on the systems with the standard values of the parameters set at the beginning. Further investigation is considered necessary to investigate a method of parameterizing the systems to minimize the variance of the scores.

(Concluding remarks). In conclusion, this paper is a first attempt to quantitatively compare the performance of three AI interactive agents in automatic scoring of short answers. Although the systems showed positive results, however, it highlights the need for further investigation and optimization of these models to ensure maximum accuracy and transparency of their results. AI models have the potential to support the educational process, however, their proper integration and ongoing monitoring of their accuracy and reliability are crucial for their success. Future research is needed to support or challenge the results of both the present and previous work. The correlation between the length of the answer, the answer score (reference score), the type of question, the subject matter, the language in which the question is worded and the performance of a system are research questions that need further investigation. Moreover, with a dataset available to LLMs, it is unclear whether grade predictions reflect robust grading ability or dataset familiarity, which threatens the validity of automated assessment claims. In subsequent research, we intend to develop and test a rigorous evaluation framework for LLM-based grade assessment. At the same time, questions about how we can know whether an automatic scoring system was used and whether we can identify it (which system was used) also need to be investigated.

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Ethical and Social Dimensions of Artificial Intelligence in Primary Education: An Educational Intervention in School

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Abstract - This paper investigates the ethical and social dimensions of Artificial Intelligence (AI) in Primary Education through an educational intervention implemented with sixth-grade primary school students. The aim is to explore how children perceive AI as a social phenomenon, how they express moral reflection and critical thinking in relation to issues of algorithmic bias, and how its pedagogical integration can enhance social awareness and responsible digital literacy.

The intervention was implemented through experiential activities in two AI environments — *AI for Oceans* (Code.org) and *AI4EDU* (Institute for Language and Speech Processing / "Athena" Research Center) — which enabled students to actively interact with machine learning models and language-based AI systems. Through thematic analysis of students' worksheets and observational data, findings indicated that students developed a basic understanding of how AI systems function, recognized phenomena of algorithmic bias, transparency, and creator responsibility, and articulated critical and ethical questions regarding the use of this technology.

The experience demonstrated that even young learners, through experiential and collaborative pedagogical approaches, are capable of engaging with complex ethical issues, cultivating critical digital literacy, and developing social awareness regarding the role of AI in contemporary society. The findings support the need for a human-centered pedagogical integration of AI in education, aligned with UNESCO's (2021) guidelines for the responsible, fair, and transparent use of technology.

Keywords— Artificial Intelligence, Algorithmic Bias, Critical Thinking, Social Awareness, Primary Education

Introduction

Artificial Intelligence (AI) constitutes one of the most transformative technological developments of the 21st century, profoundly influencing the ways in which people work, communicate, learn, and participate in society. Its applications extend across all domains of human activity, shaping a new cultural and social environment in which human–machine interaction becomes an everyday reality. Within this context, education is called upon not only to prepare students to use AI technologies, but also to develop their critical, ethical, and responsible understanding of their capabilities and limitations.

The integration of AI in Primary Education is of particular significance, as children are at a critical stage of cognitive and socio-emotional development, during which they begin to form perceptions about technology and its social role. Teaching approaches that focus exclusively on technical knowledge are insufficient; instead, a human-centered and pedagogically sensitive approach is required—one that fosters experiential engagement, critical thinking, and moral reflection. As emphasized by UNESCO (2021), AI education should be grounded in values such as justice, transparency, responsibility, and respect for human rights.

The ethical dimension of AI has become increasingly critical, as algorithmic systems may reproduce social biases and inequalities. Algorithmic bias—the distortion resulting from limited or skewed datasets—constitutes a characteristic example of how technology embodies human choices and values (Mitchell, 2019). At the same time, issues of transparency, responsibility, and accountability of AI system developers are gaining growing importance, making the cultivation of critical digital literacy from the earliest educational stages essential.

The pedagogical use of AI through experiential and collaborative activities can provide meaningful learning opportunities. Through environments such as *AI for Oceans* (Code.org) and *AI4EDU* (Institute for Language and Speech Processing / "Athena" Research Center), students can experiment with basic principles of machine learning, observe phenomena of algorithmic bias, discuss issues of responsibility, and reflect on the social implications of technology. When pedagogically framed, direct interaction with AI systems can serve as a foundation for the development of ethical awareness, social consciousness, and responsible attitudes toward intelligent systems.

The present study is situated within this framework and examines the ethical and social dimensions of AI in Primary Education through a targeted educational intervention. Specifically, it explores:
(a) how students perceive AI as a social phenomenon,
(b) how they express moral reflection and critical thinking regarding issues of bias, transparency, and responsibility, and
(c) how the pedagogical integration of AI can enhance students' social awareness, responsibility, and critical digital literacy.

This research seeks to contribute to the scientific discourse on the human-centered and ethically sensitive integration of AI in schooling, highlighting the role of experiential learning in shaping reflective, responsible, and socially engaged citizens of the digital age.

2. Theoretical Framework

Artificial Intelligence (AI) in education does not merely constitute a technological innovation, but also a pedagogical challenge and a social phenomenon. The discussion surrounding the role of AI in schools is linked to two interrelated dimensions: the cognitive–pedagogical dimension, which concerns how technology can support learning, and the ethical–social dimension, which concerns values, biases, and the societal consequences of its use (Holmes, Fadel, & Bialik, 2019; Crawford, 2021).

2.1 Artificial Intelligence in Education

AI is defined as the field of computer science that develops systems capable of performing tasks that would require intelligence if carried out by humans (Russell & Norvig, 2021). In educational contexts, Artificial Intelligence in Education (AIEd) refers to the use of AI technologies to support teaching, enhance personalization, and increase learner engagement (Luckin et al., 2016). These tools include intelligent tutoring systems, adaptive learning platforms, chatbots, learning analytics systems, and language models, which can provide targeted feedback and dynamic support to learners.

However, the educational use of AI is not value-neutral. As emphasized by the OECD (2021), technology should not be approached solely as an efficiency tool, but also as a carrier of values that shapes relations of power, access, and decision-making. Particularly in Primary Education, the pedagogical integration of AI must take into account students' developmental maturity and aim not only at concept learning, but primarily at fostering critical understanding of the social consequences of intelligent systems.

When AI is used through experiential and inquiry-based activities, it can function as a field of experimentation and reflection. Through such experiences, students gain the opportunity to recognize how algorithms operate, identify bias, reflect on accuracy and responsibility, and understand that technological systems reflect human choices and values.

2.2 Ethical and Social Dimensions of AI

The ethical and social implications of AI have become a central axis of the international research agenda. UNESCO (2021) proposes a values-based framework grounded in justice, inclusion, transparency, and accountability, emphasizing that education must contribute to the formation of citizens capable of critically evaluating technological progress.

Within this framework, three key concepts are particularly relevant to AI education:
Algorithmic bias:
Refers to biased or unfair system behavior resulting from limited or distorted datasets. Students exposed to experiential algorithm-training activities (such as *AI for Oceans*) are able to understand that data are not neutral and to reflect on the social consequences of such bias (Mitchell, 2019).
Transparency and explainability:
The need for users to understand how AI systems operate in order to evaluate and

control them critically. Explaining algorithmic outcomes is a prerequisite for the development of a democratic and participatory digital culture (Floridi, 2019).

Responsibility and accountability:
The question of "who is responsible" for AI system decisions is central both socially and pedagogically. Discussing such issues in school contexts can serve as a foundation for moral reflection and ethical sensitivity development.

The integration of these themes in educational practice aligns with the demand for a critical pedagogy of technology (Selwyn, 2019), where students are not passive users but active thinkers who interpret and question the systems around them.

2.3 Critical Digital Literacy and Moral Reflection

Critical digital literacy refers to individuals' ability to analyze, evaluate, and question the information and technologies they use (Buckingham, 2015). In the context of AI, this implies that students must understand how systems "learn," what data they use, and what values they embed. Thus, critical literacy extends beyond tool-use skills to critical understanding of the social implications of technology.

Moral reflection constitutes a core component of education aimed at cultivating responsible and conscious citizens. According to Dewey (1933), thinking acquires moral significance when it involves reflection on the consequences of actions. In the context of AI, such reflection concerns students' ability to consider justice, equality, transparency, and social responsibility in technological applications.

Through experiential activities involving interaction with "intelligent" systems, such as the *Conversation with Ioannis Kapodistrias* activity in AI4EDU, children are given the opportunity to explore the concept of "intelligence," question authority and truthfulness, and recognize that machines do not possess human judgment or moral intention. This process cultivates metacognition, critical thinking, and empathy—fundamental components of moral reflection (Zawacki-Richter, 2019).

3. Methodology

3.1 Research Design

The present study adopted a qualitative approach, specifically a case study design, aiming at an in-depth understanding of students' perceptions, attitudes, and forms of moral reflection developed through interaction with Artificial Intelligence (AI) environments. The qualitative approach was considered appropriate, as it allows for the interpretation of students' experiences in authentic learning contexts and highlights the social and emotional dimensions of learning (Creswell, 2014).

The research was embedded in an educational intervention implemented in a sixth-grade primary school classroom, with a duration of three teaching hours. The intervention was designed based on principles of experiential and inquiry-based learning and aimed at cultivating critical digital literacy, moral reflection, and social awareness through direct interaction with AI applications.

3.2 Research Sample

The sample consisted of 16 sixth-grade students from a public primary school. Purposeful sampling was applied, as participants met the characteristics considered appropriate for achieving the research objectives: basic familiarity with digital tools, willingness to collaborate, and developmental readiness for reflective activities. Participation took place following parental informed consent and in full compliance with ethical research standards and personal data protection regulations in accordance with GDPR.

3.3 Research Instruments

Data collection was based on three complementary tools, allowing for data triangulation and enhanced validity of findings:

AI digital environments:
The *AI for Oceans* environment (Code.org), through which students trained an image classification algorithm, observing algorithmic bias and misclassifications due to limited data.
The *AI4EDU* platform (ILSP / "Athena" RC), where students participated in the activity "Conversation with Ioannis Kapodistrias," interacting with an AI-based language model agent and exploring issues of responsibility, authority, and transparency.

Worksheets:
After each activity, students completed short open-ended worksheets designed to capture perceptions, emotions, and reflections regarding AI operation and ethical dimensions.

Observation sheets:
The researcher systematically recorded verbal and non-verbal student reactions, group discussions, moments of surprise or doubt, and indications of reflection or disagreement, focusing on both cognitive and emotional engagement.

3.4 Procedure and Data Analysis

Data collection was conducted in two phases:
(a) interaction with *AI for Oceans* and
(b) interaction with *AI4EDU*.
Each phase included a short introduction by the teacher, guided activity, and group discussion. Data from worksheets and observations were analyzed using thematic analysis (Braun & Clarke, 2006), identifying recurring meaning patterns and forming thematic categories aligned with the research questions.

3.5 Ethical Considerations

The study fully adhered to educational research ethics, ensuring participant anonymity, data confidentiality, and pedagogical safety. All activities were developmentally appropriate and designed with respect for children's expression and emotional well-being.

4. Results and Discussion

The analysis of data revealed cognitive, ethical, emotional, and social forms of student engagement with Artificial Intelligence. Students developed an understanding of AI as a human-designed system, recognized algorithmic bias, expressed moral reflection, and demonstrated social awareness and responsibility.

Findings showed a transition from anthropomorphic perceptions of AI toward causal and human-centered interpretations, recognition of responsibility and accountability, critical questioning of authority and transparency, and the development of critical digital literacy.

The triangulation of data sources confirmed consistency between students' verbal expressions and observed behaviors, indicating authentic cognitive and emotional engagement rather than superficial responses.

Overall, the intervention confirmed that AI can function as a pedagogical field of ethical and social education, fostering reflective, responsible, and socially conscious participation in digital society.

Conclusion

This study demonstrated that primary school students are capable of approaching Artificial Intelligence (AI) not only as a technological tool but also as a social and ethical phenomenon. Through experiential participation in activities using the *AI for Oceans* and *AI4EDU* environments, students developed a multifaceted understanding of how intelligent systems operate while simultaneously expressing moral reflection, critical thinking, and social awareness.

Students initially approached AI through anthropomorphic perceptions, which were progressively reconstructed through experiential algorithm training. They developed causal understandings of how data influence AI decisions and recognized the human role in shaping algorithmic behavior.

Furthermore, students expressed ethical reflection on issues of justice, bias, and responsibility, understanding that algorithms are not neutral but reflect human choices and values. They also demonstrated critical awareness of transparency and authority in AI systems.

Finally, the pedagogical integration of AI enhanced students' critical digital literacy and responsible attitudes toward technology. Students recognized the importance of human oversight and connected AI use with social and environmental purposes.

Overall, the results confirm that AI, when pedagogically and critically integrated, can contribute to the formation of active, responsible, and reflective citizens of the digital age. It is therefore recommended that similar experiential and ethically grounded AI learning activities be systematically incorporated into school curricula, supported by interdisciplinary approaches and teacher professional development programs that promote critical digital literacy and human-centered technology education.

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Metazoë and Artificial Continuity: Ethical and Educational Implications of Immortality through Artificial Intelligence

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Abstract - This paper explores the concept of "Metazoë" as an ontological and pedagogical framework for understanding the artificial continuity that arises from the convergence of Artificial Intelligence (AI) and human existence. Through the analysis of the "Tofflerian Analytical Framework" (TAF), it examines how education is called upon to manage the "Shock of the Future" provoked by digital immortality and algorithmic traces. The adoption of "tentacular thinking" is proposed as an alternative epistemology that promotes networked relevance and "sympoietic" learning. The paper delves into the ethics of care and memory, arguing that pedagogical responsibility in the age of AI is shifting from the simple transmission of knowledge to the formation of an ethic of continuity, where the digital footprint of the teacher and student is treated as a living part of a post-anthropocentric and ecological continuum.

Keywords— Metazoë, Artificial Continuity, Artificial Intelligence, Tentacular Thinking, Digital Immortality, Meta-anthropocentrism.

Introduction

Acceleration has become a challenge in the digital age. The contemporary educational reality is not merely experiencing a technological transition, but a profound ontological shift that redefines the essence of the subject. The rapid advent and integration of Artificial Intelligence (AI) into every aspect of social life has brought about what Alvin Toffler (1970) prophetically described as the "Future Shock": a state of collective paralysis and disorientation, where the pace of change far exceeds the human capacity to process and adapt. In the educational landscape, this disruption manifests itself as an inability of institutions to keep up with developments, with the result that education is often trapped in a sterile technocratic approach. By treating AI exclusively as a tool for efficiency or automation, we overlook its potential to reshape our very existential foundations.

However, through the Tofflerian Analytical Framework (TAF), it becomes clear that the need for a radically new educational strategy is not merely useful, but imperative (Oikonomou et al., 2025). AI does not just invade the classroom as a digital assistant; it reshapes the traditional boundaries between physical and digital presence, creating hybrid forms of existence that challenge classical anthropocentric theories. This acceleration requires the educational world to abandon passive adaptation and cultivate a proactive ability to diagnose future trends before they turn into a management crisis.

The central question of our time, therefore, is shifting. It no longer concerns only the functional use of algorithms in learning or the acquisition of digital skills, but how AI creates an "artificial continuity" of human existence. The persistence of data, the algorithmic reproduction of voice and thought, and the creation of autonomous digital avatars introduce a new dimension to human mortality and memory.

This paper introduces and develops the concept of "Metazoë" as the necessary ontological and ethical framework for understanding this new reality. Metazoë is not approached as a technological utopia, but as a complex situation where digital traces, algorithmic simulations and digitally mediated memory constitute a form of survival that transcends biological death. This "artificial continuity" challenges traditional pedagogical certainties and forces us to re-examine the concepts of responsibility, care and continuity within an ecosystem where humans and machines are now organically and inseparably connected.

2. The Ontological Framework of Metazoë

The concept of Metazoë is both a theoretical construct and, above all, a necessary ontological response to the challenges of the digital age. To understand how human presence is transformed through Artificial Intelligence, it is necessary to analyse Metazoë on two levels: firstly, as a process that transcends traditional biological boundaries and, secondly, as a phenomenon that redefines our social and educational reality. In the present framework, we aim to extent the stereotypical binary scheme of life and death. The concept of Metazoë transcends the linear perception of time and the dualistic distinction between biological existence and non-existence. As analysed by Oikonomou (2025), Metazoë is a "transcription process" that evolves on three levels: technological, ecological and cultural.

At the technological level, "artificial continuity" is achieved through data collection and algorithmic processing. Deathbots and digital memorials are not simply archives, but active digital presences that preserve the voice and behaviour of the individual (Puzio, 2023). Metazoë, therefore, is not a metaphysical promise, but a material and digital reality based on the continuous flow of information. Artificial continuity is a socioeducational phenomenon that overturns the concept of the "archive" (Derrida, 1996). The digital trace of a teacher or student is not a static memory, but a dynamic set of data that can continue to interact, teach, or influence future generations. This is where the concept of "relational persistence" comes in: existence is not defined by biological autonomy, but by participation in a common field of relationships mediated by the machine.

3. Tentacular Thinking – A New AI Epistemology

Understanding Artificial Intelligence requires more than technical familiarity; it requires a radical change in the way we understand cognition and learning. The transition from the linear, hierarchical thinking of the industrial age to a networked and interdependent perception of the world is imperative. In this context, we introduce, not merely as a metaphor, but as a new epistemology that redefines the relationship between humans, machines, and the environment. Tentacular thinking (Oikonomou, 2025a), as a biophilosophical term, draws its inspiration from the living world, specifically from organisms that survive through networking and touch, such as mycelial networks, cuttlefish and coral reefs. In biology, the tentacles and textures of fungi are not simply organs for gathering food, but sensory networks that transmit information and sustain entire ecosystems. Linking this biological reality to Donna Haraway's philosophy (2016), complex thinking invites us to "stay with the trouble." Tentacles (from the Latin tentaculum - test, and tentare - to touch, to try) symbolise the ability to reach out to the "Other" - whether it is an algorithm or an ecosystem - creating relationships of relevance. Instead of the arrogance of the "Human Emperor" standing above nature, complex thinking proposes action as "making kin".

Another central concept is, also, sympoiesis, which refers to "co-creation" or "producing together" (Haraway, 2016). In contrast to the autopoiesis of closed systems, sympoiesis argues that no system—including the human mind—is self-contained. In the context of AI, learning is not an internal process of the learner, but a sympoietic process where humans and algorithms "weave" knowledge together. AI functions as one of many "nodes" in a mycelial network of information. When a learner interacts with a generative model (Generative AI), they do not simply extract information; they participate in a process where human intention and algorithmic processing intertwine to produce something new. The adoption of complex thinking in education entails a radical change in the curriculum, the elimination of silos. Knowledge is no longer divided into isolated subjects. Complex thinking connects mathematics with poetry and technology with ethics, recognising that all branches of knowledge belong to the same body. Students are no longer passive recipients, but parts of a living network. Their ability to perceive "relatedness" allows them to see how the use of AI affects social memory and the environment. They are “prosumers” (producers/consumers) and “makers”. Complex thinking also cultivates responsibility, in a society where coexistence is of vital importance. If we are all part of a network, then "damage" to one node (e.g., the spread of fake news through AI) affects the entire system. Education thus becomes an exercise in the "art of coexistence" within artificial continuity.

4. Digital Memory and the Ethics of Care

The transition to an environment where AI plays a central role in storing and reproducing human experience shifts the focus of ethics from simple data processing to existential responsibility. In this section, we examine how memory is transformed from a static archive into an active digital presence, highlighting the need for an ethics of care that protects the right to human continuity and the dignity of memory. The dominant discourse on Artificial Intelligence often focuses on its cognitive ability (intelligence). However, in the context of Metazoë, the question shifts from "Can machines think?" to "Can machines remember us?" (Oikonomou, 2025b).

Digital memory is not a passive storage of information, but an active "artificial continuity" that preserves human presence through algorithmic traces. This shift requires a new ethical approach, the "Ethics of Care." As Puig de la Bellacasa (2017) argues, care is not just a feeling, but a practice that sustains the fabric of life and relationships. In the digital world, care is about the responsible management of our data as "living traces." Education must teach that the digital footprint is not just "data for consumption," but part of our ontological continuity that requires respect and ethical protection against commercialisation (Sciolla et al., 2025). The use of deathbots and digital memorials (memorial chatbots) in everyday life creates a new pedagogical challenge: how do we manage the presence of those who have "passed away" but remain active through AI? Metazoë proposes "relational persistence" as the answer. Education must prepare citizens to coexist with the digital presence of their ancestors or teachers, maintaining a balance between memory and forgetting (Ricoeur, 2004).

5. Educational Implications and Practical Application

The theoretical foundation of Metazoë and Complex Thinking acquires its full meaning when it is transformed into pedagogical practice. Education is called upon to function as a laboratory where new generations will learn to navigate artificial continuity. Next, we analyse how the TAF framework can be applied in the classroom, how a new pedagogy of continuity is being shaped, and what is the revised role of the teacher as a thinker and guardian of ethics. The application of the TAF (Tofflerian Analytical Framework) in educational practice allows teachers to navigate the "Shock of the Future" (Toffler, 1970). Instead of passive acceptance of technology, TAF favours a strategy of "adaptive resilience". In practice, this means: a) Adhocracy in learning: Abolishing rigid timetables in favour of flexible working groups that solve real problems with the help of AI, b) Personalised learning: Using IT not for automation, but to create 'continuity paths' that respect each student's pace and history (Oikonomou et al., 2025).

"Tentacular thinking" is transforming teaching methodology. The teacher ceases to be the only source of authority and becomes a "hub" in a wider network. In the context of sympoiesis, students are asked to work on projects where AI does not provide the answer, but acts as a "conversationalist" that helps connect disparate fields (e.g., biology, poetry, and programming). Through the teaching of Metazoe, students learn to create content (as prosumers) by becoming aware of the "artificial continuity" of their thinking. Every post, every code, and every digital work is treated as a "memory deposit" that influences the future, i.e. a digital imprint. This new reality requires

teachers who are both technologically savvy and philosophically trained. Teacher training must incorporate the "pedagogy of responsibility." The teacher of the AI era is the guardian of human continuity, the one who will help the student find meaning in the ocean of data, cultivating an "emotional ecology" (Oikonomou, 2025a).

6. Meta-anthropocentrism and Ecological Continuity

The concept of Metazoë is not limited to digital survival, but extends to a deep ecological consciousness that challenges the dominance of humans over nature and machines. At a time when the climate crisis and the technological explosion are evolving in parallel, education must adopt a post-anthropocentric approach. In the following subsections, we examine how human presence is reintegrated into biospheric and technological networks, favouring an aesthetic ecology that recognises the continuity of life through care for all forms of existence. The discussion of Artificial Intelligence in education is often limited to humans, ignoring the wider environment. However, Metazoë, as "metabolic continuity," recognises that technology and biology are intertwined (Oikonomou, 2025b). "Complex Thinking" teaches us that human presence does not end at the boundaries of the skin, but extends to the data we produce and the energy we consume (Haraway, 2016). In education, this means transitioning to a post-anthropocentric pedagogy. AI is not a competitor to humans, but a "cohabitant." Education must highlight "ecological continuity": how our digital traces and algorithmic influences affect the "collective body" of the earth (Morton, 2018). Metaverse offers the vision of an existence that cares for the continuity of species and systems, using AI as a tool to restore our bonds with the non-human world.

As a final concept, "Affective Ecology" proposes learning based on connection and emotion (Oikonomou, 2025a). AI can help us understand complex ecological data by turning abstract information into lived experience. Through its poetic dimension (Rilke, 1923, as cited in Oikonomou, 2026), Metazoë invites us to view technology not as something foreign, but as a new "landscape" where the human soul continues to breathe and form relationships.

Conclusions – Policy Recommendations

The exploration of Metazoë and artificial continuity highlights that Artificial Intelligence is not just a technical challenge, but a radical reshaping of human experience and the educational mission. Education must be transformed into a space for cultivating ontological readiness and ethical responsibility. In the conclusions that follow, we attempt to translate this philosophical quest into practical proposals, laying the foundations for a pedagogy that embraces the future without sacrificing humanity.

This paper argues that FI in education requires more than digital skills; it requires "ontological readiness." The Tofflerian Analytical Framework (TAF) shows us that if we do not act now, the "Shock of the Future" will render our educational systems irrelevant to the reality of the Post-Life (Oikonomou et al., 2025).

The transition to an education that embraces artificial continuity requires structural interventions that go beyond the simple provision of material and technical infrastructure. Policy proposals focus on restructuring content, ethics and human resources:

- The traditional division of sciences into "positive" and "theoretical" is an anachronism of the industrial age that hinders the understanding of AI. The integration of Complex Thinking as a cross-curricular competency at all levels is recommended.
- The interconnection of STEM with Humanities is an inevitable reality. The teaching of algorithms should not be separated from philosophy and ethics. For example, learning programming can be combined with the analysis of linguistics or the social influence of automated decisions.
- Learning must be integrated, curricula should favour "learning through relevance," where students solve complex problems (e.g., the climate crisis) using AI as a "co-worker" that connects ecological data with social impacts.
- In a world where digital footprints persist beyond biological life, managing "artificial continuity" is a key survival skill.
- Students must be educated not only in the protection of personal data (GDPR), but also in the "ontological responsibility" of their digital selves. The course will examine how their actions in the digital space shape a lasting memory and how this "digital immortality" affects human identity. This will shape a new domain of ethics, the ethics of memory and data.
- To manage continuity, education must provide the tools for young people to understand that they are "prosumers" (producers-consumers) not only of information but also of their existential footprint, cultivating a conscious relationship with their own Metazoë.
- Teacher training must shift from the "what" (tools such as ChatGPT) to the "why" (philosophical and existential dimension).
- Teachers are called upon to understand the human-machine relationship not as competitive, but as one of "kinship" and interdependence. This necessitates a good understanding of the philosophical extensions of AI.
- Training should focus on developing empathy and care in digitally mediated environments. The teacher becomes the "guardian of continuity," the one who helps the student find meaning and human connection within the flow of artificial continuity.
- Teachers are trained to recognise the signs of "Future Shock", in the context of the Tofflerian Analytical Framework, and develop resilience strategies (adhocracy), allowing the school to function as a flexible hub within the mycelial network of knowledge.

Metazoë is not the end of man, but his expansion. Education is the place where this expansion can take place in terms of responsibility, memory and love for the continuity of life in all its forms.

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Pedagogical Reflection Theory Through the Implication of A Compound Didactic Scenario Using ChatGPT AI. By Religion Teacher in the Greek Middle Education Field

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Abstract – Individual and social development through school learning highlights a crucial need in the current era, especially within the Greek educational context. However, the need to support new teaching practices and innovations in the education system, while also implementing strategies to assist students with mild Special Needs within the same educational environment, makes this task even more challenging. Additionally, a game-changing leader in innovation is Artificial Intelligence (AI), which steadily but aggressively builds a strong presence in educational practice by bringing the future into the present. Consequently, a substantial academic debate has developed. It continues in the field, with varying optimistic or even restrictive views on how AI could positively impact humanity—particularly among middle school students—by enhancing cognitive skills, addressing learning difficulties, and fostering intrinsic and mental development through the mature use of AI as a learning tool. Nonetheless, many key factors could significantly influence this area.

In the current context, possible scepticism about education is being closely examined through the implementation of a teaching approach that combines religion classes with modern Greek history for 3rd-grade Junior High School students, using the ChatGPT AI tool for instructional purposes. The focus topic is: "Athanasios Diakos' contribution to the Greek Revolution of 1821 ACE and his relation to the church, presented using ChatGPT." ChatGPT is a well-known AI tool that students can easily access, allowing a religion teacher to adopt a different teaching and learning approach. Students can subsequently reflect on their active participation in uncovering information and critically applying it to build understanding. This reflection theory process is a broad psychological and pedagogical tool that distinguishes between AI's function and human engagement. The latter plays a significant role in the long-term development of Greek students, both individually and socially.

Keywords- Reflection theory, ChatGPT, social formation, pedagogical tool, teaching approach.

1. Introduction

A school day in middle school is never the same. The mobility of students and teachers always creates a different and promising atmosphere, a slight anxiety about the curriculum that reflects the school board's teachers' educational scheduling, and a more trouble-free style among the students (Klugman, 2017, pp. 31–32). Indeed, the new creative air came in the form of new AI applications in the Greek educational realm, affecting the pedagogical approaches so far adopted in everyday teaching praxis (Williams et al., 2022, pp. 325–327).

AI and its forms did not suddenly appear in education but were carefully developed (Williams et al.,2022), with many variations for each use. Science has integrated AI (Xu et al., 2023, pp. 1–2) to support calculations, access large datasets, synthesize interdisciplinary information, categorize data, and suggest new research ideas. When humans lead, AI development is an art, considering high-tech system implications. Growing human research interests and intellect have driven AI, with computing creating scientific frameworks for its progress (Xu et al., 2023), as shown below:

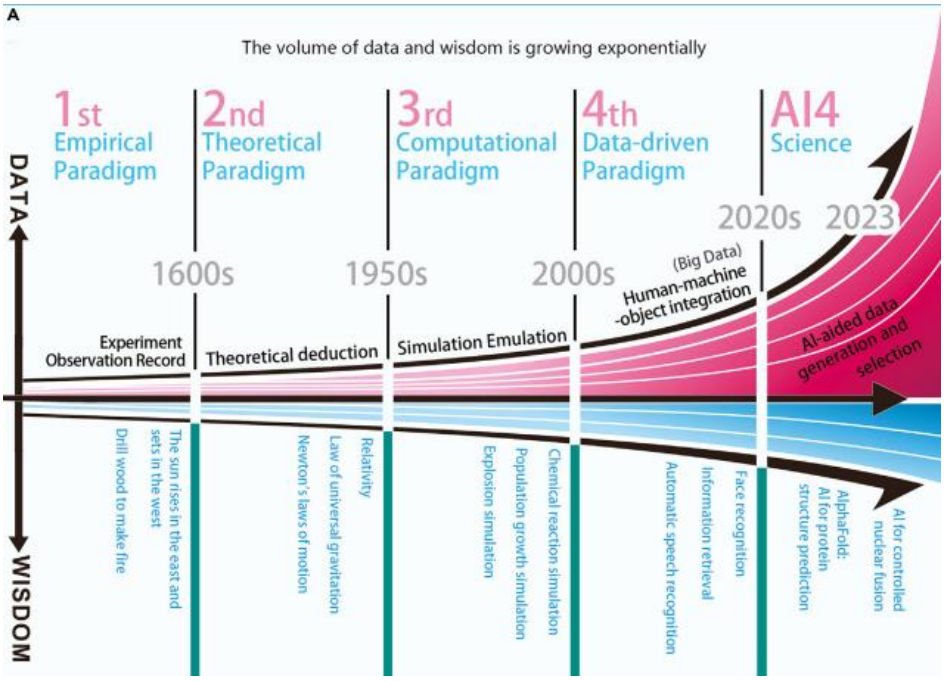


Table 1: The development of the cognitive paradigm

In the large European Union Community, educational prosperity is closely tied to AI achievements across most of its member countries, with a strong desire to maintain high academic standards and prestige through the AI Act Requirements (Kalodanis et al., 2024, p. 281). Hence, the Greek educational intranet has been set ablaze with a wealth of peculiar information and directions for every school unit regarding AI school programs held by several middle education units across Greece, lifelong seminaries for educators on related topics, and many conferences organised to delve into the same experience (Polak et al., 2022, pp 1–7). In addition, it is not regarded as awkward at all; the emerging expectation of using AI during the teaching process in class. So, teachers across most disciplines hear the bell and adjust their teaching accordingly, cultivating numerous inquiries and theoretical approaches, such as: *How can AI function or facilitate the teaching model? How familiar are students with AI? Is AI utility in the educational realm ethical or non-ethical? How could AI promote knowledge and*

experience in school? The questions, as mentioned earlier, are just a sample of the new optimisation process that has begun in the Greek educational reality, affecting, or even questioning, the teachers' gained teaching experience (Dagdilelis, 2018, pp. 109–110). However, academically speaking, AI questioning opens a new spectrum of research and application, always promising to improve teachers' skills, equipping them with practical teaching tools to use appropriately. (Dagdilelis, 2018),

According to motivation theory, the self-generated drive to improve professional performance and attitude positively influences the workplace by boosting the quality and quantity of output (Liu et al., 2022, p. 923). It helps create an appealing self-image by projecting inner motives that echo peers' stances, forming a creative circle that benefits everyone. This is intriguing for AI's educational potential, allowing students to build on their existing knowledge (Ausubel, 2000). Teachers can develop a positive attitude toward AI, choosing its best features for daily teaching. Guided by motivation theory, the researcher experimented with AI (Williams et al., 2022b, pp. 325–383), adapts it creatively for interdisciplinary teaching in Religion and History for C-grade students, using AI as a tool (2022b). The initial idea operated in a multiplicative mode for the researcher, who decided to make the necessary reframing by first providing a specific lecture on the know-how of the concept to colleagues for attitude measurement (Athanasiades, 2021, p. 149). The chosen topic was part of the previous year's legacy of connecting ecclesiastical personalities associated with the Orthodox Church with the revolutionary struggle of the Greek people to attain their freedom from Ottoman captivity (Wallace & Lambropoulos, 2021, p. 572). The picked-up title of the topic is: "*Athanasios Diakos' contribution to the Greek Revolution of 1821 ACE and his relation to the church, presented using ChatGPT*". Last year, Papaflesas and his devotion to the revolutionary case of 1821 were the subject of the researcher's study, to be presented in an interdisciplinary context without AI aid, though. However, the proposed teaching continuity appeared to be designed to benefit student learning as a good and innovative practice and was well received by the school board. The proper analysis shall be presented in the methodology section.

The inquiries highlight a sound theoretical and practical framework, especially in education. AI, as part of high-tech digital engineering, aids scientific and academic tasks via specialised algorithms (Xu et al., 2023). It retrieves large data, categorises it, creates diagrams, and provides analytical views of references. Teachers can then access and utilise needed educational information. Completed plans also help educators present their material effectively.

Ethical issues emerge about AI's use for students, as AI can generate responses to questions, tasks, and writing, often exploited to avoid effort (Zhang et al., 2022, pp. 5–7). Students' ethical norms break down not just regarding responsibilities but also regarding fairness among classmates, highlighting disparities. AI's capabilities risk turning learning into a hypnotic distraction, potentially reducing education. However, some research suggests AI influences students' psychological attitudes and may aid cognitive recovery (Wang et al., 2022, p. 63). This contradiction presents an interesting area for further study.

Similarly, this issue extends to educators and students alike, as AI promises to fix and complete all assigned tasks. Of course, there is always a way out of this complex maze, as Zhang et al. (2022) propose: systematic teacher supervision of students during their

school projects, accompanied by appropriate motivation. Teachers in middle education are steadily familiarised with their student population and have many opportunities to learn the pros and cons of each student during their own classes, to estimate the quality and quantity of their school performance, and to enhance it effectively. According to Barley and Waller (2005, p.10), the encouragement results seem to be tremendous, according to the following charts:

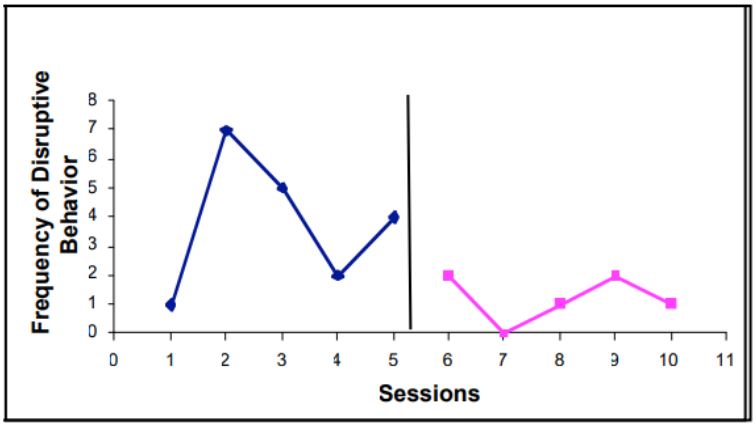


Table 2: Comparison of Disruptive Behaviour Prior to and During Intervention in Social Studies Class (Burley & Waller, 2005, p. 10)

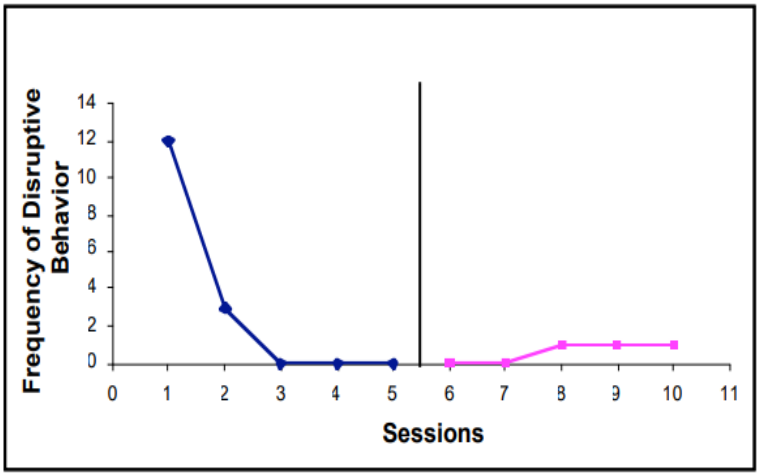


Table 3: Comparison of Disruptive Behavior Prior to and During Intervention in Language Arts Class (Burley & Waller, 2005, p. 10)

As shown in the tables, monitoring AI-assisted teaching in Social and Art classrooms revealed a significant increase in students' interest—up to 7.5 units in Social Studies and 12 in Art. This suggests AI can incorporate effective didactic content for Religious Education (RE), boosting interest and adding a modern tech aspect to subject management. This enhances the school's external prestige and students' skills. The AI teaching approach shifts focus toward the functionality of AI, encouraging curiosity and representing a form of curriculum integration between RE and technology. The data also shows a quantitative link between Art and Social subjects, with a variation of 4 units (Burley & Waller, 2005, p. 10).

In Greek Middle Education, Religion teachers have seized great opportunities to enhance their teaching subject and objectives, despite the many critical engagements they have been forced to cope during their teaching carrier, since their roles and teaching content have undergone over the last fifteen years or so, due to governmental policy changes on the religion subject and its generic role in education (Liagkis, 2015, p. 94). The problem has ceased for the time being, although it has left its mark in the ambiguous structuring of the textbooks for the religion classes. Recently, school advisors have visited public schools to inform teaching boards about the multiple book development in Greece, which has finally led to the development of the religious subject in more prosperous but not problem-free ways. In the midst of great storms, religion teachers can find many creative teaching opportunities within their curriculum (Karpouzis, 2024, pp. 2–7). One of the features is AI, offering valuable teaching materials and methodologies to enrich colleagues' personal teaching vaults within the school board. Interdisciplinary approaches enhance their task force by linking religious topics with other disciplines, reinforcing the religion teacher's role as a crucial figure for opening new cognitive horizons. Religious Education (RE) can transform religious education into a catalyst for all disciplines (Daskalaki et al., 2024, pp. 1–5). This experimental approach represents a serious educational effort.

2. Methodology

Regardless of the previous statistics on students' interest in improving their school performance, which already serve as a basic standard for the present research paper, there is always room for new teaching practices and modifications related to AI with the same scope (Serrano et al., 2025, pp. 507–527). ChatGPT is one of the AI applications, well known and familiar in broader educational and student circles, that simultaneously meets the academic criteria for implementing a specific didactical approach (Halaweh, 2023, pp. 1–2).

It functions as a search engine like Google, combining global databases for research. The key advantage is its free utility. Since the researcher lacked a premium version, initial inquiries were limited to essential ones, and the ChatGPT project was saved for class presentation if needed.

The discussed topic is: "*Athanasios Diakos' contribution to the Greek Revolution of 1821 ACE and his relation to the church, presented using ChatGPT*". The latter fits the History and RE of the C-Grade class. The didactic scheme is planned based on specific steps each time in the middle of October 2025, according to the table (4):

Steps	Actions	Duration	Total duration
1st	Presentation of the topic to students, definitions of the alignment between the two disciplines, and the importance of both in the cognitive realm and the ChatGPT AI.	5 min	45 min.
2nd	General question to the whole class regarding the personality or the fight performance of Athanasios Diakos.	5 min.	
3d	Initiation of the ChatGPT application and didactic frame through questioning ChatGPT. Students can also perform their own questioning ideas in class.	15 min.	
4th	Discussion and Cognitive enrichment of the material, as appropriate (according to students' needs).	5 min.	
5th	Working in Groups (WiG) based on a predesigned sheet by the RE teacher.	10 min.	
6th	Evaluation of the Process and Feedback by the students	5 min.	

Table 4: Step-by-step didactic scheme

Specifically, the first step (table 4) provides an opportunity to introduce students to ChatGPT (Halaweh, 2023) and briefly describe its potential during the class. Besides, the use of AI in educational praxis brings a welcome breath of change to the everyday classroom routine. Therefore, in the second step, the cognitive fuel of the historical personality of Athanasios Diakos' introduction, through general questioning of students, promises a quick implication of related questions through ChatGPT and inspires a creative pedagogical anxiety for using it by making a novice educational eco-system (Zamana, 2022, pp. 1–2). The latter applies during the fourth step, since it concludes the core of the teaching regarding: a. The personality of Athanasios Diakos, illustration b. His interior attachment to Orthodox Christianity and the great idea of patriotism c. His combat against the Ottomans d. His relation with the church and at the same time his great wish to fight against the enemies of the Greek Nation, and many other inquiry-related topics. Since the ChatGPT services were not premium, the AI's simple historical context could be enriched with the teacher's background, stimulating classroom interest in new questions. The WiG method used a material consolidation platform (Gordalla & Baumann, 2014) to foster love for the country, illustrate the character of men like Athanasios Diakos, and highlight a passion for Christ. The group task involved two questions on the sheet: a. What does Diakos' patriotism mean to you today? and b. What does Christ tell you about your life and neighbours today? The process ended with students sharing their impressions.

The researcher was concerned about which part of the present paper was better able to incorporate the theoretical *frame of reflection.* The part of the introduction seemed right from the start. Still, it doesn't serve as a natural continuation or coherence with the teaching plan to which it is essentially connected. On the other hand, the application itself as well as its value through the frame of reflection, are the main pillars of the whole teaching plan. Hence, the methodology was considered the most appropriate for the purpose.

When students used ChatGPT for step-by-step learning, they unconsciously opposed a full-time teaching machine serving their teacher. The teacher issued commands, and ChatGPT responded. Students mirrored this attitude in response to their RE teacher's instructions. The AI provided detailed knowledge from vast databases and complex algorithms. In this context, two reflections emerge: one from teachers or students and

another from AI (Mossbridge, 2024, pp. 1–4). Two opposite-directed reflections of knowledge power are coworking or competing (unconsciously from the human perspective so far) with one another. In addition, there is one more reflection working in the background regarding the ongoing information and data filling process of the AI by humans through the continuous upgrading of the databases, illustrated in figure (1) below:

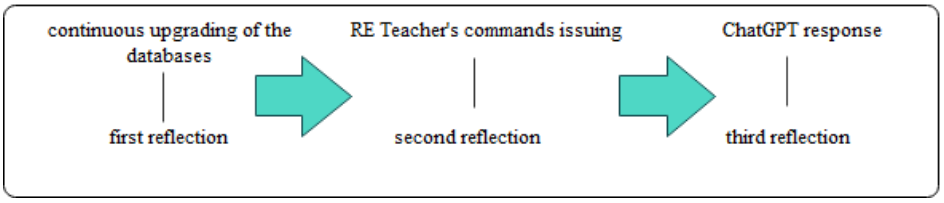


Figure 1: Working Reflections

As it is profound, three autonomous reflections are underway to connect and function in complete rational harmony. The AI databases are always up to date, 24/7, on the latest developments in knowledge and ready to handle every user inquiry. The first arrow (fig. 1) primarily serves as a ready-to-use provider, whereas the others are more responsive. When continuously studying the above figure (1), the second reflection could interact as a prime one regarding the first, as it seems in figure (2) below:

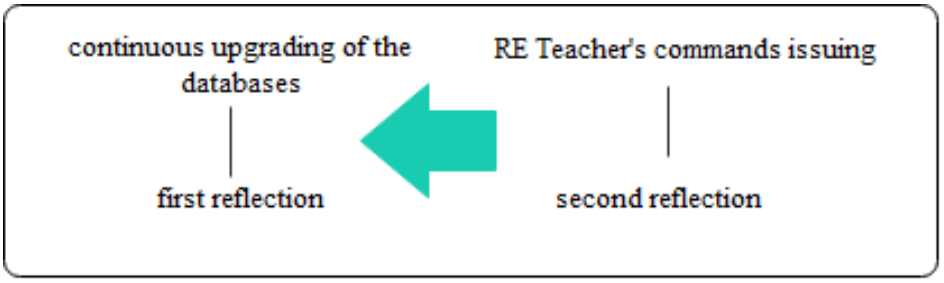


Figure 2: Opposite Reflection

The feedback may inform ChatGPT by capturing research interests or opinions as additional input. The third reflection is ignored to maintain human sovereignty. Behind the scenes, a specialised community actively intervenes in ChatGPT's AI processes (Mossbridge, 2024), showing that human contribution shapes the AI's output. Essentially, alongside the teacher-user, an allied teaching team contributes through AI as a medium. So, there is an actual projection of data by both sides (seeker and responder), taking the form of a mutual cognitive reflection. It is not a simple interaction through questioning and replying, but a dynamically formatted data platform that will be completed as long as the puzzle pieces of the project are correctly attached and fixed. In that case, reflection theory is considered a dynamic enhancement of the teaching and learning process through AI.(Yuan & Hu, 2024). In the present teaching plan, that enhancement was present throughout.

3. Results

The reflection theory significantly influences students' and humans' attitudes. Reflection involves projecting and then externalising what is taken in (Radović et al., 2021, p. 139). Using this method in class, several notable results occurred, detailed below:

a. The feeling of laziness about the historical part of the topic was transformed into anticipation, since the topic was not unilaterally articulated.
b. Students' anxiety gradually gave way to great interest when ChatGPT was introduced into the classroom.
c. Interest gave way to students' participation in formulating and typing the questions via the interactive board keyboard.
d. Their inquiries didn't focus only on the teaching material but expanded to the general functionality of ChatGPT and AI in relation to human capabilities and interference.
e. The communication attribute of the directed response of ChatGPT stimulated students' creativity all the more, and
f. Students engaged with a more upgraded mood in the WiG process.

The climactic feeling highlights the teaching effect and procedure with AI help, but it also cultivated internal information processing, shaping, and student output (Cukurova, 2024, pp. 1–2). Focus is on inner shaping, connected to the self. ChatGPT's role in cognitive growth was evident (Cukurova, 2024). Discussions included Athanasios Diakos' Orthodox Church ties, youth shaping, his devotion in the liberation fight, the Alamana war, and related cognitive elements examined via ChatGPT. Nevertheless, one more question still drives the present scholar's research: *what might the inner formulation's impact be on humans during and after the AI encounter?* The latter is examined directly below.

4. Discussion

Cukurova (2024) illustrates clearly: "*Intelligence is not only about what is certain, decontextualized, disembodied, tokenised and reduced to its parts, so that it is predictable and controlled. It is also about understanding things that are fluid. It is about the ability to live with, and survive despite uncertainty, and that what we are seeing as parts may indeed be wholes at another level. Today, most AI we see in educational research and practice considers AI as tools that have been developed to replace decision-making processes through analysis of big data, and prediction of the best value for a designated outcome variable, which is conveyed through a user interface. Intelligence, in my opinion, is more than that.*". From the above, fluidity really matters. During education, the learning object is defined and much effort is spent on conveying knowledge, especially for exams. But the learning case should be more. Teaching and learning are different but connected to the social environment—both play roles in social formation. Students learn, feel, and shape themselves within this context. Teaching isn't just transferring knowledge, nor is learning just acquiring it; it's about humans adapting and thriving. Therefore, teaching and learning should constantly reframe and reflect for mutual benefit.

In addition, Boyd and Fales (1983) define the essence of reflection term used upwards: "*Reflective learning, a process through which learners critically assess their experiences to gain insights and improve future performance, holds a central role in educational theory and practice*", which directly indicates the upgrading of human experience through teaching and learning approach by gaining more cognitive or even social feedback from their academic and social habitat. The puzzle of the reflection framework remains incomplete, as students' educational and social environments don't fully explain their intrinsic processes. Students shouldn't be seen as passive recipients

of AI or other messages, which depend heavily on internalized familial, school, and social influences. Family, school, and social settings are interconnected, shaping internal development. AI machines, created for human interaction, are thus considered additional parameters in this intrinsic formation framework (Kundu & Bej, 2024, p. 2).

Examining the previous context, Kundu and Bej (2024) argue: " *Findings revealed that the use of AI in schools can have both positive and negative impacts on the psychological well-being of students. Increased engagement, cognitive achievement, self-efficacy, learning autonomy, and decreased frustration are among the benefits of this strategy; nevertheless, over-reliance, anxiety, stress, social isolation, unstable mental health, and moral dilemmas, including privacy, bias, and justice, are among its drawbacks. Overall, the psychological impacts of AI use among school students are multifaceted, context-dependent and across grades.".* The authors have correctly focused on the cognitive and psychological processes students undergo when using AI, as well as the psychological consequences or impacts it may have on their overall school and social life. School life is not only a Vygotskian archetype, according to which students, within the school, are destined to seek and learn the proper scientific articulation of a phenomenon and the right match of term and meaning (Tartas, 2015, p. 50), but it is more than that. School life purpose also aims to promote students' well-being, providing them with the intrinsic skills needed to build their own tools for happiness later. Unhappy people illustrate a background of failing schools. On the contrary, Happy people reflect a successful school unit (Govorova et al., 2020, pp. 1–14).

AI's role in education benefits RE for two reasons: first, RE materials focus on moral insights rather than just scientific or cultural development; second, these insights help enhance human spirituality. While having a kind heart is more valuable than just knowledge, the real question is: what's the use of expertise if humanity can't become wiser and more compassionate?

Bellous (2021, p. 1) states that children's and students' spirituality is connected to the development of self-awareness. This was a key theme in Socrates' teachings, illustrated by the didactic analogies of gold, silver, and bronze used with young learners. Their spirituality was (and still is) shaped through introspection, which develops gradually as they mature mentally and psychologically, with teachers supporting this process. Introspection is the first step toward understanding the meaning of God's love and care for humanity. Children need love, care, and devotion (Krane et al., 2016, p. 378), and through the affection they receive, can give it back. Learning how to care for one another and provide care is essential to achieving God's conception and planning (Decock, 2015, p. 6), especially in the context of Christianity. Specifically, love is not just an emotion, as many think, but a powerful attribute that unites diverse beings without abrogating or marginalising any of them. Individuals build their personalities within a supportive system that promotes self- and social improvement. In the Church, supportive inclusion is fulfilled through pastoral care, which has grown during Greece's difficult times, reflecting love, compassion, justice, and liberty, and fostering love as the foundation of connection and partnership.

Reflecting connection and partnership—love and will as one—represents a major risk for the educational system, especially in Greece (and worldwide), as it prepares students for mental and psychological maturity through knowledge and interaction. Before

students learn how to love, they first have to learn how to interact so that their love can develop of their own mature and natural will. Project learning activities in the school context, combining WiG and partnership (Shimabukuro, 2008, p. 508), as well as small-scale presentations of didactic material, gradually cultivate the essence of belonging and acceptance, no matter what (mistakes and failures are always on the run), thereby enhancing not only learning but also self-awareness and introspection —the main tools for seeking the presence of God. During the learning and group engagement effort, any tool is permissible as long as it serves a specific purpose. ChatGPT is considered such a tool, leading education one step closer to its existential goal (Yaumi, 2024, p. 1), without which human beings count the days before their extinction.

5. Conclusions

After all the previous analytical engagement with the topic, essential overall conclusions emerged as follows:

a. The ChatGPT implication cultivated a creative anxiety in students, since the utility of an advanced AI technology stimulated their research skills and learning curiosity.
b. The engagement of students to ask ChatGPT questions regarding the class topic made them feel like coordinators of the process, using AI as a tool.
c. The integrated learning project combining History and RE discipline inspired them with the fact that knowledge of the past could be highly linked with Religion or Theology, producing new knowledge bases for novice start points and discussions.
d. The Working in Groups (WiG) method, which followed the teaching via ChatGPT, functioned as a catalyst, enhancing teamwork and communication among the peers.
e. Through the usage of AI, intense academic criticism emerged, setting up the barriers of the relationship that has been built between technology and human beings. Limits begin to be set accordingly, though many questions remain, such as the issue of AI autonomy. However, AI remains an educational tool in use.
f. Cognition progress consists of one part of the learning process, while the other is the development of the inner self through private introspection.
g. Private introspection denotes private feedback for self-improvement and development, providing vivid links with other humans and society.
h. Self-awareness and social interaction both comprise fundamental elements that gradually guide individuals towards the initial steps of developing an interest in understanding and experiencing the divine presence through connection (Frohlich, 2020, pp. 2–4). Religious Education (RE) should serve as the cornerstone of educational processes in Greece concerning this matter, not only today but also in the future.

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Artificial Intelligence as a Transformative Factor of the Educational Role: Training and Professional Development in the Digital Age

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Abstract- The rapid evolution of Artificial Intelligence (AI) and digital technologies is radically redefining the educational landscape, changing not only learning processes but also the very role of the teacher. In this new environment, the training and professional development of educators are becoming critical factors for the effective and responsible utilization of AI's potential in teaching and learning.

The transition from conventional to technology-enhanced pedagogical practice requires teachers to possess not only digital skills, but also a critical, ethical, and pedagogical background for using AI systems. Teacher training in AI cannot be limited to technical instruction; it must be integrated into a broader framework of professional learning that enhances their reflective and research capacity. Through structured continuing education programs, teachers need to understand how algorithmic systems work, recognize their limitations and biases, and integrate them into their teaching practice in a pedagogically substantiated manner.

Furthermore, cultivating critical AI literacy is essential for educators to act as conscious mediators between technology and students, protecting rights, privacy, and equitable access to learning for all. Professional development in the field of AI is further strengthened through the creation of communities of practice, the exchange of experiences, and collaboration with the research community. Cooperation among educators, researchers, and educational bodies can lead to the development of innovative pedagogical approaches and the formation of a school that promotes creativity, adaptability, and ethical consciousness.

Training, therefore, is not merely a tool for technological adjustment, but a lever for transforming the teacher's professional role into an active, responsible, and socially conscious professional of the digital age. Overall, the need for a pedagogical and ethically grounded approach to AI in education is highlighted, where the educator is not a passive user of technology, but a central factor in shaping a sustainable, human, and fair digital future.

Keywords: Artificial Intelligence (AI), Training, Professional Development

Introduction

Contemporary educational research and practice stand at the center of a historic juncture, as the rapid development of Artificial Intelligence (AI) fundamentally redefines the terms of knowledge, learning, and professional activity. The introduction of AI into the school unit, while offering unprecedented possibilities for personalization and optimization of learning outcomes, simultaneously poses complex ethical and pedagogical dilemmas concerning equity, transparency, and the very anthropocentric nature of education. In this context, the present presentation explores the critical role of teachers' professional development as the lever that will enable the effective, ethical, and pedagogically sound integration of AI, analyzing how the teacher's competencies must be restructured to function as a critical mediator in the digital age.

Artificial Intelligence and the Transformation of Educational Reality

Global society is undergoing a period of profound and fundamental change, widely identified as the Fourth Industrial Revolution. This new technological paradigm is characterized by the radical and exponential convergence between the physical, digital, and biological spheres. Artificial Intelligence (AI) is emerging as the quintessential catalyst for this transition, determining the future of production, communication, and social structures (Schwab, 2024). As a general-purpose technology, AI is forcefully and irreversibly penetrating every institutional sector, including the educational system. The rapid development of advanced Generative AI systems now confronts the educational community with the urgent need to restructure the learning environment, teaching methodologies, and, critically, the very philosophy governing learning.

The integration of AI in education offers significant opportunities, particularly concerning issues of learning personalization and the provision of immediate and adaptive feedback. However, its application cannot be uncritical. It requires a critical, scientifically, and pedagogically grounded approach that recognizes and manages the risks associated with the transparency of algorithms, the safeguarding of data privacy, and the potential manifestation of algorithmic bias (Holmes et al., 2022). The conscious and ethical management of the technological transition is, therefore, a central pillar of modern educational policy, as also noted by the Institute of Educational Policy (Institute of Educational Policy, 2025).

The Paradigm Shift of the Educational Role and the Necessity of Professional Development

In this constantly changing environment, the classic role of the educator undergoes a substantial paradigm shift. The teacher ceases to be the sole transmitter of knowledge, transforming into a facilitator of complex learning experiences, a designer of innovative cognitive projects, and a critical mediator between the student and automated algorithmic systems. This new, complex reality necessitates the cultivation of new cognitive, pedagogical, methodological, and ethical skills.

In order for the educator to successfully respond to these new and demanding duties, continuing professional development emerges as a critical institutional and individual factor for the success of the educational transformation (Guskey & Huberman, 1995). Training in AI must not be limited to superficial technical instruction in software usage; rather, it must be integrated into a holistic framework that enhances the competencies of critical thinking, systematic reflection, and deep ethical awareness. Only through such a framework can the anthropocentric and equitable use of AI in the educational process be ensured.

Purpose of the Theoretical Analysis

The central purpose of the present presentation is the execution of a systematic and thorough theoretical analysis of the framework for redefining the professional role of the educator in the age of AI. The methodological focus is placed on the need for the pedagogical and ethical foundation of professional development programs. The analysis aims to highlight the best practices for shaping the educator as an active and responsible professional of the digital age.

Central Research Questions

The basic research questions guiding the development of the discussion are the following:

1. What are the fundamental changes in the educator's cognitive, technological, and pedagogical models brought about by the integration of AI, and how do these models differ from traditional teaching models?
2. How should professional development programs be structured to enhance the teacher's critical, ethical, and reflective role toward algorithmic systems, moving beyond the level of mere technical training?
3. What are the critical ethical risks (such as data privacy and algorithmic bias) that must be effectively addressed through training to ensure educational equity and equality in access to knowledge?

Theoretical Review and Detailed Analysis

Transformation of the Didactic Paradigm: Overcoming the Banking Model and the Personalization of Learning

Traditional teaching, which was critically described by Paulo Freire (1970) as the "banking model of education," is now scientifically and functionally inadequate. AI provides the technological means for the systematic overcoming of this outdated model, encouraging the transition to a constructivist learning model that is deeply personalized and adapted to the needs of each student. Consequently, the educator is liberated from the secondary role of a simple content deliverer and focuses on the emotional, social, and cognitive guidance of the students, enhancing inquiry-based and problem-based learning.

The Educator as Data Interpreter and Reflective Professional

The use of AI systems generates large volumes of learning data, known as Learning Analytics. The ability to collect, analyze, and interpret these algorithmic results is crucial for making informed pedagogical decisions. The educator must be able to engage in reflective practice, continuously questioning the validity, reliability, and potential biases of the AI data, thereby ensuring the preservation of the anthropocentric character of teaching against technological automation.

The New Framework for Professional Development

Pedagogical Documentation of AI and the Triple Competencies

It is imperative that effective training in AI is based on a comprehensive tripartite model of competencies, which must include Technical competence (understanding the function of the algorithm), Pedagogical competence (evaluating didactic suitability), and Ethical/Critical competence (recognizing biases). It is vital that educators understand the basic mechanisms of machine learning and evaluate the pedagogical suitability of an AI tool before integrating it into the school unit. This knowledge is essential for controlling quality and equity in educational practice.

Collaborative Learning, Communities of Practice, and Collective Reflectiveness

Professional development achieves its maximum effectiveness when it is continuous, experiential, and collaborative, moving away from fragmented models. The systematic creation of Communities of Practice (CoPs) or Collaborative Learning networks is vital for developing collective reflective capacity and effectively addressing the complexity of AI. Collaboration strengthens the social capital of the school (Guskey & Huberman, 1995). Furthermore, the enhancement of the educators' role in professional development issues, with emphasis on the creation of learning communities, has been the subject of study in the Greek context as well, confirming the importance of collective action (Tiligada, 2023).

The Ethical Dimension: Critical Literacy in AI

Algorithmic Bias, Equity, and Educational Justice

The most serious ethical challenge highlighted by scientific literature is algorithmic bias, which can perpetuate and reinforce existing social inequalities, especially if algorithms are trained on unrepresentative data (Holmes et al., 2022). Training must cultivate Critical Literacy in AI, meaning the ability to critically read the results of the algorithm, recognizing the political and social footprint of the technology, thus functioning as a "guardian" of educational justice.

Data Protection, Privacy, and Ethical Leadership

The use of students' personal data for training algorithms raises serious issues of privacy and security, requiring full compliance with legal and ethical frameworks. Ethical Leadership plays a decisive role in the school unit, as it ensures that AI usage policies are anthropocentric, transparent, and accountable, promoting a culture where technology is used to enhance rather than undermine the rights of students (Michopoulou & Gan, 2025).

Conclusions and Recommendations

Overall Assessment and Future Direction

The professional role of the educator is in a phase of radical and inevitable redefinition, which is taking place under the influence of Artificial Intelligence. The central conclusion of the present analysis is that the success of the systematic and equitable integration of AI into the educational system depends directly on the structuring of a comprehensive, critical, and ethical framework for professional development. The educator of the future must be a professional with deep pedagogical autonomy, capable of managing technology as a powerful, yet human-dependent, tool, and not as an end in itself that substitutes for didactic judgment.

Proposals for Educational Policy and Research

Educational Policy: Institutionalization and Funding

The success of the systematic and equitable integration of Artificial Intelligence (AI) into the educational system depends directly on the structuring of a comprehensive, critical, and ethical framework for professional development. Therefore, the institutionalization of a national framework for continuous training is required. This framework must make Critical Literacy in AI mandatory for all educators, focusing primarily on ethics, deontology, and addressing algorithmic biases. This knowledge is essential for controlling quality and equity in educational practice.

Furthermore, the strengthening and systematic funding of Communities of Practice (CoPs) at the school unit level is imperative. The creation of such networks is vital for developing collective reflective capacity and exchanging best pedagogical practices related to AI. This collaboration enhances the social capital of the school and ensures that professional development is continuous, experiential, and collaborative, moving away from fragmented models.

Research Direction: Quantitative and Qualitative Assessment

To ensure a fair and effective digital educational future, the research community must focus on conducting empirical, longitudinal studies. These studies are essential for the quantitative and qualitative assessment of the effects of AI. Specifically, research needs to examine the emotional, social, and cognitive impacts of Generative AI on students.

In addition, it is critical to capture the new dynamics in the interaction between the educator and the algorithm. In this context, the educator is transformed into a coordinator of complex learning experiences and a critical mediator. Conducting this research will provide documented findings for the restructuring of the educator's competencies and will help shape policies that ensure the preservation of the anthropocentric character of teaching against technological automation.

The Role of the Teacher as Guardian of Justice

Finally, in the area of the Teacher's Role, the educator ceases to be a passive user of technology and becomes a central factor in shaping a sustainable, human, and just digital future. Their role now requires the cultivation of Critical Literacy in AI. This capacity means the critical reading of algorithmic results, the recognition of the political and social footprint of technology, and the educator's function as a "guardian" of educational justice. Training must ensure that the educator has the deep pedagogical autonomy to manage technology as a powerful, yet human-dependent, tool, and not as an end in itself that substitutes for didactic judgment.

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Integrating AI-Mediated Feedback in the FLE Classroom: A Reflective Action Research Study on Mizou

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Abstract - Foreign language learning is conceptualized as an interactive and co-constructive process in which authentic communication, learner agency, and meaningful feedback play a central role. Contemporary pedagogical approaches grounded in social constructivism emphasize the importance of collaborative tasks and formative support mechanisms that enable learners to reflect on and improve their language use. Within this framework, the integration of Artificial Intelligence (AI) tools in language education offers new opportunities for supporting written interaction and learner autonomy.

This paper presents a qualitative, descriptive account of the pedagogical use of Mizou, an AI-based application designed for foreign language learning, in a French as a Foreign Language (FLE) classroom. Mizou provides immediate, personalized feedback on learners' written productions through lexical and grammatical suggestions and reformulations, thereby facilitating revision processes and raising learners' awareness of linguistic choices. The tool was integrated into a communicative task involving the preparation of a cultural outing among peers, aiming to promote the production of authentic written messages and to prepare learners for subsequent oral interaction.

The intervention adopts an action research approach, prioritizing pedagogical reflection and the practical integration of AI tools over the production of generalizable findings. The implementation involved A2-level learners and was documented through the teacher's reflective field journal, which recorded the progression of the activity, learners' reactions, emerging difficulties, and the written products generated.

Rather than evaluating learning outcomes quantitatively, the paper offers pedagogical insights into the affordances and constraints of AI-assisted formative feedback in foreign language teaching. It argues that tools such as Mizou can meaningfully contribute to the renewal of FLE pedagogy by fostering personalized guidance, learner engagement, and the articulation between written and oral skills, if their use remains pedagogically grounded and teacher-mediated. The study contributes to ongoing discussions on human-centered and reflective uses of AI in language education.

Keywords— Artificial Intelligence, foreign language teaching, formative feedback, written and oral interaction

Introduction

Foreign language learning is increasingly understood as a dynamic process of interaction, meaning-making, and social engagement rather than the mere acquisition of linguistic structures. From a social constructivist perspective, learning emerges through collaboration, dialogue, and participation in authentic communicative situations, where learners actively co-construct knowledge and develop communicative competence (Vygotsky, 1978). Within this framework, interaction—both written and oral—occupies a central position in foreign language pedagogy, as it enables learners to negotiate meaning, experiment with language, and progressively gain confidence in their communicative abilities.

In recent decades, digital technologies have significantly reshaped the landscape of language education by expanding the spaces, modalities, and opportunities for interaction. Online platforms, collaborative writing tools, and digital communication environments have made it possible for learners to engage in meaningful written exchanges beyond the temporal and spatial limits of the classroom. Written interaction, in particular, has emerged as a powerful pedagogical space for language learning, as it allows learners time to reflect on form and meaning, to revise their production, and to engage more consciously with linguistic choices (Manchón, 2011). At the same time, written interaction can function as a preparatory stage for oral communication, supporting learners' fluency, accuracy, and self-confidence.

Within this evolving digital ecosystem, Artificial Intelligence (AI) has begun to play an increasingly visible role in foreign language education. Advances in Natural Language Processing (NLP) have enabled the development of tools capable of simulating interaction, providing immediate feedback, and adapting responses to learners' linguistic level. When pedagogically framed, such tools can support formative feedback processes, foster learner autonomy, and encourage experimentation with language. Importantly, current educational discourse emphasizes that AI should not be viewed as a substitute for the teacher, but rather as a complementary resource, that enriches teaching practices and supports learners.

Despite growing interest in AI-enhanced language learning, a gap remains in the documentation of classroom implementations, particularly regarding everyday pedagogical practice. Teachers often encounter practical questions about how to meaningfully integrate AI tools into communicative tasks, how to pedagogically exploit AI-generated feedback, and how AI-supported written interaction may contribute to oral language development (Dou, Xu, Li, & Zhang, 2025). Addressing these questions requires not only empirical studies, but also reflective, practice-based accounts that illuminate how such tools function within real classroom contexts.

In response to this need, the present paper documents and reflects on the pedagogical use of Mizou, an AI-based application designed for foreign language learning, in the teaching of French as a Foreign Language (FLE). The focus is not on measuring learning outcomes quantitatively, but on describing and analyzing how Mizou was integrated into a communicative writing task and how its feedback mechanisms supported learners' written interaction and preparation for oral communication. The teaching intervention adopts an action research–informed approach, prioritizing

pedagogical exploration and reflective practice over the production of generalizable findings.

By presenting a qualitative, descriptive account grounded in the teacher's reflective field journal, this paper aims to contribute to ongoing discussions on the pedagogically responsible integration of AI in foreign language education. More specifically, it seeks to highlight the potential of AI-assisted formative feedback to support learner engagement, autonomy, and the articulation between written and oral skills, while also acknowledging the central mediating role of the teacher in designing, guiding, and contextualizing AI-supported learning activities.

2. Pedagogical and Theoretical Framework

2.1 Social Constructivism and Action-Oriented Language Teaching

Contemporary approaches to foreign language education are strongly influenced by social constructivist theories, which conceptualize learning as a socially mediated process emerging through interaction, collaboration, and dialogue. From this perspective, knowledge is not transmitted passively but actively co-constructed by learners as they engage with others in meaningful communicative situations. Vygotsky's seminal work (1978) emphasizes the central role of social interaction in cognitive development, introducing key concepts such as mediation, scaffolding, and the Zone of Proximal Development (ZPD), which remain foundational in language pedagogy.

In foreign language teaching, these principles are reflected in action-oriented and communicative approaches that position learners as social agents who use language to accomplish tasks, negotiate meaning, and participate in authentic exchanges (Council of Europe, 2021). Interaction—both written and oral—is therefore not merely a means of practicing linguistic forms, but a core learning mechanism through which learners experiment with language, receive feedback, and progressively develop autonomy. Scaffolding, whether provided by the teacher, peers, or pedagogical tools, plays a crucial role in supporting learners as they move from assisted performance toward more independent language use.

Within this framework, written interaction occupies a particular pedagogical position. Unlike spontaneous oral production, written communication allows learners time to reflect, revise, and consciously engage with linguistic choices, making it a privileged space for guided learning and interactional support. When written tasks are embedded in meaningful communicative scenarios, they align closely with action-oriented principles and prepare learners for subsequent oral interaction.

2.2 Formative Feedback and Learner Autonomy in FLE

Feedback is widely recognized as a key factor in language learning, particularly when it is formative in nature and integrated into the learning process rather than used solely for summative evaluation. Formative feedback aims to support learners' understanding of their current performance, highlight areas for improvement, and guide subsequent learning actions. In this sense, feedback functions as a learning resource rather than as a judgment of achievement.

Research in educational assessment underscores that effective formative feedback is timely, specific, and oriented toward improvement (Black & Wiliam, 1998). In the context of foreign language learning, such feedback can raise learners' awareness of linguistic forms, support noticing of errors, and encourage reflection on language use. Chapelle (2001) emphasizes that computer-assisted language learning environments can offer valuable opportunities for feedback, particularly when they enable learners to interact with language, test hypotheses, and revise their production.

Importantly, formative feedback is closely linked to the development of learner autonomy. When learners are given opportunities to engage with feedback, make choices, and revise their texts, they gradually assume greater responsibility for their learning process. Nicol and Macfarlane-Dick (2006) argue that feedback is most effective when it supports self-regulation and metacognitive engagement, allowing learners to monitor their progress and make informed decisions about their learning strategies. In FLE classrooms, this perspective shifts the focus from teacher correction to guided learner reflection, positioning feedback as a dialogic and developmental process.

2.3 Artificial Intelligence as a Pedagogical Support Tool

Recent advances in Artificial Intelligence, particularly in Natural Language Processing (NLP), have expanded the range of digital tools available for language education. AI-based applications can simulate interaction, generate linguistic reformulations, and provide immediate, individualized feedback, thereby supporting learners during the writing process. However, current educational discourse strongly emphasizes that AI should not be conceived as an autonomous instructor, but as a pedagogical support tool whose effectiveness depends on thoughtful integration and teacher mediation.

Human-centered approaches to AI in education highlight the importance of aligning technological affordances with pedagogical intentions and ethical considerations (Kasneci et al., 2023). In language teaching, this implies that AI-generated feedback should be contextualized, interpreted, and pedagogically exploited by the teacher, rather than accepted uncritically by learners. Without such mediation, there is a risk that learners may focus on surface-level corrections without developing deeper linguistic understanding.

Within this perspective, tools such as Mizou can be situated as scaffolding resources that support written interaction and formative feedback processes. By offering immediate suggestions, reformulations, and linguistic prompts, Mizou can encourage learners to revise their texts, experiment with alternative expressions, and engage more actively with language. At the same time, the teacher retains a central role in designing communicative tasks, setting boundaries for tool use, and guiding learners toward reflective and critical engagement with AI feedback. As highlighted by Dou, Xu, Li, & Zhang (2025), digital tools can effectively support interaction and oral language development when they are embedded in coherent pedagogical scenarios and aligned with communicative objectives.

3. Context and Description of the Teaching Intervention

3.1 Educational Context

The teaching intervention was implemented in a public lower secondary school (Gymnasium), specifically at the 4th Gymnasium of Veria, in the regional unit of Imathia (Central Macedonia, Greece). The participants were 14 students attending the third grade of lower secondary education, second section, studying French as a Foreign Language (FLE) with an overall proficiency level corresponding to A2 of the Common European Framework of Reference for Languages (CEFR). At this stage of learning, students are expected to be able to participate in simple communicative exchanges related to familiar topics, while still requiring substantial support in terms of accuracy, fluency, and confidence.

The pedagogical objectives of the intervention focused primarily on the development of written interaction skills, understood as the ability to engage in short, meaningful written exchanges in authentic communicative contexts. In line with action-oriented principles, written interaction was not treated as an isolated skill, but as a preparatory and supportive stage for oral communication. Particular emphasis was placed on helping learners plan, formulate, and revise written utterances that could later be mobilized in spoken interaction, thereby strengthening the articulation between written and oral language use.

3.2 The Mizou Application

Mizou is an AI-based educational platform designed specifically to support foreign language learning through interactive dialogue. It allows teachers to create simple, customizable chatbots adapted to the linguistic level and pedagogical needs of their learners. From a didactic perspective, Mizou functions as an interactive conversational partner that guides learners through written exchanges while providing immediate, individualized feedback.

The feedback offered by Mizou is primarily formative in nature. It includes gentle corrections of grammatical and lexical errors, suggestions for reformulation, and prompts that encourage learners to improve the clarity and naturalness of their messages. Rather than simply providing correct answers, the tool supports revision processes and helps learners become more aware of their linguistic choices.

A pedagogically significant feature of Mizou is its support for oral language development alongside written interaction. Learners have the opportunity to listen to the AI's voice, which simulates a natural francophone speaker, and to record their own spoken production. When the AI successfully recognizes the learner's speech, it converts it into written text, allowing students to verify how their oral production is perceived and transcribed. This process enables learners to implicitly test aspects of pronunciation, intonation, and intelligibility, while maintaining a strong link between spoken and written language. For this reason, Mizou was selected not only as a writing support tool, but also as a pedagogical bridge between written interaction and oral expression.

3.3 Task Design and Classroom Implementation

The AI-supported activity was embedded in a communicative scenario closely aligned with learners' everyday experiences: the planning of a cultural outing among peers,

specifically going to the cinema. This scenario was chosen because it involves frequent and meaningful speech acts (making suggestions, asking questions, agreeing or disagreeing, negotiating details) and lends itself naturally to both written and oral interaction.

The activity unfolded in several phases. First, the teacher designed the chatbot by defining its pedagogical objective, communicative role, and linguistic constraints. A clear title was selected to contextualize the interaction and engage learners (e.g., *"On va au ciné ? – Planifions ensemble une sortie en français"*). The teacher then provided explicit instructions to the AI, specifying the target level, the types of communicative acts to be practiced, and the manner in which feedback should be delivered. Particular attention was paid to ensuring that corrections were formulated in a supportive and encouraging way, consistent with the learners' level.

During the classroom implementation, students worked collaboratively in pairs using school-provided tablets. They interacted individually with the chatbot in a written format, negotiating the details of the outing by exchanging short messages. They were encouraged to test hypotheses, revise their formulations based on the feedback received, and, when appropriate, use the oral recording function to experiment with spoken production. The learners' role was thus active and exploratory: they were invited to engage in dialogue, make decisions, and progressively refine their language use.

The role of the teacher remained central throughout the process. Beyond creating the chatbot, the teacher established the communicative framework, set the rules of interaction, and monitored learners' engagement with the tool. The teacher also supported reflection on the feedback provided by the AI, helping learners interpret corrections and connect them to previously taught linguistic content. In this way, the AI tool was integrated as part of a teacher-mediated pedagogical scenario, rather than as an autonomous learning environment.

4. Methodological Orientation and Data Sources

4.1 Action Research Perspective

The teaching intervention described in this paper is informed by the principles of action research (recherche-action), understood as a reflective and cyclical process through which practitioners systematically examine their own practice with the aim of improving it. Action research is particularly suited to educational contexts, as it allows teachers to investigate pedagogical innovations within authentic classroom settings, while maintaining a close connection between theory and practice (Cohen, Manion, & Morrison, 2018).

In this study, action research does not function as a framework for hypothesis testing or the production of generalizable results. Rather, it provides a methodological orientation that supports pedagogical exploration, reflection, and informed decision-making. As emphasized by Cohen et al. (2018), action research prioritizes contextual understanding and professional development over statistical representativeness, making it especially appropriate for examining the integration of innovative tools, such as AI-based applications, in everyday teaching practice.

The exploratory nature of the intervention justifies this methodological choice. The study primarily examines how to meaningfully integrate an AI tool into a communicative task within a real classroom, how learners engage with the tool, and how it supports written interaction and oral communication preparation. Consequently, the study avoids establishing causal relationships, comparing groups, or measuring learning gains quantitatively. This pedagogical inquiry deliberately excludes issues of generalization, experimental control, and statistical analysis

By adopting an action research perspective, the teacher-researcher was able to remain fully involved in the instructional process, simultaneously acting as designer, facilitator, and reflective observer. This dual role is characteristic of action research and is considered a strength rather than a limitation, as it allows for situated insights grounded in lived classroom experience (Cohen et al., 2018).

4.2 Reflective Data Collection

Data for the pedagogical reflection were collected primarily through a reflective teaching journal. This tool served as the main source of qualitative documentation throughout the implementation of the activity.

The reflective journal included systematic notes on several aspects of the teaching intervention. First, the analysis prioritized students' reactions to the AI tool. Learners responded predominantly positively, perceiving the activity as innovative and expressing strong interest in the possibilities Mizou offered. Many students showed curiosity about the feedback provided by the AI and were eager to compare comments on their own performance with those received by other pairs, indicating a high level of engagement and motivation.

Second, the journal documented difficulties encountered during the implementation, which were mainly technical in nature. In one or two instances, the school tablets experienced temporary freezing, shortly disrupting the flow of the activity. These incidents were noted as contextual constraints rather than pedagogical obstacles and were taken into account during the reflective analysis.

Third, observations were recorded regarding the ways in which students used the tool. Learners worked in pairs and interacted with the AI by negotiating meaning, revising their messages, and experimenting with alternative formulations. This collaborative use of the tool supported peer interaction and encouraged discussion about linguistic choices.

Finally, the written productions generated by the students constituted an important source of pedagogical insight. Through their interaction with the AI, students managed to co-construct short dialogues in which they successfully arranged a meeting to go to the cinema. The teacher had access to these written exchanges both during and after the activity, which made it possible to provide additional feedback. This feedback extended beyond surface-level linguistic correction to address textual coherence, pragmatic adequacy, communicative effectiveness, and learners' overall progress.

5. Pedagogical Observations and Reflective Insights

5.1 Learner Engagement and Motivation

The observations recorded in the teacher's reflective journal indicate a high level of learner engagement throughout the activity. Students responded positively to the introduction of the AI tool, perceiving it as an innovative and motivating element within the language lesson. The interactive nature of the task, combined with the familiarity of the communicative scenario, appeared to encourage active participation and sustained attention.

Learners showed particular interest in the feedback generated by the AI, frequently expressing curiosity about how their written production was evaluated and reformulated. The possibility of comparing the AI's comments on their own work with those received by other pairs fostered informal peer discussion and reflection. Although this comparative dimension was not formally structured, it contributed to a sense of shared involvement and collaborative learning within the classroom.

Overall, the activity appeared to reduce learners' anxiety related to written production. The presence of an AI interlocutor was often perceived as less judgmental than direct teacher correction, which may have encouraged students to take linguistic risks and experiment more freely with language. This sense of reduced affective pressure suggests that AI-mediated interaction can create a psychologically safer space for written communication, particularly for learners who are hesitant to expose linguistic uncertainty in front of the teacher or the whole class.

5.2 Use of Feedback for Revision

Reflective notes indicate that learners actively engaged with the formative feedback provided by the AI. Rather than simply accepting corrections, many students revised their messages several times, testing alternative formulations and adjusting lexical or grammatical choices. This iterative process suggests that feedback functioned as a support for revision and reflection, rather than as a final evaluative judgment.

The immediacy of the feedback played a significant role in this process. Learners were able to notice problematic forms, interpret suggested reformulations, and apply them directly within the ongoing interaction. In several instances, written revisions were followed by oral attempts using the voice-recording feature, reinforcing the connection between written and spoken language.

These patterns of engagement indicate that learners did not perceive feedback as an external corrective mechanism, but as an invitation to reflect on language use and make informed choices. Such interaction with feedback aligns with formative assessment principles that emphasize learner agency, self-regulation, and active involvement in the learning process.

5.3 Emerging Difficulties and Limitations

Some limitations emerged during the implementation of the activity. Technical issues were observed in one or two instances, as school tablets temporarily froze and briefly interrupted the flow of interaction. Although these disruptions did not significantly

affect the overall lesson, they highlight the importance of reliable digital infrastructure when integrating technology into classroom practice.

From a pedagogical perspective, reflective notes also point to a potential risk of learners accepting AI-generated reformulations without fully understanding the underlying linguistic rationale. Without guided reflection, there is a danger that feedback may lead to surface-level correction rather than deeper learning. This observation raises broader pedagogical questions regarding how learners cognitively process AI feedback and reinforces the need for teacher mediation to ensure that corrective input is transformed into meaningful linguistic understanding.

5.4 Teacher Mediation and Pedagogical Decisions

The teacher's role proved central at all stages of the activity. Beyond designing the chatbot and defining its communicative parameters, the teacher continuously monitored learners' interactions and intervened when necessary to clarify feedback or draw attention to linguistic, pragmatic, and communicative aspects of the exchanges.

Having access to students' written productions both during and after the activity enabled the teacher to provide complementary feedback that extended beyond formal accuracy. This feedback addressed textual coherence, communicative effectiveness, and task achievement, supporting a more holistic view of language use. These pedagogical decisions were guided by ongoing reflection and aimed at maintaining a balance between AI-supported feedback and human instructional judgment. The observations confirm that the pedagogical value of AI-supported activities lies not in the tool itself, but in the teacher's capacity to orchestrate interactions and align technological affordances with learning objectives.

6. Discussion

The observations presented above can be meaningfully interpreted in relation to the pedagogical and theoretical framework outlined earlier. First, the use of an AI-supported communicative task appears to confirm the pedagogical value of written interaction as a space for experimentation and reflection, particularly when embedded within an action-oriented scenario. Supported by immediate feedback, written exchanges enabled learners to negotiate meaning, revise their production, and prepare for oral communication, in line with social constructivist principles and CEFR-oriented approaches.

This finding reinforces the view that written interaction can function not merely as a preparatory step, but as a reflective learning space in its own right. By allowing learners time to consider form, meaning, and pragmatic appropriateness, AI-supported writing tasks can contribute to more confident and intentional oral language use.

Second, formative feedback emerges as a key element shaping learners' engagement with the task. The AI tool supported revision processes by offering timely and individualized feedback, which encouraged experimentation and sustained involvement. At the same time, the observations underline that feedback alone does not guarantee learning. Its pedagogical effectiveness depends on learners' ability to

interpret and use it meaningfully, a process that requires explicit guidance and mediation by the teacher. In this sense, AI-supported feedback functions most productively when it complements, rather than replaces, established formative assessment practices.

From a broader pedagogical perspective, the findings invite reflection on the evolving role of digital mediation in foreign language classrooms characterized by limited instructional time. In such contexts, AI-supported written interaction may offer additional opportunities for practice, individualized support, and reflective engagement with language, provided that these tools are embedded within coherent, teacher-led instructional designs.

Finally, the discussion highlights the importance of a human-centered approach to AI integration in FLE. Rather than acting as an autonomous instructional agent, the AI tool functioned as a scaffolding resource that complemented teacher expertise and pedagogical intent. The effectiveness of this integration relied on careful task design, clear communicative objectives, and continuous teacher mediation. At the same time, the contextual and exploratory nature of the intervention calls for cautious interpretation. These insights suggest that AI tools such as Mizou can enrich foreign language teaching when used as part of reflective, pedagogically grounded practice that prioritizes interaction, learner agency, and meaningful language use.

Conclusion

Summarize the main findings, implications, and any limitations of your study. This paper set out to offer a reflective, practice-based account of the pedagogical integration of the AI tool Mizou in the teaching of French as a Foreign Language, with particular attention to written interaction as a scaffold for oral communication. Grounded in an action research–informed perspective, the study did not aim to measure learning outcomes or produce generalizable results, but rather to explore how AI-supported formative feedback can be meaningfully embedded in a communicative classroom task.

The observations emerging from the teaching intervention suggest that AI-supported written interaction, when pedagogically framed and teacher-mediated, can create favorable conditions for learner engagement, experimentation with language, and iterative revision. The communicative scenario selected for the activity provided learners with a clear pragmatic objective, enabling them to mobilize language resources in an authentic and purposeful manner. Within this context, immediate feedback offered by the AI tool appeared to support learners' awareness of linguistic choices and encouraged them to refine their written production before transferring it to oral expression.

From a pedagogical standpoint, the study highlights the value of written interaction as a reflective space that supports the development of oral skills, particularly in instructional contexts characterized by limited teaching time. The use of AI-generated formative feedback contributed to individualized support and differentiation, while also fostering learner autonomy. However, the observations equally underline that such feedback does not operate in isolation. Its educational value depends largely on teacher mediation, which is essential for contextualizing corrections, supporting understanding,

and guiding learners beyond surface-level revision toward more meaningful language use.

The intervention also brings to light important limitations. Conducted within a single classroom and over a short time span, the study is inherently contextual and exploratory. Technical constraints related to digital infrastructure occasionally affected the flow of the activity, reminding us that pedagogical innovation with AI remains closely linked to material conditions. Moreover, the reliance on reflective qualitative data calls for cautious interpretation of the insights presented.

Despite these limitations, the study contributes to ongoing discussions on human-centered uses of Artificial Intelligence in foreign language education. It illustrates how AI tools such as Mizou can function as pedagogical support resources rather than autonomous instructional agents, complementing teacher expertise and reinforcing action-oriented teaching practices. Future reflective inquiries could explore similar integrations across different proficiency levels, communicative tasks, or institutional contexts, as well as examine how learners' engagement with AI-generated feedback evolves over time.

Overall, the findings suggest that the pedagogical value of AI in FLE lies not in technological novelty, but in its thoughtful integration into coherent, teacher-led instructional designs that prioritize interaction, reflection, and meaningful language use.

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AI-Based Concept Development in Design Education: A Case Study of Interior Architectural Applications

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Abstract- Design education has traditionally emphasized creative design courses that focus on concept development for projects involving architecture, interior spaces, products, and visual communication. These courses employ a range of analytical and creative tools—such as mind maps, mood boards, sketches, models and prototypes—to support the generation of design ideas. In this context, instructors play a pivotal role in fostering the conditions necessary for students to develop original and conceptually grounded design solutions with potential real-world applicability. The aforementioned design methodologies rely on diverse data inputs, including text, imagery, sketches, and material samples, which are synthesized to produce two- and three-dimensional design representations (2D and 3D). Recent advancements in artificial intelligence (AI) enable the processing of such specific data, facilitating the generation of high-fidelity digital representations across various design domains. This study proposes an educational methodology that integrates traditional concept development tools with AI-based processes, aiming to enhance creativity, documentation, and visualization in design education. The paper concludes by presenting applications of the proposed approach within the field of interior architecture.

Keywords— Concept Design Methodology, Design Education, Educational Framework, AI Tools, Interior Architecture Applications.

Introduction

Traditionally, design education has emphasized creative design courses via design thinking tools that focus on concept development for projects involving architecture, interior spaces and products. Specially, design thinking is a creative methodology used to understand users, redefine problems and create innovative design solutions. Dobras et al. (2021) mention that, design thinking process involves the ability to synthesize knowledge from variety of sources that includes textual and imagery data (i.e. mind maps, mood boards, sketches and 3D digital prototypes).

With the rapid progress of technology changes, design thinking has become essential for developing 21st-century skills (Sreenivasan& Suresh, 2024). Nowadays, artificial intelligence (AI) replicates fundamental aspects of human cognition in a great number of professions including architecture and product design (Harika et al., 2022). According to Chandrasekera et al. (2025), AI-based design applications comprise an extensive set of capabilities—including perception, reasoning, learning, problem-solving, and creativity—that allow them to address complex and multidimensional design challenges. Moreover, Artificial Intelligence (AI) as a tool can greatly be combined with a series of methodological and technological tools used currently and thus enhance their ability to promote productivity and innovation (Manavis, 2023).

De Vries (2020) outlines three main uses of creative AI: (a) Understanding (AI uses knowledge to perform creative behaviors), (b) Representation (AI generates synthetic data to fill gaps in real datasets) and, (c) Creation (AI produces new artefacts, such as image-to-image transformations or text-to-image outputs).

The incorporation of artificial intelligence (AI) into educational contexts has the capacity to transform the ways in which students' approach and complete academic tasks (Elal et. Al., 2024). The proposed paper examines the impact of AI on creative ideation in educational environments, aiming to assess the extent to which AI can enhance human creativity. Finally, the present research proposes an educational methodology that integrates traditional concept development tools with AI-based processes, aiming to enhance creativity, documentation, and visualization in design education according to interior architecture design principles.

Background and Literature Review

Conceptual design is often seen as an artistic rather than a scientific process (Manavis, 2024). Specifically, Manavis et al. (2021), highlighted that conceptual design methodology is rooted in design-thinking principles, and designers typically work through iterative sessions using tools such as mind maps, mood boards, sketches, storyboards, and prototypes to generate alternative design solutions (Manavis, 2020). A mind map visually organizes ideas using associative, hierarchical links based on texts (Buisine et al., 2007). Mood boards are artistic tools that convey emotions, atmospheres, and experiential qualities through images, helping designers express concepts beyond meaningful texts (McDonagh et al., 2002). Sketching and digital prototyping serve as flexible exploratory tools in early design stages, supporting the creation and evaluation of multiple concepts (Bao et al., 2018). Finally, digital prototyping, based on CAD methods, also improves understanding of an application's form, function, and construction (Barros, 2010).

Artificial Intelligence and concept design work together to improve problem-solving and innovation. Specifically, A.I. enables personalization, while design thinking keeps solutions user-centered according to end-user's personal characteristics and needs (Haleem et al., 2022). In practice, A.I. applications automate routine tasks like data processing, freeing designers to focus on creative strategy (Rezwana & Maher, 2023). Moreover, the relationship between A.I. and concept design strengthens communication through advanced visualization tools, fosters visual thinking by identifying patterns, and offers inspiration by examining extensive datasets (Perna & Kyratsis, 2025).

From an educational perspective, Artificial Intelligence (A.I.) is transforming design education, evolving from a basic assistance tool into an active collaborator in creative processes (Hasaan, 2025). With the advancement of generative A.I., learners can now produce images, text, code, and 3D models, broadening their creative possibilities. AI also develops visual identities and architectural concepts, evaluates feedback, and proposes enhancements (Balta-Salvador et al., 2025). By adjusting to each learner's skill level, it delivers personalized support that strengthens creativity, skill growth, and the overall educational experience (Balta-Salvador et al., 2025).

Developing a design concept with AI generally mirrors the steps used in traditional design education (Kahraman et al., 2024). Designers begin by researching styles, materials, colors, and spatial needs, then move on to generating ideas through mind maps, mood boards, sketches, and digital prototypes. AI can enhance this workflow by creating clear visual outputs that effectively convey mood and style to clients (Meddain, 2025). Looking forward, immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) can further enrich this process: VR offers immersive and real-scale spatial exploration, enabling designers and clients to "walk through" and experience the proposed spaces before construction, while AR allows overlaying conceptual designs onto real environments to assess context, scale, and realism. Research shows that although AI and immersive tools can spark creativity and offer novel visualization capabilities, human judgment remains essential to meaningful design decisions (Gupta et al., 2024). Incorporating these technologies into interior and architectural design curricula helps students stay aligned with evolving professional practices and better prepare for the future of design (Huh et al., 2025; Çalışkan & Kayaakdag, 2025).

Methodology

This paper proposes a methodological framework that integrates traditional design tools with Artificial Intelligence applications. In this approach, the trainer provides a structured educational framework that helps trainees/students understand key design aspects (i.e. Understanding, Representation and Creation). These fundamental features are connected to essential design tools, including mind maps, mood boards, digital sketches, 3D model design, and the production of photorealistic videos for virtual and augmented reality environments. Specially, Figure 1 illustrates the specific processes of Creative Design by Human (CDbH) and Creative Design by Artificial Intelligent (CDbAI) that form the core components of a contemporary educational methodology that engages both trainers and trainees across design-related fields such as architecture, graphic design, and product design.

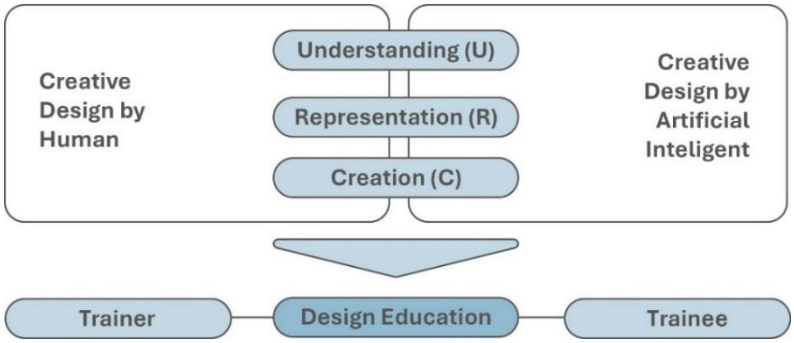


Figure 1: Methodology framework.

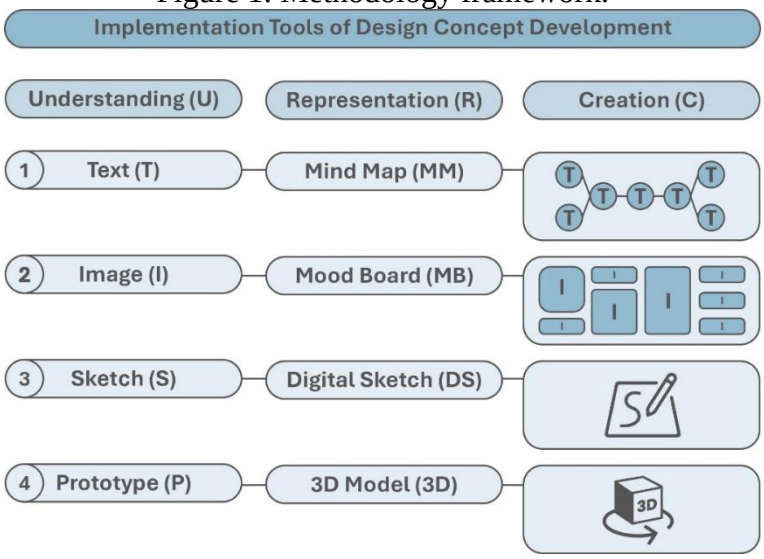


Figure 2: Implementation tools of design concept development.

The outcome of the proposed educational framework is the development of holistic and well-structured design concepts. These concepts are expressed through fundamental elements (i.e. words, images, sketches, and digital or physical prototypes). Specially, each element aligns with specific design tools used to document ideas relevant to architectural, graphic, and product design applications, such as mind maps, mood boards, digital sketches, 3D model design (Figure 2). Moreover, the final produced design concept should incorporate the three key principles outlined earlier: Understanding, Representation and Creation. Nowadays, design schools ensure that all students engage with these traditional design tools when developing project proposals. At the same time, the aforementioned educational courses place strong emphasis on digital media to present design outcomes more effectively to end-users. These digital tools enhance both the aesthetic quality and the technical clarity of the final results.

Proposed AI-based Concept Development Framework

The present paper proposes a methodological framework that integrates traditional design development processes with contemporary approaches supported by Artificial Intelligence techniques and applications (Figure 3). The following framework is organized into two sub-stages: Stage A, Creative Design by Human and Stage B, Creative Design by Artificial Intelligence

In Stage A (Creative Design by Human) the trainer guides trainees in using design tools to generate preliminary design concepts through specific elements such as words, images, digital sketches, and 3D models. It is crucial to noted that, these elements serve as pure data for A.I. platforms due to they clearly specify concepts and ideas that can be effectively processed to produce visual or textual outputs. Before progressing to Stage B (Creative Design by Artificial Intelligence), trainees refine and organize the material produced in Stage A so it can be appropriately used within AI applications. Specifically, textual inputs are first employed to generate images through AI systems. These images are then processed further by other AI tools to produce sketch-level visual representations. The resulting sketches subsequently serve as the foundation for generating 3D renderings. Finally, Stage B (Creative Design by Artificial Intelligence) encompasses the results of all these sequential steps. It is important to note that the starting point for the entire process remains the final concept developed in Stage A (Original Image), shaped through the trainer's guidance and feedback.

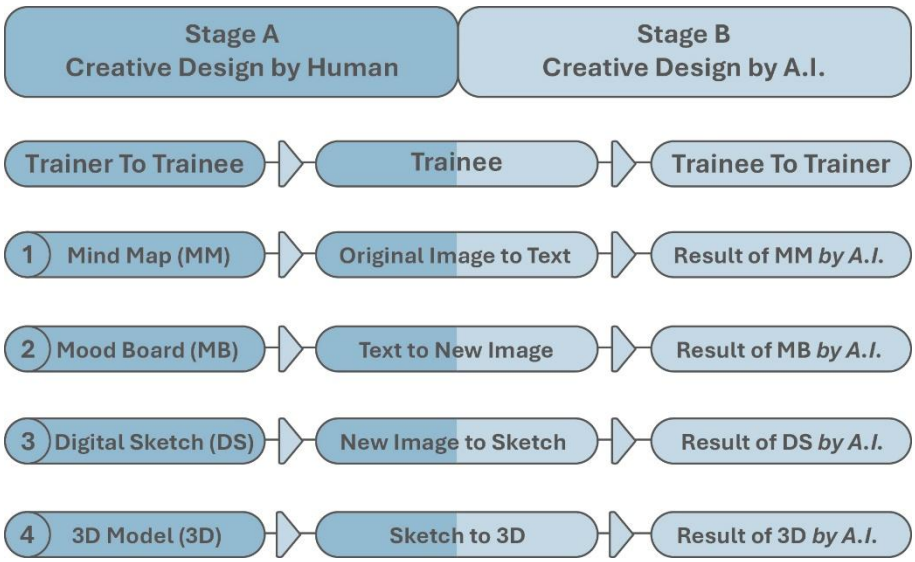


Figure 3: The proposed educational framework.

Figure 4 presents the traditional digital tools recommended for visualizing and developing design concepts. Specifically, Mindmeister® for mind maps, Canva® for mood board, Sketchbook® for digital sketches and Sketchup® for 3D models. Parallelly, it also highlights selected artificial intelligence applications that are well-suited for generating corresponding design elements: iWeaver AI® for mind maps, Pixazo.ai® for mood board, Chat GPT® digital sketches for and Meshy® for 3D models.

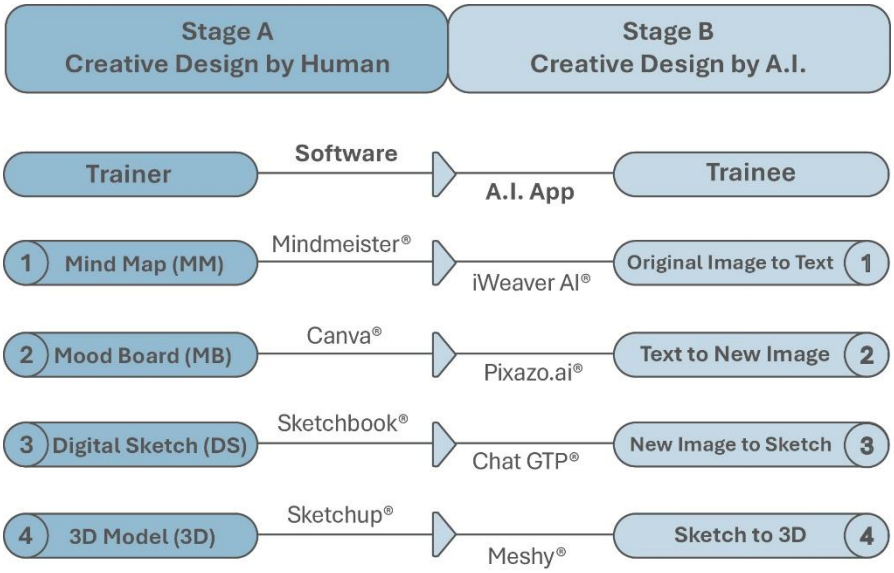


Figure 4: Softwares and A.I. applications for design development.

Case Study: Interior Architecture Applications

The final part of this article presents a case study of the proposed methodology, focusing on the interior design of a restaurant. A rendered video showcasing the restaurant's design concept served as «Original Image». The video provides comprehensive visual information about the interior architecture, including spatial layout, furniture, lighting, materials, fabrics, and other design elements.

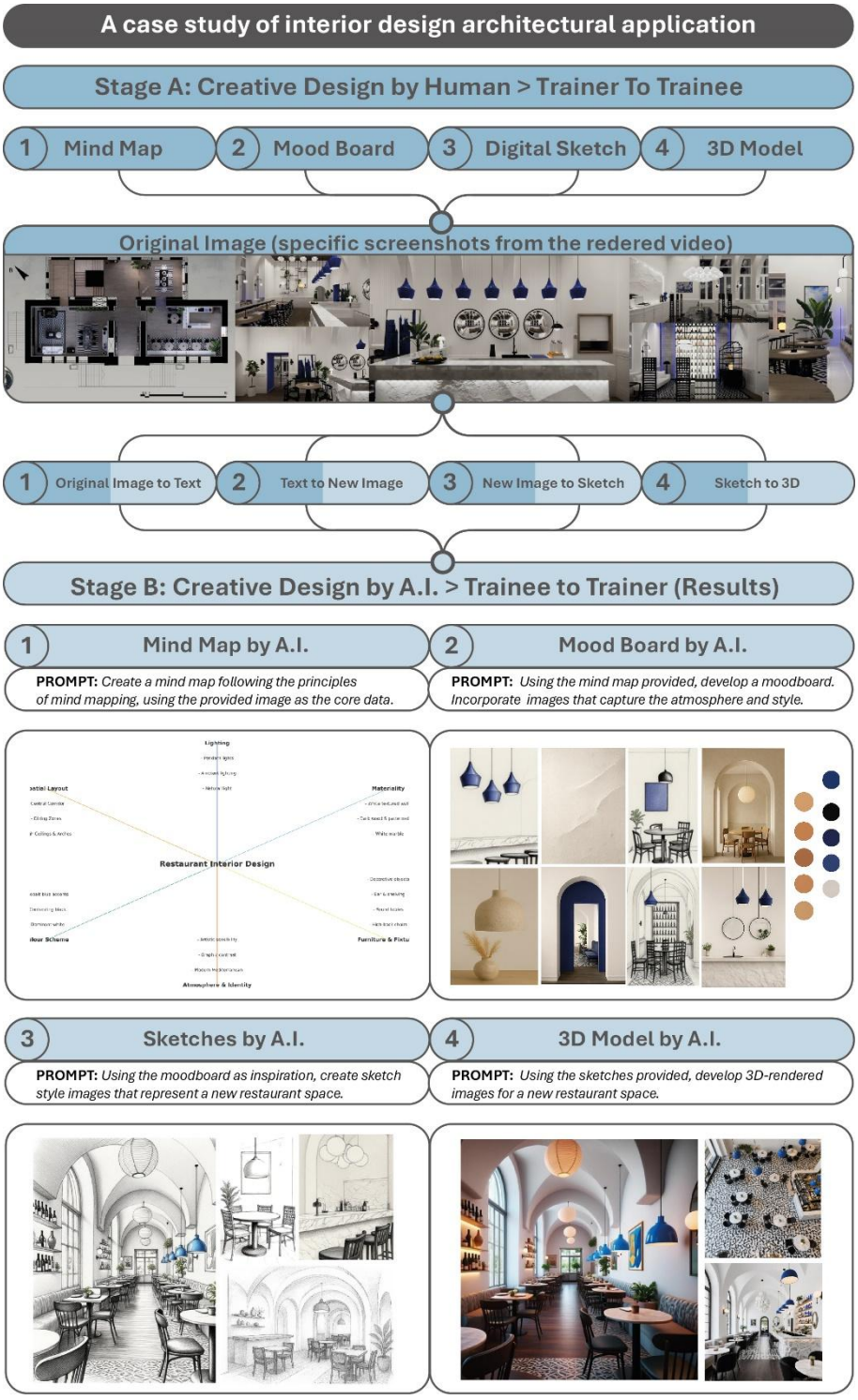


Figure 5: A case study of interior architecture application (restaurant).

It crucial to noted that the video was created by Grigoris Ziambras as part of his thesis (2023-2024) at the Department of Interior Architecture, International Hellenic University, under the supervision of Dr. Paraskevi Kertemelidou. This design proposal was developed and realized using both traditional and digital tools, reflecting the practices taught in architecture and design courses.

Specifically, visual material extracted from the video was used (screenshots). The researchers selected key image excerpts that highlighted the elements and features of the proposed restaurant space, thereby creating the «Original Image». This initial reference image then served as the basis for analysis using appropriate artificial intelligence tools to generate alternative design proposals for the new space of restaurant. This procedure corresponds to Stage A (Creative Design by Human) of the methodology.

The primary objective of the proposed case study was to examine how A.I. can replicate the tools of mind map, mood board, digital sketching and 3D modelling using data derived from an «Original Image».

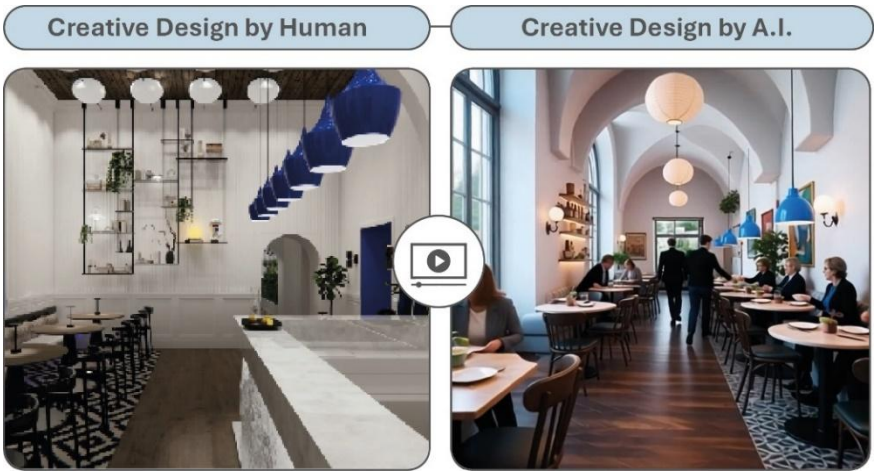


Figure 6: Softwares and A.I. applications for design development.

In the second stage of the framework (Stage B, Creative Design by Artificial Intelligence), researchers utilize artificial intelligence tools to generate new design proposals for the interior design of the restaurant. Specifically, the results produced by these tools are as follows:

1. Mind Map by A.I. (Result): The original image served as the reference for creating the new mind map. This image was imported into the Mindmeister® application to develop a mind map capturing the key concepts of the initial restaurant. These keywords established the overarching design theme. Specifically, the central keyword was «Restaurant Interior Design», with the thematic areas defined as Spatial Layout, Colour Scheme, Atmosphere/Identity, Furniture, Materiality and Lighting. The prompt entered into the app was as follows: *Create a mind map following the principles of mind mapping, using the provided image as the core data.*

2. Mood Board by A.I. (Result): The mind map generated in the previous stage using Mindmeister® served as the reference for creating the new mood board. Using the iWeaverAI® application, the following prompt was applied: «*Using the mind map provided, develop a mood board. Incorporate images that capture the atmosphere and style»*. The resulting mood board included images reflecting the intended ambiance of the restaurant. Notable elements identified in the board included arches, blue tones, earthy colors, minimal furniture, and marble, among others.

3. Digital Sketching by A.I. (Result): Creating on the mood board, ChatGPT® was used to generate digital sketches of the new restaurant design. It is noteworthy that the resulting sketches adhered closely to the overall design theme established by the initial reference image, while also presenting novel and original interpretations of the space. The prompt used by the researchers was as follows: *Using the moodboard as inspiration, create sketch style images that represent a new restaurant space.* Key features highlighted in the digital sketches included arches, blue accents, earthy tones, minimalist furniture, and marble, among other design elements.

4. 3D Modelling by A.I. (Result): The final stage involved transforming the sketches into photorealistic 3D images of the new restaurant, a process carried out using Meshy®. The resulting 3D images offered compelling variations of the original design developed in Stage A under the guidance of the trainer. These three-dimensional renderings effectively showcase the updated features of the space, as identified in the previous stages of the mind map, mood board, and sketches.

At the end of the case study, the researchers extended the proposed model by using the Deevid.AI application to create a video of the new proposed restaurant, based on the final 3D images generated in the previous step. This approach was intended to analyze the relationship between the final video and the original design, while also exploring the broader potential for developing VR (Virtual Reality) and AR (Augmented Reality) applications from content produced entirely through artificial intelligence. Figure 6 presents a comparison between the two videos: the initial video from Stage A (left image) and the final video generated in Stage B (right image).

Conclusion

The proposed AI-based Concept Development Framework demonstrates that the integration of traditional design methods with AI-driven processes can significantly enhance concept development in design education. Findings from the case study indicate that AI effectively interprets and transforms human-generated material—mind maps, mood boards, sketches, and 3D models—into coherent and visually rich design representations. The restaurant design example showed that starting from a single "Original Image," AI applications were able to produce alternative conceptual pathways that preserved the core spatial identity while introducing new creative variations. This confirms that AI can function as a complementary creative partner, expanding visual exploration, improving documentation, and accelerating iterative refinement. At the same time, the framework reinforces the indispensable pedagogical role of the trainer, whose guidance shapes the quality and direction of the inputs used by AI systems.

Future work should focus on evaluating the framework across diverse design domains, integrating multimodal data inputs, and assessing student learning outcomes. Moreover, expanding the methodology to include VR/AR environments and interactive AI feedback loops could further strengthen its applicability, offering immersive and adaptive design experiences aligned with evolving professional practices.

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Assessing Farmers' Readiness for AI: Implications for Agricultural Education in Imathia Prefecture, Greece

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Abstract - The rapid development of Artificial Intelligence (AI)[1] and digital technologies is transforming the way education is designed, delivered, and evaluated in all sectors, including agriculture. The use of innovative AI tools, such as adaptive learning environments, learning analytics systems, and virtual teaching assistants, offers new opportunities for the personalized and continuous training of professionals in the primary sector. This paper explores the level of digital readiness and the prospects for integrating these technologies into agricultural education and presents the case of the prefecture of Imathia as an example of a region with significant challenges but also emerging opportunities.

The analysis focuses on assessing the "digital divide" and identifying the current educational needs of producers in Imathia which concern their training in innovative farming practices, sustainable forms of resource management, and the effective use of digital technologies. The integration of IT tools, blended learning, and educational programs that combine theory and practice offers producers the opportunity to develop skills to adapt to technological, economic, and environmental developments in the agricultural sector.

This research highlights the urgent need to design targeted educational interventions so that the integration of IT contributes not only to improving productivity but also to creating a culture of lifelong learning and innovation. The example of Imathia highlights the value of educational actions that link technological progress with the social and professional empowerment of farmers, offering a model that could be replicated in other regions of Greece.

Keywords— AI in Agriculture, Digital Readiness, Agricultural Education, Imathia Prefecture

[1] The term "Artificial Intelligence" (AI) is the English translation of the Greek term "Τεχνητή Νοημοσύνη" (TN).

Introduction

The integration of Artificial Intelligence, which is a key pillar of Agriculture 4.0 (Liu et al., 2020), is now one of the most important drivers of global economic growth. Recent studies show that the integration of AI technologies is now considered imperative for the transition to the era of Agriculture 4.0, radically transforming traditional practices through automation and data-driven decision-making (Subeesh & Mehta, 2021). The use of these technologies promises significant increases in productivity and reductions in operating costs, making farms more sustainable and competitive (Benos et al., 2021).

Indeed, as Choruma et al. (2024) show, despite the existence of digital technologies for agriculture—from information and advisory services to digital marketing—many small family farms do not adopt them due to limited internet access, low digital skills, inadequate infrastructure, and cost. This reinforces the "digital divide" between technologically advanced and non-advanced farms (Choruma et al., 2024). In Europe, and particularly in Greece, this problem is exacerbated by a lack of digital skills. For example, official data show that while the European average of farmers trained in new technologies is 25%, in Greece this percentage remains extremely low, at only 6.7% (European Parliament, 2023).

Factors such as the aging of the rural population and lack of familiarity with information and communication technologies (ICT) act as a brake on the digital transition (Kernecker et al., 2020). In this context, agricultural education emerges as the most critical factor in bridging the gap. This paper focuses on the Prefecture of Imathia, with the aim of assessing the level of "digital readiness" of producers and identifying the educational needs that arise for the effective integration of IT into the production process.

Artificial Intelligence in Modern Agriculture

Modern agriculture is undergoing a radical transformation through the adoption of Artificial Intelligence (AI) technologies, which enable the transition from traditional practices to precision and automation models. AI in agriculture is not limited to a single application, but includes a wide range of tools, such as Machine Learning, Computer Vision, and the Internet of Things (IoT), which work together to optimize the production process (Benos et al., 2021; Khatibi & Ali, 2024).

One of the main applications is the use of Machine Learning algorithms for crop yield prediction. By analyzing historical data, climatic conditions, and soil data, these systems provide accurate estimates of expected production, enabling better financial planning (Shawon et al., 2025). At the same time, computer vision technology has revolutionized plant protection. Modern systems integrated into drones can detect plant diseases at an early stage, often with accuracy that exceeds that of the human eye (Jafar et al., 2024).

Furthermore, the integration of IoT creates the framework for "Smart Farming," where sensors collect real-time data on soil moisture and nutrients. Analysis of this data enables automated irrigation, reducing resource waste (Ravichandran et al., 2024).

Finally, the adoption of these technologies enhances sustainability by reducing the environmental footprint of crops (Khatibi & Ali, 2024).

The Digital Skills Gap in Farming

Despite the rapid development of smart farming technologies, their widespread adoption faces significant obstacles, the most important of which is the "digital divide." This term describes the inequality in access to and, above all, in the ability to use new technologies among different groups of the rural population (Salemink et al., 2017). In rural areas in particular, this divide is not only about a lack of infrastructure, but primarily a lack of digital skills, which prevents producers from making full use of the tools available (Arangurí et al., 2025).

Unlike large farms in northern Europe, small family farms in Greece are at a disadvantage. Recent research in Northern Greece has shown that almost half of farms are small-scale and low-capitalized, which drastically limits their ability to finance the necessary smart farming equipment (Siogkas et al., 2025).

Demographic and social factors are noteworthy. The rural population is characterized by a high average age and low level of formal education, factors that discourage the learning of complex digital tools. Research in Greek rural regions (such as Crete) shows that producers are skeptical of technology, believing that its complexity is incompatible with their traditional experience and knowledge (Lioutas & Charatsari, 2020). Consequently, technology remains the privilege of the few, creating inequalities based on socioeconomic status and farm size.

Furthermore, the lack of specialized training creates a vicious circle. Producers do not invest in AI technologies because they do not know how to use them, and because they do not use them, they never acquire the necessary familiarity. This "knowledge gap" makes it necessary to redesign educational policy so that small farmers are not excluded from the benefits of the new era (Charatsari et al., 2023).

The Role of Agricultural Education

At the institutional level, the European Union now recognizes the central importance of knowledge through the "Agricultural Knowledge and Innovation Systems" (AKIS). According to the new Common Agricultural Policy (CAP 2023-2027), AKIS is a key tool not only for modernization but also for achieving sustainability goals (Kountios et al., 2024). Therefore, training farmers in Imathia is not just a technical necessity, but a prerequisite for the effective management of natural resources and harmonization with European strategies.

Addressing the "digital divide" and successfully integrating IT into the production process requires a radical redesign of agricultural education at all levels. Modern curricula must abandon the one-dimensional agronomic approach and adopt an interdisciplinary character, incorporating courses in computer science and data analysis. Education is no longer just about plant biology, but also about understanding digital information flows, making digital literacy a fundamental skill for the modern farmer (Fielke et al., 2020).

In addition, the complexity of digital tools requires a different educational approach based on practical application and interaction. While collaborative learning models are being promoted internationally, in Greece the knowledge provision system remains fragmented and "weak." In the absence of organised state support structures for new technologies, Greek producers are often forced to rely on informal personal networks for information, which, however, rarely have the specialised know-how required by artificial intelligence (Koutsouris & Zarokosta, 2021).

A critical factor for the success of this transformation is the agronomist-advisor himself. In the era of Agriculture 4.0, the role of the consultant is expanding and becoming that of a "digital mediator," as they are called upon to bridge the gap between complex technology and the needs of the producer. If the advisors themselves do not have the necessary training in AI and Big Data, it is impossible for them to support their clients' digital transition. Therefore, investing in train-the-trainer programs is a prerequisite for creating a digitally literate agricultural population (Eastwood et al., 2019).

Methodology

This study adopted a quantitative approach in order to investigate farmers' digital readiness and their attitude towards innovation. The Regional Unit of Imathia was selected as the study area, a region with intense agricultural activity and a significant contribution to national production. The selection of this particular area was deemed necessary as it is a typical example of small farms that are in the process of integrating digital data to optimize the production process and ensure the economic sustainability of the farms (Tsiligiridis & Ainali, 2025).

A structured questionnaire was designed and distributed for data collection, as it allows for the collection of measurable data from a large sample and the statistical correlation of demographic characteristics with digital readiness. The questionnaire consists of 10 questions and was structured around three main research axes:

1. **Demographic Profile:** Includes data such as age, level of education, and agricultural income. According to the literature, these factors have a decisive influence on the likelihood of producers adopting innovations.
2. **Digital Skills and Innovation Adoption:** Examines the use of basic digital tools (smartphones, computers, email) as well as the adoption of specialized precision farming technologies (such as GPS, drones, weather stations) in everyday life.
3. **Attitudes, Barriers, and Willingness to Pay for Consulting:** Measures farmers' attitudes toward technology and records the main barriers they encounter. In addition, it explores producers' willingness to invest financially in specialized consulting services.

The research was designed and implemented as a case study in the Regional Unit of Imathia. Sampling was carried out using the random selection method at gathering points for farmers, friends, friends of friends, family, and relatives who had ties to the agricultural sector and rural communities. A total of 78 questionnaires (n=78) were collected and processed. Although the sample size does not allow for the generalization of the results to the entire population (N), it is considered sufficient for the purposes of an exploratory analysis and for highlighting qualitative trends and correlations in the

study area. The data were processed using SPSS and Microsoft Excel statistical software. Descriptive statistics were used to capture the current situation.

Results

Descriptive Statistics

Demographic Characteristics

CHARACTERISTIC	CATEGORY	FREQUENCY (N)	PERCENTAGE (%)
AGE	18 - 34 years	12	15.4%
	35 - 44 years	14	17.9%
	45 - 54 years	30	38.5%
	55+ years	22	28.2%
EDUCATION LEVEL	Primary School	17	21.8%
	Junior High School	25	32.1%
	High School	19	24.4%
	Vocational Training (IEK/OAED)	3	3.8%
	University / TEI	10	12.8%
	Master's Degree (MSc)	3	3.8%
	Doctoral Degree (PhD)	1	1.3%
ANNUAL INCOME	< 5.000 €	10	12.8%
	5.000 € - 10.000 €	13	16.7%
	10.000 € - 15.000 €	16	20.5%
	15.000 € - 20.000 €	20	25.6%
	20.000 € - 25.000 €	9	11.5%
	> 25.000 €	10	12.8%
TOTAL SAMPLE		78	100.0%

Table 1: Demographic characteristics of the sample (Age, Education, and Income).

The analysis of the age distribution clearly shows the aging of the rural population in the sample. The majority of respondents belong to the older age groups, with 38.5% in the 45-54 age group and 28.2% aged 55 and over. Overall, two-thirds of the sample (66.7%) are over 45 years old. In contrast, young farmers (aged 18-34) represent only 15.3% of the total.

This finding is fully in line with the prevailing trend in Greece and the European Union, where the agricultural sector is characterized by a high aging index, which is a major structural barrier to the rapid adoption of digital innovation and Agriculture 4.0 (Eurostat, 2023).

The distribution of educational attainment is a critical finding for digital readiness. The vast majority of producers have only basic or secondary education. The largest percentage (32.1%) have only graduated from middle school, while the total percentage of those who have up to a high school diploma is 78.3%. In contrast, producers with higher or tertiary education (university/technical college, master's, doctorate) represent only 17.9% of the sample.

This low educational profile acts as a serious structural barrier to the adoption of complex digital technologies (AI), as Agriculture 4.0 requires a high level of cognitive and analytical skills (Dibbern et al., 2024).

Most producers are concentrated in the middle income bracket. Specifically, the most populous category is that of €15,000 - €20,000 with a percentage of 25.6%, while cumulatively with the category of €10,000 - €15,000 (20.5%), almost half of producers (46.1%) fall within an income range of €10,000 to €20,000. A significant percentage of 29.5% report an income of less than €10,000 (12.8% below €5,000 and 16.7% between €5,000 and €10,000), which suggests the existence of small, possibly economically unsustainable farms or cases of part-time farmers. Only 12.8% of respondents report an income above €25,000, while the €20,000-€25,000 category accounts for 11.5%.

Summarizing the demographic findings, it can be observed that the sample is representative of the prevailing trend in the Greek agricultural sector, which is characterized by an aging population, a low level of formal agricultural education, and limited agricultural income (Alpha Bank, 2024). The analysis confirms the existence of a significant structural barrier to digital transition, as the majority of producers are men, belong to older age groups, and have a low average level of education. This profile is directly linked to a reduced willingness and ability to adopt the knowledge and digital skills required for the successful integration of Agriculture 4.0 (Farmaki, 2024).

Digital Adaptability and Innovation Adoption

Digital Adaptability

DIGITAL TOOL	USAGE: YES (N)	USAGE: YES (%)	USAGE: NO (N)	USAGE: NO (%)
SMARTPHONE	72	92.3%	6	7.7%
COMPUTER (PC/LAPTOP)	59	75.6%	19	24.4%
E-MAIL	59	75.6%	19	24.4%
TOTAL SAMPLE	78		78	

Table 2: Farmers' Digital Readiness and Usage of ICT Tools.

The analysis of basic digital readiness reveals a clear stratification in the sample, which is the first indicator of the digital divide.
Smartphone penetration is almost universal, with 92.3% of farmers using them. This percentage confirms that the basic infrastructure and familiarity with applications (apps) exist, despite the structural barriers of age and education observed in section 4.1. However, the use of more complex tools shows a noticeable decline. Both computers and email are used by exactly the same percentage, 75.6%. This similarity suggests that email use is directly linked to computer ownership and the ability to perform more complex digital tasks.
This percentage of producers (computer and e-mail users) faces a steady digital divide of 24.4%, as they are excluded from performing complex digital tasks and official administrative communication. This finding confirms the existence of a gap between basic digital access and effective professional adoption, a phenomenon that is observed internationally even in advanced agricultural countries (McFadden et al., 2023).

Adopting Innovation

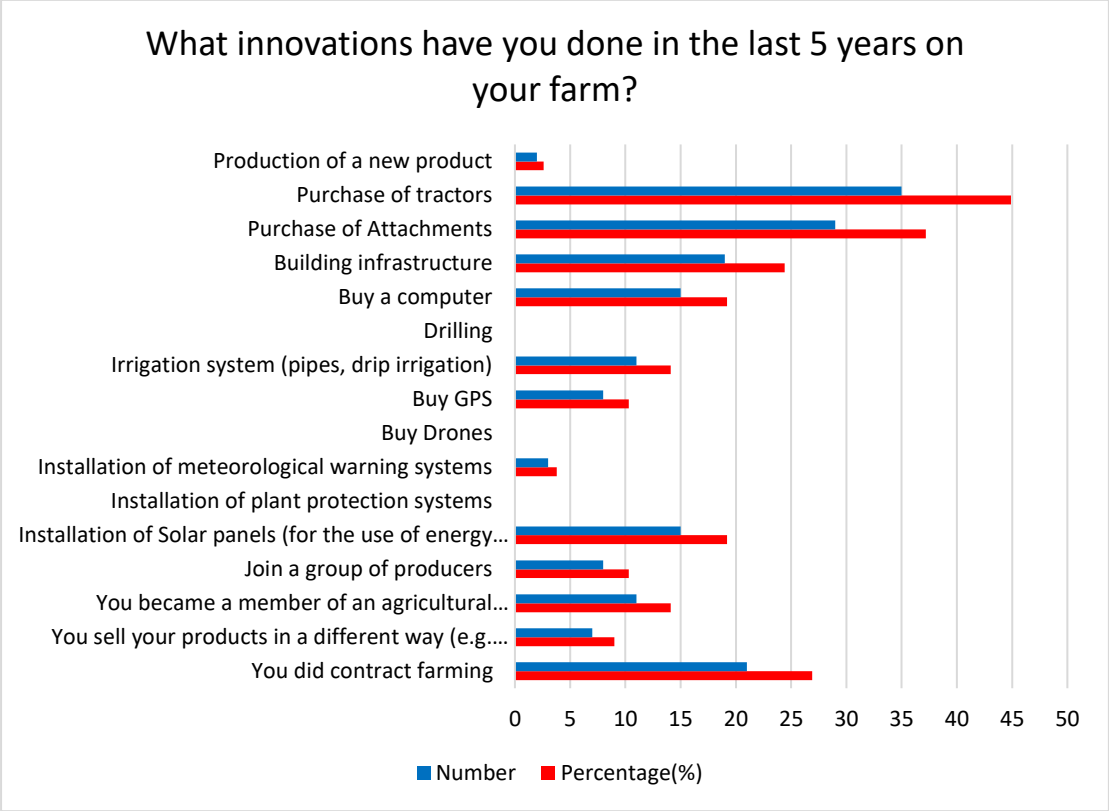


Figure 1: Ranking of Innovations Adopted by Farmers in Imathia (Multiple answers allowed).

According to the graph above, the tractor market is clearly a leading innovator, with an adoption rate exceeding 45%. This suggests a continuing need for mechanical upgrades and replacement of old equipment, which is considered a fundamental investment. Infrastructure construction follows closely behind with a rate of around 40%. This probably includes warehouses, greenhouses, or other permanent structures that improve production efficiency and protection. A significant proportion of farmers are adopting innovations related to irrigation, organization, and energy. Contract farming, at around 25%, shows a growing trend towards organising product distribution and securing income, a form of organisational innovation. Drilling and participation in cooperatives are around 15-20%. Drilling highlights the criticality of access to water, while participation in cooperatives shows a moderate trend towards collective action and economies of scale. The installation of photovoltaics, at around 20%, reflects the search for lower energy costs and the adoption of green technologies. The adoption of innovations related to digitization and precision agriculture remains very low. The GPS market is around 10-12%, suggesting that the adoption of guidance systems for precision agriculture is still in its early stages. The installation of meteorological systems has the lowest adoption rate (around 5%). Low adoption may be due to high costs, complexity, or lack of trust in technology.

According to the findings of the study by Masi et al. (2022), the adoption of innovations in agriculture focuses mainly on material investments, while digital technologies are at an extremely low level (Masi et al., 2022).

Attitudes, Barriers, and Willingness to Pay Consulting

Attitude Toward Innovation

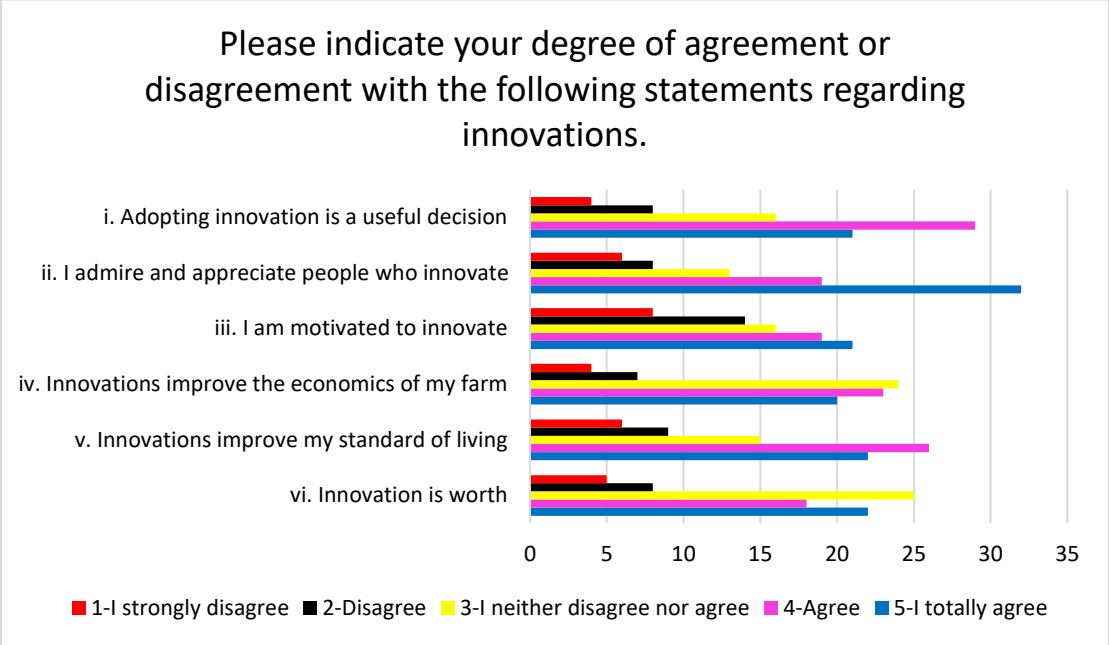


Figure 2: Farmers' attitudes and perceptions towards innovation adoption.

In all statements, the overwhelming majority of farmers express agreement. This suggests that farmers theoretically understand the value of innovation, even though previous data showed low adoption of specific digital technologies.

The highest absolute agreement is recorded in the statement "I admire and appreciate people who innovate," suggesting that innovation is considered a value and carries social recognition. There is very high overall agreement on the statements "Adopting innovation is a useful decision" and "Innovation is worthwhile," reinforcing the general belief in its positive impact. The majority strongly agree that innovations improve the profitability of their farms and their standard of living. The statement "I am motivated to innovate" shows a significantly higher percentage of neutral responses (~15%) compared to the other statements.

While farmers believe that innovation is useful, improves the economy, and is worthwhile, a significant proportion do not feel sufficiently motivated or do not receive enough incentives (financial, advisory, etc.) to take action. This discrepancy between attitude (value) and intention (motivation) explains why the adoption of new technologies remains low, despite the positive theoretical perception (Forero et al., 2025).

Barriers to the Adoption of Innovations – New Technologies

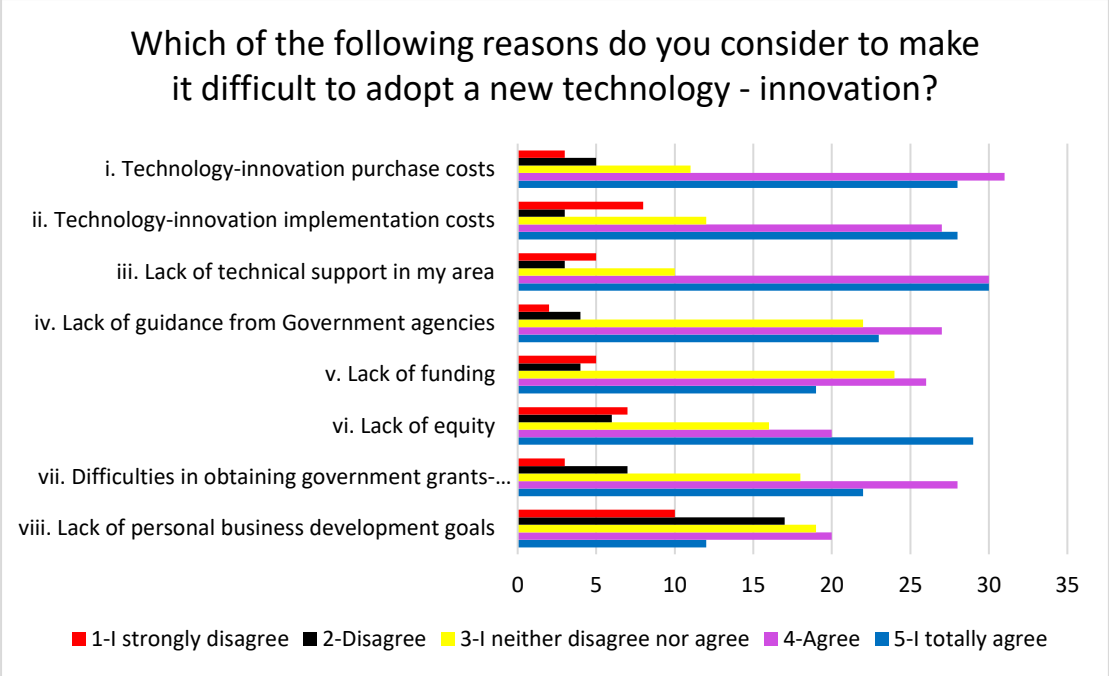


Figure 3: Main barriers hindering the adoption of AI and new technologies by farmers.

According to the bar chart above, analysis of the barriers faced by farmers in adopting innovation shows that the main problems are external and relate to financing and institutional support, while the view that the problem is a lack of personal ambition is rejected.

The lack of own funds, i.e., the unavailability of liquidity from own resources, is the most important single factor, with the highest percentage (approximately 32%) agreeing completely. The high purchase cost and the cost of implementing and operating the technology are key practical obstacles. The lack of access to investment capital is also confirmed as a major problem. Furthermore, the lack of support from the wider environment acts as a strong deterrent. The absence of specialized technicians and agronomists in the region to support new systems is a serious deterrent. Farmers feel alone in their efforts, as there is a very high level of agreement on the lack of guidance from government agencies. The difficulties in obtaining government subsidies highlight the problem of bureaucracy and the complexity of development programs. Farmers strongly disagree with the statement "Lack of personal business development goals" (the highest percentage of disagreement). This proves that the inability to adopt is not due to a lack of ambition or goals on the part of the farmers themselves, but to external obstacles that they cannot overcome.

Farmers have a fundamentally positive attitude towards innovation, recognizing its usefulness, but its practical adoption is hampered by strong external economic and institutional factors, as confirmed by recent research by Kountios et al. (2024) in Northern Greece—highlighting the gap between intention and final implementation due to cost (Kountios et al., 2024). The main obstacle is financial, with the lack of own funds being the most significant single deterrent, followed by the high cost of purchasing and implementing new technologies. At the same time, serious institutional gaps—such as the lack of technical support and inadequate guidance from state

agencies—act as additional barriers, while farmers reject the view that the failure to adopt is due to a lack of personal goals or ambition (Manning, 2024).

Willingness to pay for advice

VARIABLE	CATEGORY	FREQUENCY (N)	PERCENTAGE (%)
INTENTION TO PAY *(WILLINGNESS)*	Yes, I would pay	37	47.4%
	No, I would not pay	41	52.6%
	Total	78	100.0%
AMOUNT TO INVEST *(ONLY FOR THOSE ANSWERING YES)*	Low (0% - 15% of income)	25	67.6%
	Medium (15% - 30% of income)	10	27.0%
	High (> 30% of income)	2	5.4%
	Total (Sub-sample)	37	100.0%

Table 3: Farmers' willingness to pay for specialized advisory services and the percentage of annual income they are willing to invest.

The willingness to pay is almost evenly split (52.6% versus 47.4%). The fact that almost half of farmers are willing to pay for advice is a positive sign of recognition of the value of expert knowledge, especially considering that cost and lack of liquidity were cited as the main obstacles. However, the small majority who say "No" may reflect economic hardship, a lack of confidence in the quality of available advisory services, and a belief that advice should be provided free of charge by government agencies. Although farmers recognise the value, their willingness to pay is very conservative (almost 7 out of 10 commit less than 15% of their income). Demand for advice is likely to be price elastic. Farmers seek expert knowledge (to overcome the lack of guidance), but only if the cost remains low.

The table shows that there is almost equal recognition of the need for specialized advice (47.4% answer Yes), but financial hardship (confirmed in the obstacles) limits their ability and willingness to allocate significant funds to this service (Rizzo et al. 2024).

Correlations and Statistical Hypothesis Testing

Correlation of Age with Digital Skills

In the context of this study, it was deemed necessary to examine the phenomenon of the "digital divide," i.e., the inequality in access to and use of technology among different population groups. Age is considered to be a key factor that differentiates digital behaviour in the agricultural sector.

Specifically, the aim of the statistical analysis that follows is to investigate the correlation between Age Group (Independent Variable) and Computer Use (Dependent Variable). The research hypothesis being tested is that older farmers are statistically significantly less likely to use digital tools than younger farmers. Confirmation of this

hypothesis is crucial, as it substantiates the need for targeted education and training programs for older age groups.

To test the hypothesis, a chi-square independence test (Pearson Chi-Square Test) was performed, while for more accurate statistical processing, the sample was grouped into two basic categories: young farmers (aged 18-44) and older farmers (aged 45 and above).

AGE GROUP	DIGITAL USE: NO	DIGITAL USE: YES	TOTAL
18-44	2 (7.7%)	24 (92.3%)	26
45+	17 (32.7%)	35 (67.3%)	52
TOTAL	19 (24.4%)	59 (75.6%)	78

Table 4: Cross-tabulation of Age Groups and Digital Tool Usage (Chi-Square Test).

STATISTIC	VALUE	DF	ASYMPTOTIC SIGNIFICANCE (2-SIDED)	EXACT SIG. (2-SIDED)	EXACT SIG. (1-SIDED)
PEARSON CHI-SQUARE	5.880	1	.015		
CONTINUITY CORRECTION	4.601	1	.032		
LIKELIHOOD RATIO	6.781	1	.009		
FISHER'S EXACT TEST				.023	.012
PHI / CRAMER'S V	.275		.015		
N OF VALID CASES	78				

Table 5: Chi-Square Tests and Symmetric Measures for Age Group and Digital Tool Usage.

The analysis showed a statistically significant correlation between age group and digital media use [χ^2=5.88, p=.015].

The vast majority of farmers aged 18-44 (92.3%) use digital tools. In contrast, in the age group of 45 and over, the percentage of use drops significantly to 67.3%. Furthermore, the Phi index (φ=0.275, p=.015) indicates a moderately negative relationship, confirming that as age increases, the likelihood of using digital technologies decreases.

The results fully confirm the existence of a digital divide, as farmers over the age of 45 show statistically significantly lower rates of digital integration than their younger colleagues.

Correlation between Educational Level and Innovation Adoption

This section explores the correlation between producers' educational level and their innovative behavior. The analysis is based on two axes. First, it examines whether the level of education affects the total number of innovations adopted and then analyzes whether it differentiates the type of innovations chosen by farmers.

Specifically, the following analyses include:

1. Analysis of Variance (One-Way ANOVA): First, an innovation index (Total_Innovative) was created by adding up the individual actions of each

producer. Using ANOVA, we checked whether the level of education affects the total number of innovations adopted (i.e., whether the more educated innovate more).

2. Multiple Response Crosstabs: Next, the nature of the innovations is examined. Using contingency tables, the type of choices (e.g., purchase of mechanical equipment versus digital tools) that predominate at each educational level is mapped.

INNOVATION TYPE	PRIMARY / JUNIOR HIGH	HIGH SCHOOL	IEK / OAED	UNIVERSITY / MSC / PHD	TOTAL MENTIONS
TRACTOR	21	6	3	5	35
ATTACHMENTS	15	8	2	4	29
CONTRACT FARMING	7	8	1	5	21
BUILDING INFRASTR.	12	4	1	2	19
NEW COMPUTER	5	4	2	4	15
SOLAR PANELS	9	2	1	3	15
IRRIGATION SYSTEM	4	4	1	2	11
COOPERATIVE MEMBER	6	4	1	0	11
GPS	2	3	2	1	8
PRODUCER GROUP	5	2	1	0	8
MET. STATION	1	2	0	0	3
TOTAL RESPONDENTS	42	19	3	14	78

Table 6: Type of Innovation Adopted by Educational Level.

Since the quantity of innovations does not vary significantly, interest shifts to the type of innovations selected. The crosstabulation table reveals significant qualitative differences:

1. **Mechanical Equipment:** The purchase of a tractor is the most popular choice at all levels, especially among primary school graduates, where it constitutes the overwhelming majority of responses.
2. **Technology & Extroversion:** In contrast, more modern forms of innovation, such as buying a computer and participating in producer groups, are almost completely absent among primary school graduates. We find them mainly among high school/junior high school and vocational school graduates.
3. **Contract Farming:** It is noteworthy that contract farming seems to be preferred by 8 people with a high school education.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
BETWEEN GROUPS	26.037	6	4.340	1.266	.284
WITHIN GROUPS	243.296	71	3.427		

TOTAL	269.333	77

Table 7: One-Way ANOVA Results for Educational Level and Total Number of Innovations.

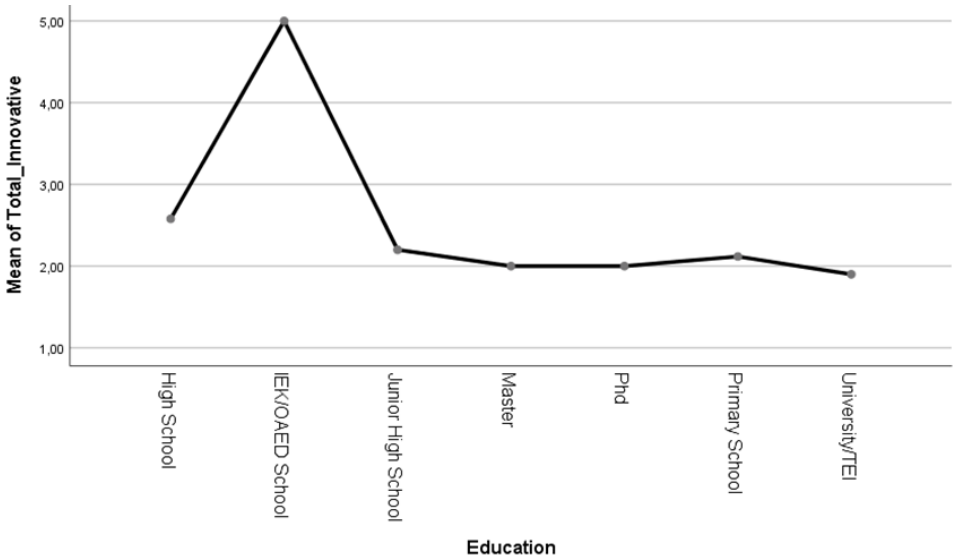


Figure 4: Means Plot of Total Innovations across different Educational Levels.

First, we examined whether educational level affects the total number of innovations adopted by producers (i.e., whether more educated producers make more changes). As shown in the ANOVA table, no statistically significant difference was found (Sig. = 0.284 > 0.05). This means that the average number of innovations is similar for most levels of education (ranging close to 2).

However, in the Means Plot, we observe a striking peak in the IEK/OAED category, where the average skyrockets to 5. It should be noted, however, that, as shown in the descriptive data table, the sample in this category is very small (N=3), which explains why this difference was not sufficient to give statistical significance to the model. In conclusion, education does not seem to determine the "quantity" of innovation.

The general conclusion of the research is that educational level does not function as a "quantitative multiplier" (i.e., it does not necessarily increase the total number of innovations adopted), but as a "qualitative selection filter." Specifically, a higher level of education directs producers towards more specialized and intangible digital investments, in contrast to a lower level of education, which is mainly associated with the adoption of conventional mechanical equipment such as the purchase of tractors. Less educated producers focus on strengthening their fixed capital (tractors, accessories), while producers with secondary or technical education (vocational training institutes, high school) seem to be more open to administrative and technological innovations (computers, cooperation).

Correlation between Income and Willingness to Pay for Consulting Services

To investigate the relationship between the economic status of farms and their willingness to invest in consulting services, a chi-square (Pearson Chi-Square) independence test was performed.

MONTHLY INCOME	WILLING TO PAY (YES)	NOT WILLING (NO)	TOTAL
LOW (<10K€)	8 (36.4%)	14 (63.6%)	22
MEDIUM (10K-25K€)	23 (51.1%)	22 (48.9%)	45
HIGH (>25K€)	6 (54.5%)	5 (45.5%)	11
TOTAL	37 (47.4%)	41 (52.6%)	78

Table 8: Willingness to Pay for Advisory Services by Income Category.

Looking at the crosstabulation table, we see a very interesting phenomenon: the percentage of refusal to pay remains consistently high, regardless of economic comfort. Specifically, in the high income category (>€25,000), the percentage of producers who refuse to pay is 45.5%. This percentage is almost equivalent to that of the middle income category (48.9%).

STATISTIC	VALUE	DF	ASYMPTOTIC SIGNIFICANCE (2-SIDED)
PEARSON CHI-SQUARE	1.548	2	.461
LIKELIHOOD RATIO	1.565	2	.457
N OF VALID CASES	78		

Table 9: Chi-Square Tests for Monthly Income and Willingness to Pay.

The results of the test show that there is no statistically significant correlation between monthly income and willingness to pay ($p=0.461 > 0.05$). This means that the producer's decision to pay or not to pay for specialized advice is independent of his income category.

The fact that almost one in two financially sound producers chooses not to invest in consulting services suggests that "cost" as a deterrent is, to a large extent, fictitious or secondary. The refusal of high-income producers demonstrates a lack of specialized technical culture. These producers, despite having the resources, fail to perceive intangible information as a productive factor that adds value. Therefore, the problem is not a lack of capital, but an inability to evaluate knowledge as an investment. The low adoption of smart farming and advisory services is not due to economic constraints, as is often claimed, but to deeper causes related to mindset.

Conclusions

This study revealed that the readiness of farmers in Imathia to adopt artificial intelligence (AI) and digital tools is at a critical transitional stage. Despite a positive theoretical attitude towards innovation, practical application remains low, highlighting a multidimensional "digital divide" that concerns not only a lack of equipment, but mainly a lack of specialized skills.

One of the most important findings of the research in the region of Imathia is the absence of a statistically significant correlation between the level of formal education and the number of innovations adopted. The finding that university graduates do not outperform compulsory education graduates in terms of innovative activity highlights a significant gap: theoretical training does not necessarily translate into agricultural innovation. This finding, combined with the reluctance of even financially sound producers to invest in consulting services, leads to the central conclusion that the

adoption of new technologies and AI in Imathia is not a matter of general education or economic status, but rather a question of cultivating a specialized technical culture. It is about shifting the mindset to perceive technology not just as a tool, but as a vital productive asset.

Therefore, for a successful transition to Agriculture 4.0, it is essential to radically strengthen agricultural education and training. The complexity of AI algorithms and Big Data cannot be addressed with empirical knowledge. Only through targeted agricultural education programs will producers be able to understand the real value of innovation.

The goal of future interventions (through AKIS) must be to cultivate this digital culture so that farmers do not view artificial intelligence in a fragmented or fearful way, but as a necessary strategic tool for developing the sustainability of their farms.

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Artificial Intelligence in Education: Educational Justice and the Public Interest

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - The rapid integration of Artificial Intelligence (AI) into education is reshaping teaching and learning processes worldwide, introducing unprecedented opportunities alongside significant ethical and social challenges. This paper examines AI in education through the dual lens of Educational Justice and the Public Interest. Drawing on a systematic review of scholarly literature and key institutional and regulatory documents, it explores how AI can enhance equity through personalized learning, data-driven support, and expanded access to educational resources, while also identifying risks such as algorithmic bias, digital inequality, opacity, and threats to privacy. The study further analyzes normative principles that should guide AI adoption in educational systems, emphasizing data protection, accountability, transparency, human oversight, and pedagogical autonomy. Finally, it investigates how AI transforms the professional role of teachers, arguing that AI should function as an assistive tool rather than a replacement for human judgment. The paper concludes that AI can contribute to a more just and inclusive educational system only if embedded within a robust ethical and regulatory framework that prioritizes human rights, democratic values, and the public interest.

Keywords: Artificial Intelligence, Educational Justice, Public Interest, Ethics of AI, Educational Policy

1. Introduction

Artificial Intelligence (AI) is transforming the educational landscape at an accelerating pace, reshaping not only classroom practices but also the broader architecture of educational governance and policy. From adaptive learning platforms and automated assessment systems to predictive analytics and intelligent tutoring systems, AI technologies increasingly influence how students acquire knowledge, how teachers design instruction, and how institutions monitor performance and allocate resources. These developments promise improved efficiency, personalized instruction, early identification of learning difficulties, and more data-informed decision-making at both micro and macro levels of the educational system. By analyzing large volumes of learner data, AI systems can identify patterns that might otherwise remain unnoticed, potentially enabling more timely interventions and more inclusive educational strategies. However, alongside these opportunities, AI integration raises profound and multifaceted questions concerning justice, equality, privacy, transparency, accountability, and the preservation of human agency within pedagogical processes.

Education has historically been regarded as a public good and a cornerstone of democratic societies, entrusted with fostering not only academic achievement but also civic responsibility, critical thinking, and social cohesion. As such, it occupies a unique normative status that distinguishes it from purely market-driven domains of innovation. The introduction of AI into education therefore cannot be evaluated solely in terms of technological efficiency, cost-effectiveness, or performance optimization. Rather, it must be assessed through normative frameworks that prioritize Educational Justice and the Public Interest. Educational Justice refers to the equitable distribution of learning opportunities, resources, recognition, and outcomes across diverse student populations, with particular attention to structural inequalities and historically marginalized groups. It demands that technological innovation contributes to reducing disparities rather than reinforcing them. The Public Interest, in turn, encompasses the protection of fundamental rights, democratic values, institutional accountability, and the collective welfare that education is designed to advance. It requires that AI systems operate within clear ethical and regulatory boundaries that safeguard privacy, prevent discrimination, and ensure meaningful human oversight.

Against this normative backdrop, the present study addresses four central research questions: How does AI enhance Educational Justice, and under what conditions can it meaningfully reduce educational inequalities? What ethical, social, and structural risks emerge from AI integration in educational settings? Which principles and governance mechanisms are necessary to ensure that AI-driven education serves the Public Interest rather than narrow institutional or commercial interests? And finally, how does AI reshape the professional identity, responsibilities, and autonomy of the teacher within increasingly data-driven learning environments? Through a systematic literature review and a critical analysis of major policy and regulatory texts, this study seeks to provide a comprehensive, theoretically grounded, and policy-relevant understanding of the ethical and institutional implications of AI in education, contributing to an informed debate about its responsible and equitable development.

2. Main Part

2.1 Methodology

This research adopts a qualitative secondary research design based on a systematic literature review. The study analyzes academic publications, policy reports, and regulatory frameworks addressing AI in education, algorithmic ethics, and data governance.

Key academic sources include Burrell (2016), Holmes, Bialik & Fadel (2019), Luckin (2018), Kearns & Roth (2020), and Selwyn (2019). Institutional and regulatory documents examined include the European Commission's AI Act proposal (2021–2024), the European Data Protection Board's Guidelines on Data Protection in Education (2020), UNESCO's Recommendation on the Ethics of Artificial Intelligence (2021), and the OECD report AI in Education: Opportunities and Risks (2023).

The selection criteria emphasized works that address transparency, fairness, governance, and ethical implementation of AI within public institutions. The analysis is interpretative and normative, synthesizing insights to construct a coherent framework connecting AI, Educational Justice, and the Public Interest.

2.2 AI as a Driver of Educational Justice

2.2.1 Personalized Learning and Adaptive Systems

One of the most frequently cited benefits of AI in education is personalized learning. AI-powered systems can analyze student performance data to adapt instructional content, pacing, and feedback to individual needs. Holmes, Bialik, and Fadel (2019) argue that adaptive technologies can provide tailored support that traditional classroom settings often struggle to offer due to time and resource constraints. In conventional instructional models, teachers often face heterogeneous classrooms where differentiation is pedagogically desirable but practically difficult. AI-driven adaptive systems offer the possibility of dynamic scaffolding, where learning materials are continuously adjusted based on formative assessment data.

Luckin (2018) emphasizes that machine learning systems can detect patterns in student behavior, enabling early identification of learning difficulties and timely intervention. For students with Special Educational Needs (SEN) or those from disadvantaged backgrounds, such targeted support may reduce achievement gaps and promote inclusion. Beyond remediation, AI systems can also support enrichment, offering advanced materials to high-achieving students while maintaining engagement across diverse proficiency levels. This capacity for continuous, data-informed personalization aligns with broader conceptions of Educational Justice, which seek not merely equal treatment but equitable responsiveness to individual circumstances.

Moreover, adaptive feedback mechanisms can strengthen metacognitive skills by helping learners understand their progress and identify areas for improvement. Real-time analytics allow students to monitor their own development, fostering greater autonomy and self-regulated learning. When carefully designed, such systems can complement teacher judgment rather than replace it, functioning as assistive tools that enhance professional decision-making.

2.2.2 Data-Driven Decision-Making and Early Intervention

Learning analytics can support educators by highlighting at-risk students and informing instructional adjustments. By aggregating large datasets, AI systems can reveal patterns not easily observable by individual teachers. This capacity for early detection may contribute to reducing dropout rates and improving educational outcomes. For instance, predictive models can identify attendance patterns, assessment trajectories, or behavioral indicators associated with disengagement, enabling schools to intervene proactively rather than reactively.

The OECD (2023) highlights that AI-based predictive tools, when properly governed, can assist institutions in allocating resources more effectively, thus supporting equity-driven policies. Data-informed allocation may involve directing additional tutoring support to vulnerable students, tailoring professional development to areas of demonstrated need, or redesigning curricula based on aggregated performance insights. In this sense, AI can function not only at the micro-level of individual learning but also at the meso- and macro-levels of institutional planning and public policy.

At the same time, the use of predictive analytics must be accompanied by safeguards that prevent deterministic labeling or stigmatization. Educational Justice requires that data-driven insights remain probabilistic and supportive rather than punitive. Transparent criteria, human oversight, and opportunities for review are therefore essential components of ethically responsible implementation.

2.2.3 Expanding Access to Educational Resources

AI technologies also expand access to high-quality educational content through intelligent tutoring systems, translation tools, and automated feedback platforms. Students in remote or underserved areas can benefit from digital tools that transcend geographical limitations. When combined with inclusive design, AI systems may help bridge traditional access barriers. Automated translation and speech-recognition technologies, for example, can support multilingual learners, while AI-generated feedback on written assignments can provide timely guidance in contexts where teacher workload is high.

In higher education and lifelong learning contexts, AI-powered platforms can facilitate flexible pathways, allowing adult learners to balance study with professional and family responsibilities. Open educational resources enhanced by AI may democratize access to knowledge across socioeconomic boundaries.

However, these benefits are contingent upon equitable digital infrastructure and universal access to devices and connectivity. Without such foundational conditions, AI risks reinforcing rather than mitigating inequalities. The digital divide—whether defined by connectivity, digital literacy, or institutional capacity—remains a structural constraint. Therefore, the justice-enhancing potential of AI depends not only on technological sophistication but also on sustained public investment, regulatory oversight, and inclusive implementation strategies that ensure no learner is systematically excluded.

2.3 Risks and Ethical Challenges of AI in Education

While AI holds transformative promise for education, its integration raises substantial ethical, social, and institutional risks. These challenges are not merely technical; they concern justice, power distribution, and the protection of fundamental rights within educational systems. If not critically addressed, AI may reproduce structural inequalities rather than mitigate them.

2.3.1 Digital Divide and Structural Inequality

The promise of AI-enhanced equity is contingent upon equitable digital infrastructure. Access to advanced AI systems depends on technological resources, connectivity, institutional investment, and digital literacy. As Selwyn (2019) argues, educational technologies often reflect and reinforce pre-existing socioeconomic hierarchies. Schools in affluent contexts are more likely to adopt sophisticated AI platforms, while under-resourced institutions may lack the infrastructure to participate fully in digital transformation.

From a justice perspective, this raises concerns aligned with Rawls's (1971) difference principle: technological innovations are only justifiable if they benefit the least advantaged members of society. If AI adoption primarily advantages already privileged groups, it contradicts principles of distributive justice. Similarly, Sen's (2009) capability approach emphasizes that access alone is insufficient; individuals must possess the real capabilities to use technology meaningfully. Without digital literacy programs and inclusive infrastructure, AI may deepen educational stratification.

2.3.2 Algorithmic Bias and Discrimination

AI systems rely on historical data. When those datasets encode existing social biases, machine learning algorithms may replicate or amplify discriminatory patterns. Kearns and Roth (2020) demonstrate that fairness in algorithmic systems requires explicit mathematical constraints and normative choices; neutrality cannot be assumed.

In education, algorithmic bias may manifest in predictive analytics systems that identify "at-risk" students, automated grading tools, or recommendation engines guiding academic pathways. If these systems rely on biased historical performance data, they may disadvantage students from marginalized communities. Holmes et al. (2019) caution that predictive systems must be carefully evaluated to prevent reinforcing deficit-based narratives.

Moreover, UNESCO (2021) stresses that AI systems must avoid discriminatory outcomes and ensure inclusion. Ethical AI in education therefore demands continuous auditing, impact assessments, and participatory oversight mechanisms to safeguard fairness.

2.3.3 Opacity, Explainability, and the "Black Box" Problem

One of the most persistent concerns in AI ethics is algorithmic opacity. Burrell (2016) identifies multiple dimensions of opacity, including proprietary secrecy, technical complexity, and limited interpretability. In educational settings, opacity poses a

significant challenge because decisions about student assessment, progression, or support carry long-term consequences.

Explainability is central to procedural justice. Students and educators must understand how automated decisions are made, especially when such decisions influence grading, placement, or disciplinary measures. Without explainability, accountability becomes diluted, and trust in educational institutions may erode (OECD, 2023).

The emerging field of Explainable AI (XAI) seeks to address these concerns by developing models that provide interpretable outputs. However, explainability alone is insufficient without institutional mechanisms that ensure stakeholders can contest and review algorithmic decisions.

2.3.4 Privacy, Surveillance, and Data Governance

Educational AI systems collect extensive behavioral, cognitive, and biometric data. Such data accumulation introduces risks of surveillance and misuse. The European Data Protection Board (2020) emphasizes that children constitute a particularly vulnerable population whose data require enhanced protection under data protection principles such as minimization, purpose limitation, and proportionality.

Beyond legal compliance, there are broader ethical concerns regarding normalization of surveillance in schools. Continuous monitoring of students' performance, engagement, and emotional states may alter educational relationships and undermine autonomy. As Zuboff (2019) argues in her analysis of surveillance capitalism, data extraction practices may transform social institutions in ways that prioritize predictive control over human development.

Thus, data governance in educational AI must extend beyond regulatory compliance to encompass democratic accountability, transparency, and public deliberation.

2.4 Principles Serving the Public Interest in AI-Driven Education

The integration of AI into education must be guided by normative principles that safeguard the Public Interest. Education is not merely a service market but a public institution central to democratic life, social mobility, and civic formation. Therefore, AI governance must reflect constitutional values and human rights commitments. Beyond efficiency gains and innovation narratives, public education systems carry obligations of fairness, universality, and intergenerational responsibility. AI adoption must thus be evaluated not only in terms of performance metrics but also in terms of its long-term societal impact, including the shaping of civic culture and democratic participation.

Moreover, the Public Interest perspective requires attention to power asymmetries between technology providers, public authorities, and educational communities. Large-scale data infrastructures and algorithmic systems can concentrate decision-making authority in opaque technical environments. A pluralistic governance approach therefore demands institutional checks and balances, participatory deliberation, and alignment with established principles of public law.

2.4.1 Human-Centered and Rights-Based AI

UNESCO's (2021) Recommendation on the Ethics of Artificial Intelligence establishes a human-centered framework grounded in dignity, agency, and inclusiveness. In education, this principle requires that AI technologies support human development rather than substitute it. Luckin (2018) argues that AI should enhance "human intelligence" rather than attempt to replicate it, positioning technology as an augmentative tool.

A human-centered approach also recognizes the developmental nature of learners. Children and adolescents constitute a particularly vulnerable population whose cognitive, emotional, and social capacities are still forming. AI systems must therefore be calibrated to support growth without fostering dependency, surveillance anxiety, or excessive performance pressure.

A rights-based approach ensures that students' rights to education, privacy, and non-discrimination are not compromised by technological innovation. This aligns with broader European regulatory efforts such as the AI Act (European Commission, 2021–2024), which classifies certain educational AI systems as high-risk and subject to strict compliance obligations. Rights-based governance further implies proportionality: the data collected and the level of automation deployed must be strictly necessary for legitimate educational purposes. It also requires accessible remedies for individuals whose rights may be adversely affected by automated decisions.

2.4.2 Accountability and Democratic Oversight

Accountability is central to the Public Interest. AI systems deployed in education must be subject to clear responsibility structures. Who is accountable when an algorithm produces discriminatory outcomes? The developer, the institution, or the public authority? Clarifying lines of responsibility is essential in complex procurement chains where private vendors supply AI tools to public schools or universities.

The proposed AI Act introduces requirements for risk assessment, documentation, human oversight, and post-market monitoring for high-risk systems. These provisions reflect recognition that AI governance cannot rely solely on market self-regulation. Democratic oversight mechanisms, including transparency reporting and independent audits, are essential for maintaining public trust (OECD, 2023).

Furthermore, public engagement in AI decision-making processes reinforces legitimacy. Educational communities—including teachers, students, and parents—should participate in evaluating AI adoption strategies. Structured consultation processes, ethical review boards, and stakeholder forums can institutionalize such participation. Democratic oversight is not merely procedural; it fosters shared ownership of technological transformation and mitigates perceptions of technocratic imposition.

2.4.3 Transparency and Explainability as Democratic Safeguards

Transparency is not merely a technical requirement but a democratic safeguard. Burrell (2016) demonstrates that opacity can undermine accountability and obscure power

asymmetries. In public education systems, transparency ensures that algorithmic decision-making remains open to scrutiny by administrators, educators, students, and regulators.

Explainability allows stakeholders to understand and contest AI-driven decisions. Kearns and Roth (2020) emphasize that fairness and transparency must be explicitly embedded in algorithmic design. Institutions must also communicate clearly how data are collected, processed, and utilized. This includes providing accessible explanations rather than purely technical documentation. Meaningful transparency implies intelligibility for non-experts, enabling students and parents to grasp how recommendations, risk scores, or automated assessments are generated.

Transparency further supports procedural justice by ensuring that decisions affecting educational trajectories—such as admissions, grading assistance, or intervention flags—are not shielded from review. In democratic societies, decisions that influence life opportunities must remain contestable and revisable.

2.4.4 Protection of Pedagogical Autonomy and Professional Integrity

AI should not diminish teachers' professional judgment. Selwyn (2019) warns against narratives that frame technology as a replacement for educators. Instead, AI should function as a supportive tool that enhances teachers' capacity to deliver meaningful instruction.

Pedagogical autonomy safeguards the human dimension of education, including relational trust, moral guidance, and contextual decision-making. Teachers interpret student needs within rich social and cultural contexts that cannot be fully captured by quantitative data. Maintaining teacher agency ensures that algorithmic recommendations remain advisory rather than determinative.

Professional integrity also requires adequate training and digital literacy. Educators must be equipped to critically evaluate AI outputs, recognize potential biases, and integrate technological tools responsibly. Without such capacity-building, reliance on AI may inadvertently shift authority away from pedagogical expertise toward technical systems. Protecting autonomy thus involves both normative commitment and institutional support.

2.4.5 Equity by Design

Serving the Public Interest requires proactive equity measures. This includes bias testing, inclusive datasets, accessibility standards, and targeted support for disadvantaged communities. Holmes et al. (2019) argue that ethical AI in education must be designed intentionally to promote inclusion.

In line with Rawls (1971) and Sen (2009), equity must be embedded into technological design and governance rather than treated as an afterthought. A Rawlsian perspective would prioritize arrangements that benefit the least advantaged learners, while a capability-oriented approach emphasizes expanding substantive freedoms and real educational opportunities.

Equity by design also entails continuous evaluation. AI systems should be monitored for disparate impacts across socioeconomic, linguistic, gender, or disability-based categories. Corrective mechanisms must be in place to address emerging inequalities. Ultimately, the Public Interest in AI-driven education is served when technological innovation operates within a framework of justice, rights protection, democratic participation, and professional respect—ensuring that efficiency gains do not eclipse foundational commitments to equality and human flourishing.

2.5 The Transformation of the Teacher's Role

Artificial Intelligence reshapes but does not eliminate the role of the teacher, as its function within educational environments is better understood as augmentative rather than substitutive. By automating routine and time-consuming tasks such as grading, administrative documentation, and basic feedback provision, AI enables educators to reallocate their professional energy toward mentoring, cultivating critical thinking, and supporting students' socio-emotional development—dimensions of learning that remain inherently relational and human-centered.

At the same time, teachers increasingly assume the role of critical mediators between students and algorithmic systems, interpreting data-driven outputs, questioning automated recommendations, and embedding them within broader pedagogical, ethical, and contextual considerations. This evolving responsibility requires educators not only to understand how AI tools function but also to assess their limitations, biases, and potential unintended consequences. Effective and just integration of AI in education therefore presupposes systematic professional development and sustained training in digital and algorithmic literacy, since without sufficient competence teachers cannot meaningfully supervise AI systems, safeguard student interests, or ensure that technological tools remain aligned with pedagogical values and principles of fairness.

Discussion

AI in education represents neither a utopian solution nor an inevitable threat. Its impact depends fundamentally on governance structures, ethical commitments, and institutional capacity. As the preceding analysis has demonstrated, AI technologies possess the potential to advance Educational Justice through personalization, early intervention, and expanded access. At the same time, they may reproduce or intensify structural inequalities if embedded within asymmetrical data environments or weak accountability frameworks. The decisive variable is not technological sophistication per se, but the normative and institutional context within which AI systems operate.

Educational Justice requires that AI be deployed in ways that actively reduce disparities rather than entrench them. This involves more than technical bias mitigation; it requires deliberate policy choices that align technological design with distributive principles. Drawing on Rawls (1971) and Sen (2009), justice in AI-driven education must be evaluated according to whether it improves the position and capabilities of the least advantaged learners. Predictive analytics, adaptive systems, and automated assessments must therefore be assessed not only for accuracy but also for their distributive consequences. Equity-oriented implementation presupposes sustained public investment in digital infrastructure, teacher training, and institutional oversight

capacity. Without such structural support, AI risks becoming a tool that amplifies pre-existing socioeconomic inequalities rather than mitigating them.

The Public Interest dimension further situates AI governance within constitutional and administrative frameworks. Education in democratic states is constitutionally protected and normatively anchored in principles of equality, human dignity, and proportionality. From the perspective of constitutional law, the deployment of algorithmic systems in public education must comply with guarantees of equal access, data protection, and effective judicial protection. Greek constitutional scholarship emphasizes the binding force of fundamental rights upon public administration and the obligation of the state to secure substantive equality in access to public goods (Chrysogonos, 2013). Within this framework, algorithmic decision-making in education cannot be treated as a neutral managerial instrument; it constitutes an administrative act subject to legality, transparency, proportionality, and judicial review.

Administrative law principles reinforce this requirement. The rule of law demands that automated systems used by public authorities remain subject to accountability mechanisms, reason-giving obligations, and procedural safeguards. In line with broader administrative science perspectives, public administration is not merely a technical apparatus but a normative institution embedded in democratic legitimacy (Chevallier, 2017). From this standpoint, AI governance in education must integrate mechanisms of hierarchical control, independent oversight, and participatory deliberation. Institutional capacity-building is therefore essential: regulatory compliance, impact assessments, and audit procedures must be operationalized rather than remain abstract commitments.

Regulatory instruments such as the AI Act (European Commission, 2021–2024) and UNESCO's (2021) ethical framework provide foundational guidance, yet effective implementation remains critical. The classification of certain educational AI systems as "high-risk" under the AI Act underscores recognition of their potential impact on life trajectories and fundamental rights. However, formal compliance alone is insufficient. Public authorities must cultivate a culture of ethical reflexivity, ensuring that procurement processes, contractual arrangements with technology providers, and ongoing system evaluations align with democratic standards.

Ultimately, the discussion reveals that AI in education must be governed as a public constitutional matter rather than as a purely technical innovation. Its legitimacy derives from its capacity to serve the Public Interest, uphold Educational Justice, and strengthen—rather than weaken—the democratic and professional foundations of educational institutions. The future of AI in education will therefore depend less on algorithmic capability and more on the resilience of legal, administrative, and ethical frameworks that structure its use.

Conclusion

Artificial Intelligence is transforming education by introducing powerful tools for personalization, data analysis, predictive modeling, and expanded access to learning resources. These technological capabilities hold substantial potential for enhancing Educational Justice by supporting differentiated instruction, early intervention, and evidence-based policymaking. Yet, as the preceding analysis has demonstrated, AI does not operate in a normative vacuum. Its distributive effects are shaped by the legal,

institutional, and administrative frameworks within which it is embedded. Risks related to inequality, algorithmic bias, opacity, privacy intrusion, and technocratic overreach cannot be treated as peripheral concerns; they strike at the constitutional core of public education in democratic societies.

A just and democratic integration of AI therefore requires adherence to foundational constitutional and administrative principles. From a constitutional perspective, public education is linked to guarantees of equality, human dignity, and the effective enjoyment of fundamental rights. Greek constitutional theory underscores that fundamental rights bind all state action, including administrative practices shaped by technological tools (Chrysogonos, 2013). Algorithmic systems used in public education must therefore comply with principles of proportionality, legality, and equal treatment. They cannot function as autonomous or unreviewable mechanisms of decision-making.

From the standpoint of administrative law, AI-driven decisions in education constitute administrative acts and must remain subject to reason-giving obligations, transparency requirements, and judicial control. As Spiliotopoulos (2017) emphasizes in his analysis of administrative legality, public authorities are bound by strict adherence to statutory authorization and procedural safeguards. Similarly, Dagtoglou (2012) highlights that administrative discretion is always framed by constitutional limits and rights-based constraints. The introduction of automated systems does not dilute these obligations; rather, it intensifies the need for clarity, traceability, and accountability in administrative reasoning.

Furthermore, insights from administrative science reinforce the institutional dimension of AI governance. Public administration is not merely a technical executor of policy but a normative structure embedded in democratic legitimacy (Makrydimitris & Pravita, 2010). The deployment of AI must therefore be aligned with organizational responsibility, hierarchical supervision, professional ethics, and participatory oversight. Institutional capacity-building—through training, audit mechanisms, and procedural adaptation—is essential to ensure that AI remains a tool of public service rather than a source of opaque bureaucratic power.

A just and democratic integration of AI requires, consequently, the operationalization of core principles: meaningful human oversight, transparency and explainability, accountability structures, robust data protection, and respect for pedagogical autonomy. AI must remain a supportive instrument within an educational system grounded in human dignity, substantive equality, and collective welfare.

Ultimately, the future of AI in education will not be determined by technological capability alone but by the strength of the constitutional, administrative, and ethical frameworks that govern its deployment. Whether AI becomes a catalyst for Educational Justice or a mechanism of intensified inequality depends on our capacity to embed innovation within a legally coherent, democratically accountable, and public-oriented institutional order.

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Teachers and Artificial Intelligence: From cognitive familiarization to professional empowerment through experiential professional development

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Abstract - The rapid development of Artificial Intelligence (AI) in recent years has significantly influenced everyday school practice, providing teachers with new tools to support teaching, lesson planning, and professional development. Despite the increasing use of AI applications in education, teacher professional development often remains fragmented or predominantly theoretical, proving insufficient for the pedagogically grounded, critical, and responsible integration of AI into instructional practice.

The aim of this paper is to explore how experiential professional development in the use of Artificial Intelligence can contribute to teachers' professional empowerment and to the development of a more conscious and pedagogically oriented stance towards AI technologies. In particular, the paper examines the role of teachers' active and collaborative engagement with AI tools, systematic practice in the formulation of effective prompts, and the reflective design of small-scale instructional interventions as key factors that enhance self-confidence, professional self-efficacy, and the expansion of teachers' instructional repertoires.

The paper presents and analyses an applied model of experiential teacher professional development, implemented within the framework of professional learning initiatives and grounded in the principles of experiential learning and Communities of Practice. The model is structured around three distinct yet interconnected phases of professional learning: (a) information and reflection on the possibilities, limitations, and ethical issues of AI; (b) experiential exploration and experimentation with AI tools; and (c) collaborative design and exchange of instructional micro-scenarios, which function as shared professional artefacts.

Findings from the qualitative evaluation of the initiative indicate that participating teachers develop increased self-confidence and a stronger sense of security in the use of AI, greater flexibility in lesson design, and an enhanced ability to adapt instruction to students' individual learning needs. At the same time, a climate of collaboration, collective reflection, and continuous professional learning is fostered.

Overall, the paper highlights that experiential, collaborative, and evolutionary professional development constitutes a critical prerequisite for the meaningful and pedagogically responsible integration of Artificial Intelligence in education, underscoring the role of the Education Advisor as a key mediator between technological potential and the real needs of the school community.

Keywords: Artificial Intelligence, Teacher Professional Development, Professional Learning, Experiential Learning, Communities of Practice

Introduction

The rapid development of Artificial Intelligence (AI) in recent years has brought about substantial changes in the field of education, affecting both learning processes and the role of the teacher. AI tools and applications are already being used to support lesson planning, the production of educational materials, the personalization of learning, and the provision of feedback, shaping a new educational environment with enhanced possibilities, as well as complex pedagogical, ethical, and professional challenges (European Commission: European Education and Culture Executive Agency, 2023).

Despite the increasing use of AI by teachers, their professional development often remains limited to fragmented or predominantly theoretical approaches, which are insufficient for the pedagogically grounded, critical, and responsible integration of AI into instructional practice. International research highlights that effective teacher professional development requires active, collaborative, and practice-oriented forms of learning that connect theory with experimentation, reflection, and the systematic processing of experience (Darling-Hammond et al., 2017).

Within this context, experiential professional development and the functioning of Communities of Practice emerge as critical factors for professional learning, as they create conditions for collective inquiry, the exchange of experiences, and the strengthening of teachers' professional identity (Wenger, 1998). Mere cognitive familiarization with AI tools, without systematic experiential engagement and reflection on instructional practice, may lead to superficial or instrumental uses of technology, with limited pedagogical impact.

The purpose of this paper is to explore how a model of experiential professional development in the use of Artificial Intelligence can contribute to teachers' professional empowerment. More specifically, the paper seeks to highlight how teachers' active and collaborative engagement with AI tools, systematic practice in the formulation of effective prompts, and the reflective design of small-scale instructional interventions can enhance teachers' self-confidence, expand their instructional repertoires, and support the adaptation of teaching to students' individualized learning needs. The paper is based on the presentation and analysis of an applied model of experiential professional development, implemented within the framework of teacher professional learning initiatives and organized into three distinct yet interconnected phases of professional learning. Through this analysis, the paper aims to contribute to the scholarly discussion on teacher professional development in AI, with particular emphasis on experiential, collaborative, and evolutionary approaches to professional learning.

Available European data indicate that Artificial Intelligence is primarily used by teachers as a tool to support their professional work. According to the results of the TALIS 2024 survey (OECD), nearly two-thirds of teachers who use AI in the European Union report using it for efficient information processing and topic summarization (65%), as well as for the creation of lesson plans or learning activities (64%). These findings suggest that AI currently functions mainly as a tool for enhancing teachers' instructional preparation and professional planning, rather than solely as a means of direct instruction for students. In addition, AI is increasingly used to support learning processes, including skill practice in authentic contexts, support for students with

special educational needs, instructional differentiation, feedback generation, data analysis, and assessment. These findings indicate that AI is gradually becoming embedded in teachers' everyday practice as a tool for professional support and instructional differentiation (OECD, 2025).

Kolb's experiential learning theory in teacher professional development

Experiential learning theory constitutes one of the most widely recognized theoretical frameworks for adult learning and professional development, focusing on knowledge that is generated through the systematic processing of experience. According to this theoretical approach, learning is understood as a dynamic and evolutionary process in which experience is transformed into knowledge through cognitive and reflective processes, rather than as the passive reception of information (Watson et al., 2019).

Kolb (2015) conceptualizes learning as a cyclical process consisting of four distinct yet interconnected phases: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Meaningful learning emerges when individuals engage sequentially in all phases of the cycle, enabling the connection between experience and theory and the application of newly acquired knowledge across different contexts. This approach has been widely applied in teacher professional development programs, as it facilitates the transfer of knowledge into instructional practice and supports the development of professional autonomy.

Contemporary research confirms the effectiveness of Kolb's theory in educational environments that require active participation, critical thinking, and adaptation to complex and open-ended problems. Open-access studies indicate that the application of the experiential learning cycle enhances deeper conceptual understanding, the integration of knowledge, and the long-term retention of learning, particularly when combined with collaborative and authentic learning activities (Watson et al., 2019).

Indicative in this regard is the study by Wijnen-Meijer et al. (2022), in which the implementation of the experiential learning cycle through real-life experience, case discussions, and simulation led to increased learner engagement and more positive evaluations of the professional development process. These findings highlight the importance of systematically linking experience, theory, and practical application within structured professional learning scenarios, especially in adult education contexts.

Within the field of educational technology, and particularly in relation to Artificial Intelligence, experiential learning acquires particular significance. The effective use of digital and AI-supported tools presupposes experimentation, reflection, and the redesign of instructional practice—elements that align directly with Kolb's model. Research in educational technology emphasizes that teachers' engagement in experiential technology-use scenarios strengthens their pedagogical judgment and supports the conscious and pedagogically grounded integration of innovative tools into teaching.

Overall, Kolb's experiential learning theory provides a coherent and empirically grounded framework for the design of professional development interventions, particularly in rapidly evolving fields such as Artificial Intelligence. The emphasis on

experience, reflection, and active experimentation creates the conditions for meaningful professional learning and for the sustainable transfer of knowledge into instructional practice.

Communities of practice and teacher professional learning

The concept of Communities of Practice constitutes one of the most well-established theoretical frameworks for understanding learning as a social, participatory, and practice-embedded process. According to Wenger, learning is not exclusively an individual cognitive activity but emerges through individuals' participation in shared practices, relationships, and activities that acquire meaning within the context of a community (Wenger, 1998). This perspective shifts the focus from knowledge transmission to the collective construction of meaning and the formation of professional identity.

Communities of Practice are defined as groups of people who share a common domain of interest (domain), interact regularly as a community (community), and develop shared practices (practice) with the aim of improving their professional activity. The domain provides coherence and direction to learning by defining the area around which the community is formed. The community refers to relationships of mutual engagement, trust, and collaboration that develop among members, while practice encompasses the set of tools, narratives, ways of thinking, and practical solutions that are collectively developed and evolve over time (Wenger, 1998).

A central concept in the theory of Communities of Practice is participation, which is intrinsically linked to the process of professional identity formation. Teachers learn not only what to do, but also who they are as professionals, through the ways in which they participate, co-construct practices, and negotiate the meaning of their actions. Knowledge, therefore, is not treated as static content, but as a dynamic product of shared action, dialogue, and reflection on practice.

The theory of Communities of Practice is particularly significant for teacher professional development, as it recognizes that a substantial part of teachers' learning takes place outside formal professional development settings. Teachers learn through everyday instructional practice, collaboration with colleagues, the exchange of experiences, and the joint negotiation of pedagogical challenges. Within this framework, Communities of Practice function as spaces of informal yet meaningful professional learning, where knowledge is directly connected to teachers' experiences, needs, and authentic questions arising from practice.

Of particular importance is the concept of legitimate peripheral participation, according to which new members of a community initially engage in peripheral roles and gradually, through participation, support, and guidance from more experienced members, move toward more central forms of involvement. This process facilitates learning integration, reduces the anxiety often associated with professional learning, and fosters conditions of mutual support and professional growth.

Contemporary applications of the theory highlight that Communities of Practice can function in both face-to-face and digital environments, expanding opportunities for collaboration, communication, and knowledge sharing. Especially in rapidly evolving

fields such as educational technology and Artificial Intelligence, Communities of Practice provide a flexible and sustainable framework for continuous professional learning, enabling teachers to experiment, reflect, and collectively reframe their pedagogical practices.

Overall, Wenger's theory of Communities of Practice offers a strong socio-practice-based framework for understanding professional learning. The emphasis on participation, collective action, and professional identity formation makes Communities of Practice particularly suitable for the design of professional development interventions that aim at sustainable and meaningful teacher professional growth.

In the present initiative, the characteristics of Communities of Practice were not limited to occasional forms of collaboration within isolated professional development sessions, but were developed through a process of systematic, iterative, and evolutionary professional learning. Teachers participated in cycles of experiential professional development with a shared thematic focus, revisited issues related to the design and pedagogical use of Artificial Intelligence on a regular basis, and developed a shared professional vocabulary (e.g., formulation of effective prompts, pedagogical criteria for the use of AI tools). At the same time, they produced and utilized shared professional artefacts, such as instructional micro-scenarios, reflective records, and examples of practical applications, which functioned as means of knowledge sharing and collective construction of pedagogical meaning. In this way, the professional development initiative gradually constituted a functional Community of Practice, in which learning emerged through continuous participation, reflection, and shared professional action.

Description of the experiential professional development initiative

The initiative described in this paper concerns the implementation of an applied model of experiential teacher professional development, with a focus on the pedagogically grounded use of Artificial Intelligence (AI) in school practice. The initiative was designed and implemented within the framework of scientific and pedagogical support for school units, aiming at teachers' professional empowerment and the development of sustainable practices of professional learning.

A fundamental assumption underlying the design of the initiative was that mere technological familiarization with AI tools is insufficient for their transformative integration into teaching. Teachers require safe and supportive learning environments in which they can experiment, reflect, and connect the use of technology with the real needs of the classroom. For this reason, the initiative was grounded in the principles of experiential learning and Communities of Practice, conceptualizing professional development not as a one-off event but as a process of continuous and evolutionary professional growth. The model of the initiative was organized around three distinct yet complementary phases of professional learning, which operate cyclically and foster the collective construction of knowledge and practical experience.

The choice of experiential professional development as the core methodological approach was not incidental, but rather grounded in strong theoretical and empirical evidence. Experiential learning, as described by Kolb (1984), conceptualizes learning as a dynamic process of transforming experience into knowledge through recurring

cycles of action, reflection, and redesign. At the same time, international studies on effective teacher professional development emphasize that the most meaningful forms of professional learning are those that are directly connected to instructional practice, create safe spaces for experimentation, and promote collaboration and reflection (Darling-Hammond et al., 2017). Within this framework, experiential professional development transforms theoretical knowledge into experiential understanding, strengthens teachers' self-confidence and sense of professional competence, and supports the transition from passive models of learning to active and creative pedagogical practices.

Particularly in the field of Artificial Intelligence, where rapid technological developments often generate uncertainty and reservations, the experiential approach enables teachers to connect AI with authentic classroom needs, to experiment in a safe manner, and to develop pedagogically grounded strategies for its meaningful use.

Phase 1: Information and reflection

The first phase aims to establish a shared framework of understanding regarding Artificial Intelligence in education. Teachers are introduced to fundamental AI concepts, its possibilities and limitations, as well as the ethical, social, and pedagogical challenges that accompany its use, such as data protection, algorithmic bias, and equity of access to digital technologies. This informational component functions as a common point of reference and contributes to avoiding fragmented or superficial approaches to AI.

However, the critical pedagogical element of this phase is not information itself, but reflection. Teachers are invited to reflect on their own starting point: to identify where they stand in relation to AI, the questions and concerns they express, and the needs and challenges they recognize in their everyday instructional practice. Through individual and collective reflective processes, professional development is transformed from an external intervention into a personal and professional concern. This phase lays the foundation for meaningful engagement, as it enables teachers to attribute meaning to learning and to recognize their role as active agents in their own professional development.

Phase 2: Experiential exploration and experimentation

The second phase shifts the focus from understanding to practice and constitutes the core of the experiential dimension of the program. Teachers actively experiment with selected AI tools, test different approaches to prompt formulation, and observe in practice the generated outcomes, as well as the possibilities and limitations of these tools. Particular emphasis is placed on the critical appraisal of results, so that the use of AI is not perceived as inherently reliable or neutral.

This phase does not function as technical skills training, but rather as a laboratory for professional identity formation. Teachers explore how, and under what conditions, AI tools can be integrated into their own pedagogical philosophy, support instructional differentiation, and respond to authentic classroom needs. Through experimentation and dialogue, a more conscious and critical stance toward AI gradually develops,

strengthening teachers' sense of professional self-efficacy and reducing technological hesitation.

Phase 3: Collaborative design and communities of practice

The third phase leverages the collective dynamics of the group and transforms individual experience into shared professional capital. Teachers collaborate in the design of short, applicable instructional micro-scenarios in which AI tools are integrated in a pedagogically grounded manner. These scenarios are not treated as final products, but as starting points for testing, reflection, and redesign. In practice, this phase constitutes a Community of Practice, where knowledge is produced through collective action and returns to practice through the exchange of experiences.

The emphasis is not placed on the creation of "optimal" scenarios, but on the development of a continuous learning flow: experimentation, reflection, revision, and sharing. In this way, professional learning ceases to be fragmented and acquires a sustainable and evolutionary character. Overall, the three phases operate as a unified cycle of professional learning that begins with understanding, moves through practice, and culminates in collective creation. This cycle can be repeated and adapted, supporting teachers' continuous professional development within a constantly evolving educational and technological environment.

The initiative highlights critical pedagogical dimensions of the use of Artificial Intelligence in education, shifting the focus from technology itself to its instructional application. AI supports differentiated instruction by enabling the adaptation of instructional materials to students' needs, interests, and learning levels, while also contributing to the early identification of learning difficulties through the analysis of learning data and participation patterns. In addition, its use enhances creative thinking and skills development, as it offers both students and teachers tools for producing multimodal content and for exploring complex problems.

Within this context, the role of the teacher is redefined: from a mere transmitter of knowledge to a designer of learning experiences who makes pedagogical decisions, critically evaluates AI-generated outcomes, and shapes learning environments that respond to students' authentic needs. Emphasis is placed on the use of AI as a supportive tool that enhances instructional adaptation, without replacing the pedagogical role and professional judgment of the teacher.

Reflective practice as the core of professional learning

Reflective practice constitutes a central axis of professional learning within the framework of the present initiative, as meaningful adult learning does not emerge from linear "knowledge transmission," but from the systematic processing of experience, dialogue, and critical inquiry into practice within safe and collaborative contexts (Imel, 1992). In adult education, reflection functions as a mechanism of meaning-making: learners revisit their experiences, analyze and interpret them, and re-examine the choices and assumptions that guide their professional action. From this perspective, reflective learning is linked to Mezirow's transformative approach, not as mere introspection, but as critical examination of frames of reference and professional certainties (Taylor, 1998; Hoggan, 2023).

Within the specific professional development model, each participant is invited to systematically document their experiences with the use of Artificial Intelligence tools, including both successes and challenges encountered in instructional practice. These records do not function as individual diaries, but as material for professional reflection that returns to the group and feeds into collective analysis. This design choice aligns with contemporary literature emphasizing that reflective practice is strengthened when it is made visible, systematic, and shareable through multiple forms (e.g., written reflections, discussions, reflective cycles), allowing it to move beyond "thinking about practice" and become a tool for improvement and professional learning (Machost & Stains, 2023).

The collective processing of reflective records creates conditions for cognitive conflict and the "destabilization" of taken-for-granted assumptions: teachers are exposed to alternative interpretations of similar practices, compare pedagogical choices, recognize limitations or biases, and are led toward critical re-examination of the frames that guide their actions. The transformative dimension of reflection is also strongly supported by integrative approaches, such as critical reviews and metatheoretical syntheses, which highlight the role of dialogue, critical examination of assumptions, and action-taking as central mechanisms of professional change in adult education contexts (Taylor, 1998; Schnepfleitner, 2021; Hoggan, 2023). In other words, the "technological" experience of AI can serve as a catalyst for deeper professional learning when it is framed by critical reflection and the reinterpretation of instructional identity.

At the same time, the emphasis on reflection as a collective practice is connected to critical pedagogical perspectives that conceptualize knowledge as a product of dialogue, problematization, and conscious engagement with practice. In the context of AI, this dimension becomes particularly important, as teachers are not merely required to "use" tools, but to critically examine their relationship with them: which problems they solve, which new issues they generate, and how they affect pedagogical judgment, transparency, and ethical considerations. Moreover, the literature indicates that reflection is a multifaceted concept that requires clear methodological framing (what is reflected upon, through which guiding questions, and by means of which processes) in order to avoid being reduced to general "discussion" without professional impact (Machost & Stains, 2023).

Overall, within the present initiative, reflection functions as a mechanism linking experience, theory, and action: teachers experiment with AI tools, document what occurs in practice, critically process their pedagogical choices, receive feedback from the group, and redesign their approaches. In this way, professional knowledge is transformed from an individual experience into collective professional capital, supporting a sustainable and pedagogically grounded integration of Artificial Intelligence into instructional practice (Imel, 1992; Machost & Stains, 2023; Hoggan, 2023).

Results of the professional development initiative

The results presented below are based on a qualitative evaluation of the professional development initiative, which included participants' reflective written records, collective reflection and discussions conducted during the professional development

sessions, as well as observations derived from the implementation of the designed instructional micro-scenarios in educational practice. Overall, the findings from the implementation of the initiative are encouraging and highlight the potential and effectiveness of the proposed professional learning model.

Participating teachers report increased self-confidence in the use of Artificial Intelligence tools, along with a stronger sense of security when integrating them into instructional practice. This enhancement appears to be closely linked to the experiential nature of the professional development and to systematic experimentation within a supportive framework, which reduces technological hesitation and strengthens teachers' professional self-efficacy.

At the same time, increased flexibility in lesson planning is documented, with teachers using AI to adapt instructional materials and learning activities to students' individualized learning needs. In this context, AI is not perceived as an end in itself, but rather as a supportive tool for instructional differentiation and the strengthening of pedagogical focus.

Particular significance is also attributed to the development of a climate of creative collaboration and collective professional learning. Teachers express an increased willingness to exchange experiences, participate in collective reflective processes, and continue collaboration beyond the formal framework of the professional development initiative. This element suggests that the initiative functioned as a starting point for the formation of sustainable professional learning practices.

Overall, the results indicate that the professional development initiative was not limited to the short-term acquisition of technical skills, but contributed to the formation of attitudes, perceptions, and practices that support sustainable professional development and the conscious, pedagogically grounded use of Artificial Intelligence in instructional practice.

The role of the education advisor

The role of the Education Advisor emerges today as particularly critical in the context of integrating Artificial Intelligence into school education. AI represents a significant educational opportunity; however, it is accompanied by complex pedagogical, ethical, and organizational challenges, making systematic guidance and pedagogical orientation of school communities necessary (European Commission, 2023). Within this context, the Education Advisor functions as a bridge between technological potential and the real needs of school practice, translating technology into pedagogically applicable practices and contributing to the avoidance of uncritical or fragmented uses.

A core dimension of this role involves supporting school units in the smooth, gradual, and pedagogically grounded integration of AI. This support is not limited to the presentation of tools or technical solutions, but extends to the cultivation of a culture of inquiry, reflection, and professional learning. Within such a framework, schools are encouraged to experiment, critically evaluate their practices, adapt tools, and develop solutions that respond to the specific learning needs of their students (Darling-Hammond, Hyler, & Gardner, 2017).

At the same time, the Education Advisor plays a decisive role in creating a safe pedagogical environment for dialogue, experimentation, and reflection. The literature on Communities of Practice emphasizes that teachers are more willing to innovate and engage in collective learning when they operate within supportive environments where trial, error, and reflection are treated as integral components of professional learning (Wenger, 1998). The role of the Education Advisor is pivotal in the establishment of such environments, through coordination, facilitation, the encouragement of collective reflection, and the design of appropriate learning structures.

Within the framework of experiential professional development, the Education Advisor does not act as a provider of ready-made "solutions," but rather as a pedagogical facilitator who cultivates the conditions under which teachers assume an active role in their professional development. In this way, the school community is gradually transformed into a community of learning and knowledge production, empowerment, and continuous development. The coordinating, advisory, and empowering character of this role functions as a catalyst for the meaningful, sustainable, and pedagogically grounded integration of Artificial Intelligence into school education.

Conclusions

This paper highlighted the significance of experiential professional development as a key factor for the meaningful and pedagogically grounded integration of Artificial Intelligence (AI) into educational practice. The analysis of the proposed professional development model demonstrated that the transition from cognitive familiarization to experiential teacher engagement contributes substantially to teachers' professional empowerment and to the development of a more critical and creative stance toward the use of AI tools.

The main findings of the study indicate that teachers who participate in experiential and collaborative professional development contexts develop increased self-confidence in the use of AI, expand their instructional repertoires, and demonstrate greater flexibility in the design of learning activities. Particular importance was attributed to systematic practice in the formulation of effective prompts and to the use of a limited number of core AI tools, elements that appear to support the transfer of technology from the level of theory to everyday instructional practice. At the same time, the integration of reflective practice and collaboration within Communities of Practice strengthens collective learning and contributes to the development of a shared pedagogical culture.

At the level of implications, the findings underline the need to redesign teacher professional development programs, placing emphasis on experiential, collaborative, and dynamically updated forms of professional learning. Artificial Intelligence is not proposed as an autonomous or technocratic driver of innovation, but as a tool that acquires pedagogical value when embedded within frameworks of critical use, pedagogical design, and systematic reflection. Within this context, the role of the Education Advisor emerges as pivotal, as it functions in a supportive and coordinating capacity, bridging technological developments with the authentic needs of the school community.

Nevertheless, the paper also presents certain limitations. The analysis is based on an applied professional development model and on a qualitative evaluation of participants'

experiences, without systematic quantitative measurement of its impact on students' learning outcomes. In addition, the rapidly evolving landscape of AI tools necessitates continuous updating of both professional development content and the research approaches that accompany it.

In conclusion, the study supports the view that experiential and collaborative professional development constitutes a fundamental prerequisite for the meaningful use of Artificial Intelligence in education, enhancing teachers' professional autonomy and pedagogical competence. Future research could focus on the systematic investigation of the impact of such professional development models across different educational contexts and levels, as well as on their connection to learning outcomes and indicators of educational quality.

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Integrating Artificial Intelligence into history teaching: enhancing learning through innovation

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Abstract - The integration of artificial intelligence (AI) into history education is transforming traditional teaching and learning methods, enhancing engagement, personalization, and the cultivation of critical thinking and skills. Traditional teaching methods often rely on static content, such as books and lectures, which can limit student engagement and personalized learning experiences. This study synthesizes findings from quantitative data and qualitative information to examine the role of AI in improving historical understanding. The research questions are: Can AI enhance critical thinking? How does the use of AI affect the study and interpretation of history? The use of artificial intelligence (AI) in history education is reshaping the way students engage with historical narratives, analyze sources, and deepen their historical knowledge. The aim of this research is to highlight that artificial intelligence-based tools, such as adaptive learning platforms and chatbots, facilitate interactive learning experiences, while simulations and language processing techniques allow students to dynamically analyze and interpret historical events. By leveraging artificial intelligence, educators can present complex historical narratives through simulations, chatbots, and automated assessments, promoting deeper student engagement. Empirical data reveal improved assessment performance, reinforcing the effectiveness of artificial intelligence in education. Furthermore, teachers and students highlight the potential of artificial intelligence to promote critical thinking by reconstructing historical discussions and creating narratives based on the context. This study highlights the ability of artificial intelligence to innovate in history education, bridging technological developments with pedagogical strategies. However, despite these developments, the integration of artificial intelligence into history education is a broad field to explore, raising questions about its effectiveness, accessibility, and ethical implications. This article examines the integration of artificial intelligence into history education, specifically through the use of OpenAI's ChatGPT and other digital tools. This study is conducted with a teaching intervention and constitutes a teaching scenario in the 9th grade history curriculum, unit 29: The Balkan Wars (1912-1913), utilizing artificial intelligence. The research was conducted in a high school in a suburb of Thessaloniki during the 2024-2025 school year, and the research data were analyzed using qualitative content analysis. The application showed that the adoption of digital tools in education allows students to interact with history in an active and practical way, enriching the learning experience. The research results showed that the integration of DT in education provides opportunities for personalized learning and the development of critical thinking skills. Students interacted with the material, explored history through interactive tools, and developed a deeper understanding of the past, thereby enhancing their ability to evaluate information and think critically.

Keywords— *(artificial intelligence, history teaching, educational practice)*

Introduction

This article examines the integration of artificial intelligence into history education, specifically through the use of OpenAI's ChatGPT. The use of artificial intelligence (AI) in history education reshapes the way students, engage with historical narratives, analyze sources, and deepen their historical knowledge. Leveraging artificial intelligence educators can present complex historical narratives through simulations, chatbots, and automated assessments, promoting deeper student engagement. The aim of this research is to highlight that AI-based tools, such as adaptive learning platforms and chatbots, facilitate interactive learning experiences, while simulations and language processing techniques allow students to dynamically analyze and interpret historical events.

This study is conducted as a teaching intervention and constitutes a teaching scenario.

The subject was History of the 3rd grade of junior high school in the unit 29: The Balkan Wars (1912-1913) with the use of Artificial Intelligence. The research location was junior high school in a suburb of Thessaloniki. The research took place during the school year 2024-2025. The research data analysis was qualitative content analysis. The study analyzed quantitative data and qualitative information. The objective was to examine the role of AI in improving historical understanding. The research questions were: Can AI enhance critical thinking? How does the use of AI affect the study and interpretation of history?

The questionnaire was chosen before the teaching intervention, in order to determine the level of understanding of the students regarding the structural historical concepts, without any further preparation. After the teaching intervention was completed, the same questionnaire was given, structured in the same way but with different sources for processing, in order to determine whether the contribution of the model contributed to a deeper understanding of the structural historical concepts. The questionnaire, as a research tool, in addition to being deemed appropriate, since it meets the requirements of the present research, is widely used, since it provides the possibility of collecting data in a short period of time (Paraskevopoulos, 1993). At the same time, the questionnaire constitutes a type of standardized interview, ensuring through anonymity the honesty of the answers to a large number of questions (Kyriazi, 2011).

Thus, it was chosen as one of the basic tools for investigating the questions addressed by the research, having first established the theoretical background on which the questionnaire is based. At the same time, other factors were also taken into account during its formulation, such as the total number of questions, the order of their presentation, the way they were formulated in terms of their content and structure, as well as the time required to complete them. It would be an omission not to point out that no additional explanations were given for the way to answer the questionnaire, as it became clear from the beginning that this was a questionnaire that aimed at the level of understanding of historical concepts and not knowledge. The planning and programming of the teaching was done at a micro level (one teaching unit). The teaching format was interactive with guided dialogue and narrative with commented narration with the application of a combined teaching method. The identification and development of the activities was based on the aims and objectives of the teaching. There was feedback through short-answer questions, which contributed to the guidance

of the study. The assignments were research-based, so that the students could learn to reflect, analyze and extend learning (Mavroskoufis, 2008: 61-68).

Structure & Content of Educational Scenario

1. IDENTITY OF EDUCATIONAL SCENARIO

Title of educational scenario: The conceptual approach to the Balkan Wars: cause/effect, continuity/change, historical significance

Creator: Eleni Karamanoli

Level – Grade: 9th grade

Teaching hours: 2

Subject area of the curriculum: History – Modern and Contemporary History

Thematic unit of the curriculum: Greece and the Balkans in the early 20th century

Suggested interdisciplinary/cross-curricular connections:

- Geography: geopolitical space of the Balkans, cartographic representation of borders
- Information Technology: searching, evaluating, and presenting historical information, creating a digital poster/map/podcast, etc.
- Modern Greek Language: understanding historical discourse, composing arguments
- Social and Political Education: nation states, alliances, international relations

Student learning prerequisites (cognitive, emotional and socio-cultural, digital):

Students are already familiar with:

- basic facts about the Ottoman Empire and the Eastern Question,
- key points about the Young Turk movement

They are expected to have:

- basic internet research skills
- ability to work in teams
- interest in an experiential approach to history

Possible difficulties:

- chronological sequence
- cause-and-effect relationships

The use of digital sources, maps, and timelines helps students overcome these obstacles by making historical knowledge more tangible and understandable.

2. PURPOSE AND EXPECTED LEARNING OUTCOMES

2.1. Purpose of the educational scenario

Students will understand the causes, development, and results of the Balkan Wars and realize their importance in shaping the modern Greek state and the Balkan region through the use of digital technologies.

Desired outcome:

- historical research
- critical approach to sources
- digital literacy
- critical literacy

2.2. Expected learning outcomes

Knowledge

Students are expected to:

- recognize the causes of the Balkan Wars,
- describe the key events of the First and Second Balkan Wars,

- identify the consequences for Greece and the Balkans.

Skills / Abilities
Students will be able to:
- organize, analyze, and interpret historical sources (cartographic, photographic, historical information in chronological order)
- locate and utilize information from electronic sources (e.g., Fotodentro) utilize digital maps and sources,
- collaborate in groups through digital environments (e.g., NowComment, Padlet) and present historical data
- create digital multimodal texts (e.g., maps in My Maps, Timeline) to organize their conclusions
- utilize interactive tools (e.g., Kahoot, Quizz) for self-assessment and feedback

Attitudes
Students are expected to:
- develop a critical attitude towards historical events
- respect historical memory and different perspectives

Skills cultivated
- searching for and documenting information in digital historical sources
- critical approach and analysis of digital media
- collaborative knowledge production
- historical and digital literacy
- creative use of IT tools

3. TEACHING CONTENT
- The Balkan question in the early 20th century
- First Balkan War
- Second Balkan War
- Peace treaties and outcomes

4. TEACHING FRAMEWORK AND CLASSROOM MANAGEMENT
4.1. Central research question/problem/experience
The central research question focuses on students exploring how the Balkan Wars changed the map and history of Greece and the Balkans.

4.2. Educational strategy/ies
Inquiry-based learning with analysis of historical sources and maps
Collaborative teaching using NowComment Padlet e-me for group work
Analysis of historical sources – digital storytelling via podcast
Use of digital tools (interactive map, digital timeline)
Interactive assessment via Kahoot

In addition, Artificial Intelligence (AI) is used as a supportive research and learning tool. With the teacher acting as a guide, students use AI applications to:
- ask questions about historical events
- get short descriptions or explanations of terms (Eastern Question, Young Turk movement, cause and effect, etc.)
- approach historical events from multiple perspectives by comparing different views and interpretations. The teacher guides students to check the reliability/validity and critically approach the information provided by the TN.

Artificial Intelligence is used to help us understand that teaching history isn't just about memorizing stuff from the past, but about giving students tools to understand the present and gain knowledge they can use to build their future. but as a means of providing students with tools to understand the present and acquire knowledge that they can use to build their future. Using activities that can make historical knowledge not only fun, but also practical and applicable with the support of ChatGPT. Students interact with history in a fun and practical way. With the introduction of ChatGPT, personalized responses from historical figures to students' letters are enabled, thus increasing interaction and enriching the learning experience. It also helps with the collective analysis of historical information to identify common themes and conceptual errors, such as anachronisms. (Azevedo, 2024; Ghory & Ghafory, 2021; Santamaria-Velasco, Núñez-Naranjo & Morales-Urrutia, 2025).

4.3. Teaching activities – Student activities

Phase Teacher's role Student activity Digital tools/Resources Time
Introduction Introduces students to the historical topic under investigation/Brainstorming Discuss preliminary knowledge Fotodentro, Digital archive of Ippokratis Papavasiliou, (15 min)
Investigation Guides the groups in studying sources and maps Examine photographs, maps Digitized ELIA collections (illustrative material), Google Earth, My Maps, (15 min)
Creation Supports the creation of a podcast, digital timeline, or digital map. Guides students in the use of T.N. Create a digital map showing the borders of Greece before and after the Balkan Wars, organize the most important historical events of the period into a timeline Timeline JS, Canva, Mapcreator, ChatGpt (15 min)
Presentation-discussion Coordinates presentation and discussion of conclusions Present on Padlet/e-me Padlet/e-me (15 min)
Assessment-Reflection Highlights positive points and difficulties with an interactive quiz, feedback Participate in a quiz, write down what historical knowledge they have acquired Kahoot/Quizz (20 min)

Phase 1 – Introduction and motivation (15 minutes)

Objective: to activate prior knowledge, connect with current events, and introduce the issues addressed in the unit.

✓ The teacher has added a digital folder with proclamations, letters, photographs, maps

✓ Encourages students to share stories or objects related to the Balkan Wars

✓ A brief discussion takes place – starting point for the causes and effects of the Balkan Wars. The key terms are noted on the board (e.g., Balkan allies, Ottoman Empire).

✓ Students browse the digital hub of the IMH (Hellenic Foundation for Culture) and search the sections https://www.ime.gr/chronos/13/gr/foreign_policy/facts/05.html:

- First Balkan War
- Second Balkan War

➢ Using the digital map of the Balkan states (Google Earth), they locate the Balkan states that participated in the wars, linking historical and geographical data.

➢ The digital timeline tool (Timeline JS, Sutori) is used to create a chronological representation of the most important events of the period.
➢ At the same time, students can log on to the e-me digital platform, where relevant interactive material and group worksheets are posted.
➢ On the e-me "Wall," students can exchange views, interact, post material and questions, and provide feedback.

Digital Tools: IME, Google Earth, TimeLine JS, e-me
Teacher's role: presents, encourages, guides, coordinates the discussion
Role of students: listen, participate, search, discuss, locate on the map, exchange experiences.

Phase 2 – Group Research of Sources (15 minutes)
Objective: Familiarization with digital historical sources, digital newspapers, development of a multifaceted approach and critical thinking.
➢ The teacher divides the students into groups, taking into account learning differences and Matsaggouras' sociogram.
➢ Using the e-me or e-class platform, the teacher posts and distributes the digital folder with relevant excerpts from newspapers of the time, providing instructions and hyperlinks.
➢ Each group takes on different material (e.g., Georgios I's proclamation, personal correspondence of war participants, newspaper front pages).
➢ Students study, discuss, identify unfamiliar terms, and take notes on the padlet.com wall. They collaboratively analyze the text of George I's proclamation on NewComment in a shared commenting environment. They have the opportunity to add comments, ask questions, and respond to each other.
➢ The teacher acts in a supportive role, explaining unfamiliar terms and clarifying historical difficulties.

Digital Tools: e-me/ e- class (folders-assignments), digital newspaper sheets, Padlet for posting comments
Teacher's role: provides supporting material, guides, clarifies vocabulary and historical facts
Students' role: study sources, identify arguments (logical-emotional), focus on appropriate terms, collaborate

Phase 3 – Analysis and interpretation of content (15 minutes)
Objective: Interpretation and critical approach to sources
❖ Students proceed to the reading phase and the pictorial interpretation of newspaper excerpts in order to create their own material
❖ An interpretative dialogue is held, guided by the teacher with targeted questions:
- What events are presented and why are they historically significant?
- How are the causes and effects of the wars described?
- What has changed and what has remained the same after the wars?

❖ The groups note the main topics presented and proceed to record their findings, then draw conclusions on their "Wall."

The teacher uses the interactive whiteboard for brainstorming and creates a concept map (MindMup) with the participation of the students.
Digital Tools: e-me/ e- class, Wall, interactive whiteboard

Teacher's role: supports, guides, clarifies, organizes the exchange of ideas
Students' role: interact, interpret, construct arguments

Phase 4 – Composition and creation (2nd teaching hour, 30-35 minutes)
Objective: knowledge production – collaboration for the structuring of material, production of multimodal material
During the creation phase, students use Artificial Intelligence tools (e.g., ChatGPT) to:

- ❖ search for ideas for the structure of the podcast
- ❖ structure an interview with a fictional historical figure of their choice ("Interview with George I," "Interview with a soldier," "Interview with E. Venizelos").

Students interact by discussing the results in the group and compare the AI's answers with historical sources, revealing the importance of critical thinking and documented knowledge.

The groups work on the worksheets and compose a multimodal text structured as follows:

a brief summary of the journalistic material
a critical approach to the argumentation
presentation of the results

- The creative composition is done collaboratively in e-me or Canva.
- The assignments are posted on the "Wall" or presented orally to the whole class.
- The teacher takes on the role of discussion coordinator and provides feedback.

Each team has the opportunity to create a short podcast (2-3 minutes) entitled "The role of King George I," "Conversation with a soldier," "The leading role of Eleftherios Venizelos in the successes of the Balkan Wars," recorded using Bandicam Audio Recorder, Audacity, Anchor, Ferrite, and published on Padlet

- Creation of a digital book based on the historical knowledge they have acquired, Book Creator, Calibre

Digital Tools: e-me (Wall), Padlet Bandicam Audio Recorder, Audacity, Anchor, Ferrite, Book Creator, Calibre

Teacher's role: guides, provides feedback, offers technical support
Students' role: interact, collaborate, compose, create, present

- Students present their work (podcasts, articles, books) to the whole class
- The teacher moderates the discussion with questions:

What did we learn today about the Balkan Wars?
How did the results of the Balkan Wars affect today (geographically, historically, socially)?
What would you choose to explain to someone who does not know about the Balkan Wars, taking into account the historical information from the sources?

- At the end, an interactive quiz (Kahoot) is held to reinforce the material.
- Students write a reflective/thought-provoking sentence on the "Wall" ("What impressed me most is...", "What would happen if...", "One of the most important things I learned is...")

Digital Tools: e-me (Wall), Padlet, Kahoot
Teacher's role: evaluates, encourages, summarizes
Students' role: present, self-evaluate, reflect/ponder

During all phases of teaching, the teacher:
Observes student participation in group activities, the degree of cooperation, adherence to group work rules, and their ability to utilize digital resources
 Intervenes by asking questions for guidance, encourages interaction, reflection, the expression of informed opinions, and the correlation of historical events
 Collects and organizes learning data (notes, comments on the e-me "Wall," information from the plenary discussion)
 Uses digital feedback tools:
 Padlet, e-me Walls for expressing opinions, ideas, feelings, and difficulties
 Quizz, Kahoot for quick assessment of knowledge and understanding of concepts
 Mentimeter, AnswerGarden, Slido for anonymous formulation of questions, answers, ideas, and attitudes of students
Feedback is provided verbally through comments on the "Wall" and individually to team members, focusing on progress and the actual learning process.

Final assessment – Knowledge synthesis
The final phase of assessment is directly linked to the students' synthesis:

- ✓ Presentation of group digital products (podcast, article, book)
- ✓ Assessment based on agreed criteria (collaboration, documentation, creativity)
- ✓ Student self-assessment with a short questionnaire in e-me ("What did I learn...", "What impressed me...", "What did I find out that I didn't know before?", "What did I find difficult?")

The teacher uses the formative feedback to update the points that need further explanation, clarification, or enrichment for subsequent teaching interventions.

Reflection
Interaction with LLM-Based Assistants, Claude (Anthropic) revealed various issues regarding the validity of information and the need to develop critical and digital literacy skills. Students were asked to compare and verify the answers, making them critical thinkers and recipients of knowledge. The scenario concludes with collective and individual reflection.
For students:
 They interact about the process, what they liked, what they found difficult, what skills they developed
 They post a phrase or idea on the e-me "Wall" entitled "What I learned from the lesson on the Balkan Wars"
 Understand that learning is a dynamic process that is built through exploration, reflection, review, and collaboration.
For the teacher:
 Make notes about the groups, the effectiveness of the digital tools, and the students' participation.
 Reflect on the teaching intervention, redesign activities taking into account the needs/peculiarities of the student population in order to achieve more effective teaching.

In summary
Assessment and reflection are an integral part of the learning process:
 They empower students to take initiative
 They encourage reflection

- They cultivate skills of cooperation, interaction, and continuous learning

6. DIGITAL TECHNOLOGIES/GDP/RESOURCES TO BE UTILIZED IN THE CLASSROOM

Fotodentro – Map of the Balkans

- Google Earth, My Maps – Digital historical maps
- TimeLine JS – Digital timeline
- Digital worksheets
- Mentimeter, AnswerGarden, Slido
- Digitized ELIA collections
- Digitized Hippocrates Papavasiliou Archive
- Quiz application (e.g. Kahoot)
- Padlet Bandicam Audio Recorder, Audacity, Anchor, Ferrite, Book Creator, Calibre- podcast creation
- NowComment/Padlet/e-me, e-class- Collaborative posting of material
- General Army Staff

7. APPENDIX

Sample worksheets

Appendix

Worksheet for Group 1:

Step 1

Visit the page:
https://www.tovima.gr/2024/03/05/istoriko-arxeio/vasilias-georgios-a-to-portreto-tou-i-dolofonia-tou-kai-oi-theories-synomosias/

Read the text, take notes, and answer the question: What was the fate of George I?

The newspapers Empros and Patris of March 6, 1913 refer to the same event. Find the points in common with the text you studied above. Then organize your own text (150 words) in the form of a collaborative NowComment document with the information you found in both texts.

Step 2

The creators of the newspaper articles referring to the assassination of King George I depict and describe the king's assassination. Comment on the significance of the event based on the newspaper excerpts and write down in a text editor how the moral judgment of the editors is reflected.

Step 3

From the ERT archive, you can watch the episode that includes the assassination of King George I https://archive.ert.gr/7758/. In the software https://padlet.com/, mention the most important moments as they are represented and the thoughts they inspire in you.

Step 4

Based on what you have studied, provide a definition for the historical concepts of cause and effect. Mention other historical events that correspond to these concepts.

Worksheet for Group 2

The following excerpt describes the situation in which the soldiers on the front lines found themselves. Describe the difficulties faced by the Greek army based on the letter from Second Lieutenant D. Daras from the front lines. Write down your thoughts on the hardships of war in a 100-word essay. You can post the essay on your school's blog.

Letter from the front "Armenochori, November 16, 1912
My dear Mother and Brothers
[...] It seems that negotiations for a truce or peace are underway, but we know nothing about it because we do not receive any newspapers [...].
We have become accustomed to marching and fighting, and we try as much as possible to protect ourselves from the cold, which has become very severe with snow. Do not worry about this, because I now have enough clothes, not only those I brought from Athens, but also those I have acquired here and elsewhere. I wear two undershirts, two thick corsets, two pairs of underwear, two pairs of socks, all woolen, and I have three cloaks. When we stop in villages, we have plenty of fire. The food is somewhat irregular, and until recently we were deprived of alcohol, but a few days ago the commissariat began to provide cognac, rum, and brandy, and so we are getting drunk. The fevers, thank God, have disappeared, but lice have begun to appear to an alarming degree, because we cannot change our clothes often, as we cannot wash dirty clothes. It is limited to this, it will pass. We hear that there is a shortage of supplies in Athens. I can imagine the financial hardship our family is going through. I hope that when I return, I will have some small savings to help us out [...]. The only thing is that my shoes are completely worn out and I am wearing my rain boots, which will also wear out, and I do not know if we will go to a city where I can buy new ones. Please give my regards to all our relatives and friends and tell them to write to me so that I may be comforted.
I kiss you sweetly, D. K. Daras."

(Note: Dimitrios Daras fought on the front lines as a reserve lieutenant in the 3rd Company of the 8th Reserve Battalion of the VI Division. He studied law and served as head of military justice during the Asia Minor Campaign.) Diaries and Letters from the Front, Balkan Wars 1912-1913, introduction - edited by Lydia Tricha, ELIA, Athens 19932, pp. 229-230.

Step 2
Visit https://geetha.mil.gr/wp-content/uploads/2019/10/2-SYNTHIKI-EIRHNHS-VOUKOURESTIOU.pdf and identify the most important points of the Bucharest Treaty. Write them down in a text and upload them to the platform.

Step 3
Open the software https://padlet.com/ in the section on the Balkan Wars and record the changes in the borders of the Balkan states. What were the results of the Balkan Wars (social, political, geographical)? Write down your answers.
Step 4
What historical information can we glean about the role played by Eleftherios Venizelos in the successes of the Balkan Wars? What feelings does this evoke in you? Write a text and post it on the platform. Organize a concept map based on the key concepts.

"Despite the decisive contribution of the armed forces [...] none of the aspects of Greece's success would have been guaranteed, let alone self-evident, without the steady political direction charted and the highly skilful diplomatic manoeuvring employed at every critical juncture by Eleftherios Venizelos. In order for the country to avoid the fatal step that could have led it from triumph to disaster ―as happened in the case of Bulgaria― Venizelos had to fight a series of battles [...] both with the leader of the

"military party" (and the militaristic anti-parliamentary spirit), who was none other than Constantine, the successor who was extremely popular with his soldiers [...], as well as with the nationalist opposition of various origins and shades, which rushed to side with the army chief.
G. Gianoulopoulos, "Foreign Policy," History of Greece in the 20th Century, Vivliorama, Athens 1990, vol. A2, pp. 121-122.

Conclusion

Empirical data reveal improved performance in assessment, enhancing the effectiveness of artificial intelligence in education. Teachers and students emphasize the potential of artificial intelligence to promote critical thinking, reconstructing historical debates and creating narratives based on the context. This study highlights the ability of artificial intelligence to: innovate in history education, bridge technological developments with pedagogical strategies. The integration of artificial intelligence into history education is a broad field to explore, raising questions about: its effectiveness, accessibility, and ethical implications. The application demonstrated that the adoption of digital tools in education allows students to interact with history in an active and practical way, enriching the learning experience and allows students to actively engage with historical content, transforming learning into an experiential and meaningful experience. Moreover, it enhances their cognitive engagement and broadens their ability to understand complex historical concepts and events. It provides opportunities for personalized learning and the development of critical thinking skills. The pace and method of teaching are adapted to the specific needs of each student. Furthermore, cultivates higher-order cognitive skills, such as critical thinking, source evaluation, and the development of informed historical interpretations. Students interacted with the material, explored history through interactive tools, and developed a deeper understanding of the past, thereby enhancing their ability to evaluate information and think critically. Students gain a deeper understanding of causal relationships and multiple perspectives on the past, which contributes significantly to strengthening their analytical thinking and developing historical literacy skills.
The findings suggest that the integration of interactive technologies into history education enhances the quality of teaching, enhances students' cognitive and emotional engagement, and contributes significantly to the creation of a student-centered and critical-reflective educational environment.

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Teacher Perspectives on Implementing Artificial Intelligence in Greek Primary and Secondary Schools

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - This study focuses on investigating the attitudes, perceptions, and readiness of Greek Primary and Secondary Education teachers in utilizing Artificial Intelligence (AI) in educational practice. A systematic literature review of recent Greek empirical research from the period 2023–2025 was conducted, examining the use, prospects, and challenges of AI in the Greek educational context. The comparative analysis of the research indicated that teachers generally exhibit a positive attitude towards AI applications, recognizing AI's potential to support teaching, enhance differentiated learning, and facilitate their work. However, a clear gap is demonstrated between the intention to use AI applications and actual implementation proficiency, a fact linked to the lack of systematic teacher training, pedagogical design, and institutional support. Concurrently, within the context of AI utilization in education, significant ethical and social concerns are highlighted, such as personal data protection, academic integrity, and the risk of excessive dependence on technology. Overall, the findings demonstrate that the effective and acceptable integration of Artificial Intelligence in education presupposes a human-centric approach, the strengthening of teachers' professional self-efficacy, and the development of clear pedagogical and institutional frameworks.

Keywords — Artificial Intelligence in Education, Teachers' Perspectives, Educational Innovation, Professional Development

Introduction

The rapid development of Artificial Intelligence in recent years has brought about substantial changes in many fields of human activity, with education being one of the areas dynamically affected. Contemporary AI applications, and particularly generative systems and large language models, are redefining the way the learning process is designed, implemented, and assessed, offering new possibilities for personalization, teaching support, and enhancement of the learning experience (Holmes, Bialik & Fadel, 2023; Luckin, Rudolph, Grünert & Tan, 2024).

The utilization of AI in education is primarily associated with adaptive learning, automated feedback, support for written production, and facilitation of teachers' work (UNESCO, 2023; OECD, 2024). At the same time, it is acknowledged that the pedagogical value of AI does not lie in the technology itself, but in the way it is integrated into a human-centric and pedagogically substantiated framework, which ensures the active participation of students and the preservation of the teacher's guiding role (Williamson, Eynon, Knox & Davies, 2023).

Particular emphasis in international literature is placed on the role of perceptions, attitudes, and teacher readiness as determining factors for the successful integration of AI into educational practice. Research shows that, although teachers recognize the usefulness of AI and have a positive attitude towards its use, they often feel inadequately prepared for its pedagogical exploitation, especially concerning its instructional, ethical, and social dimensions (Holmes & Tuomi, 2022; Perla, Agrati & Beri, 2025).

Simultaneously, the integration of AI in education is accompanied by significant concerns, which pertain to personal data protection, academic integrity, algorithmic transparency, and the risk of undermining students' critical thinking (Selwyn, 2024; UNESCO, 2023). These concerns highlight the need for clear institutional frameworks and targeted training programs, which will support teachers in the responsible and pedagogically sound utilization of AI.

Recent empirical studies in the Greek educational context confirm the international trends, recording teachers' positive attitude towards utilizing AI, but also a clear gap between the intention to use and practical application. The findings of the studies underline that the successful integration of Artificial Intelligence in education presupposes not only technological infrastructure, but primarily pedagogical design, systematic training, and enhancement of teachers' professional self-efficacy (Kalota, 2025; Karagiorgou, 2025; Poulimenou & Panitsidou, 2025).

Artificial Intelligence and the Teacher's Role

The integration of Artificial Intelligence into the educational process marks the transformation of the teacher's role, who is called upon to adapt their teaching to a technologically enriched learning environment. Contemporary literature converges on the view that AI reshapes their role from an exclusive transmitter of knowledge to a pedagogical guide, mediator, and designer of learning experiences (Holmes et al., 2023; Luckin et al., 2024).

Greek research confirms the international findings, demonstrating that teachers perceive AI primarily as a supportive tool that can enhance differentiated instruction, facilitate teaching preparation, and offer personalized feedback to students (Karagiorgou, 2025). Correspondingly, international studies emphasize that the effective utilization of AI presupposes the active involvement of the teacher in pedagogical decision-making and not the passive adoption of automated systems (Williamson et al., 2023).

Importance is attributed to the teacher's role as a guarantor of pedagogical quality and learning meaning-making. Within this context, teachers are called upon to guide students in the critical evaluation of content produced by AI systems, identify errors or biases, and cultivate metacognitive and critical literacy skills (Selwyn, 2024). Qualitative studies of secondary education philologists highlight that the teacher functions as a pedagogical mediator, ensuring the authenticity of student writing and maintaining the human-centric dimension of teaching, especially when using generative language models (Pavlidou, 2025; Sakka, 2025).

Concurrently, the teacher's role is decisively influenced by their level of self-efficacy and confidence towards AI. Research shows that the relevance of AI to the subject domain strengthens the intention for integration and its active pedagogical exploitation (Kalota, 2025; Perla et al., 2025). Internationally, the lack of training is associated with insecurity and limited use of AI tools, a fact confirming the importance of teachers' professional development (Holmes & Tuomi, 2022).

A particular dimension of the teacher's contemporary role is the ethical and social responsibility accompanying the use of AI in education. Teachers are called upon to function not only as users, but also as educators in digital and ethical literacy, ensuring the protection of personal data, academic integrity, and transparency in the use of algorithmic systems (UNESCO, 2023; Poulimenou & Panitsidou, 2025). International literature underlines that the ethical dimension of AI cannot be addressed in a fragmented manner but must be systematically integrated into pedagogical design (Floridi et al., 2023).

Overall, both Greek and international research converge on the fact that Artificial Intelligence redefines the teacher's role as an active pedagogical designer and critical mediator, who leverages the potential of technology without downgrading the human-centric nature of education. The effective exercise of this role presupposes continuous training, institutional support, and the development of a pedagogical framework that places AI in the service of education, not as an end (Luckin et al., 2024; Karagiorgou, 2025).

Methodology

This study adopts a qualitative research approach, based on a systematic literature review of recent Greek empirical research concerning the utilization of Artificial Intelligence (AI) in education. The aim of the review was to map the main research trends, methodological choices, and key findings highlighted in the Greek educational context.

The body of literature consisted of postgraduate theses and scientific articles published during the period 2023–2025, focusing on the perceptions, attitudes, readiness, and role of Greek teachers in relation to AI in primary and secondary education. The selection of studies was based on criteria of thematic relevance, clear description of methodology, and their contribution to investigating the pedagogical utilization of AI in the Greek educational context.

A comparative and synthetic analysis process was applied for the analysis of the research, with emphasis on the methodology adopted (quantitative, qualitative, or mixed), the sample size, as well as the key findings and conclusions. Through the cross-referencing of results, an attempt was made to highlight common findings, divergences, and research gaps, to form a comprehensive and documented picture of the current Greek reality regarding Artificial Intelligence in education.

The choice of literature review as a methodological strategy was deemed appropriate, as it allows for the synthesis of heterogeneous research data and contributes to understanding the field's evolution, while simultaneously providing an interpretive framework for identifying future research directions.

Findings of Greek Research

The study by Kalota (2024), with a sample of 200 teachers from all levels, aimed to investigate the readiness and behavioral intention of Greek primary and secondary education teachers to teach Artificial Intelligence (AI), as well as to identify the factors influencing their attitudes and perceptions towards this emerging subject domain.

The findings indicated that teachers generally exhibit a positive attitude towards Artificial Intelligence and recognize its usefulness in the educational context, while emphasizing that they lack the necessary training. However, the intention to utilize AI is not accompanied by correspondingly high levels of readiness, a fact that suggests a gap between positive attitude and practical application capability.

A particularly significant factor influencing both behavioral intention and teacher readiness was the relevance of Artificial Intelligence to their subject domain and teaching practice. When teachers perceive that AI can be meaningfully integrated into their subject and support the learning process, they show increased willingness and readiness to use it.

Furthermore, teachers' confidence in their knowledge and skills regarding Artificial Intelligence plays a decisive role in their choice to utilize it practically. Teachers with higher levels of self-confidence in using AI exhibit a stronger intention and greater readiness to integrate it into educational practice. Conversely, a lack of training and practical experience acts as an inhibiting factor regarding AI utilization in the classroom.

On the other hand, anxiety about using Artificial Intelligence did not appear to be a decisive deterrent, a fact that reveals that teachers, despite their reservations, do not reject teaching AI, but rather feel inadequately prepared.

Overall, the study's results demonstrate that the successful integration of Artificial Intelligence into primary and secondary education depends largely on enhancing teacher readiness. A positive attitude and behavioral intention are necessary but not sufficient conditions. Systematic and targeted training is required, which will strengthen teachers' confidence, highlight the relevance of AI to teaching practice, and equip them with the necessary knowledge and skills.

The study by Moschaki (2025) investigated the views and perceptions of primary and secondary education teachers regarding the use of Artificial Intelligence in the modern educational process. The research sample consisted of 140 teachers, who were asked to answer questions concerning their knowledge of AI, their willingness to use it, and the challenges arising from its integration into teaching.

The results of the study indicated that Greek teachers, regardless of gender, age, educational level, academic degree, or years of service, have a basic familiarity with modern digital applications and satisfactory knowledge of AI technologies, view the use of Artificial Intelligence in education positively, and recognize its potential to support the teaching process, enhance personalized learning, and contribute to improving educational effectiveness.

An interesting finding is that teachers' intention to use Artificial Intelligence tools in the future is evident, but it is accompanied by reservations, which relate mainly to ethical issues, such as personal data protection, the risk of excessive dependence on technological tools, and the potential degradation of the pedagogical dimension of teaching.

No differences were found between primary and secondary education teachers regarding perceptions, attitudes, and concerns about AI. That is, homogeneity is observed in teachers' perceptions, regardless of the level at which they serve, a fact that strengthens the view that Artificial Intelligence is treated as a common challenge and opportunity by the entire educational community.

Among the findings, it is highlighted that, despite their positive attitude towards Artificial Intelligence applications, teachers do not feel prepared to use them. The need for targeted training not only in technical skills but also in the pedagogical and ethical dimensions of AI emerges as a critical prerequisite for the optimal utilization of AI in education.

Overall, the research concludes that Artificial Intelligence can be a powerful supportive tool for the teacher and the learning process, provided it is integrated in a balanced, responsible, and pedagogically substantiated manner. The positive attitude of teachers is an encouraging factor; however, the successful integration of AI in schools requires systematic training, institutional support, and clear frameworks, to ensure that the advantages of the technology are harnessed for the benefit of all students and the educational process in general.

The study by Batziakas (2025) investigated the perceptions of primary education teachers regarding generative Artificial Intelligence as a tool for supporting teaching. The research sample included 134 future primary education teachers.

The results of the study demonstrate that teachers largely recognize AI as an innovative and useful tool for the teaching process. Specifically, generative AI is perceived as a means that can support personalized learning, enrich educational material, and enhance student creativity and participation. Participants seem to perceive that AI contributes to differentiated instruction and the adaptation of the learning process to the needs and individual characteristics of each student.

Despite this positive attitude, the findings simultaneously reveal the existence of significant reservations and concerns. Teachers express concerns primarily related to ethical and security issues, such as personal data protection, intellectual property, and algorithmic transparency. Furthermore, the fear is articulated that the extensive use of generative AI tools may lead to excessive dependence on technology, downgrading the pedagogical role of the teacher.

Emphasis is placed on the need for appropriate teacher training. The results show that, although participants recognize the potential of creative AI, they do not feel adequately prepared for its substantive and pedagogically sound utilization in the classroom. The lack of systematic training emerges as one of the main inhibiting factors for the integration of generative AI into the school environment.

Overall, the research concludes that generative AI can be a powerful tool for supporting teaching in primary education, provided it is integrated in a pedagogically correct, ethically responsible, and institutionally organized manner. The positive attitude of teachers is an encouraging finding; however, the effective utilization of generative AI presupposes systematic training, the development of appropriate pedagogical frameworks, and the assurance of the teacher's active presence and guiding contribution.

The study by Pavlidou (2025) focused on investigating the perceptions and attitudes of secondary education teachers, specifically teachers of the Greek language, regarding the integration of Artificial Intelligence (AI) into the teaching process. The study adopted a qualitative research approach and was based on semi-structured interviews with twelve teachers from different school environments, including both teachers with administrative duties and classroom teachers. The aim was an in-depth understanding of teachers' knowledge, perceptions, concerns, and proposals regarding the use of AI in education.

The data analysis revealed that participants exhibit a limited level of knowledge regarding Artificial Intelligence and its applications. Although several teachers have met modern digital tools and AI applications, their understanding of their capabilities remains at a basic level and is often limited to general references. The lack of systematic training and organized guidance is recognized as a key factor hindering the substantive utilization of AI in teaching practice, especially in the field of humanities.

Despite the limited level of knowledge, teachers generally express a positive attitude towards Artificial Intelligence and recognize its potential benefits, such as enhancing personalized learning, supporting teaching preparation, and facilitating decision-making in the school environment. However, alongside the positive perceptions, significant reservations also emerged, with emphasis on personal data protection, algorithmic transparency, and the human-machine relationship. Furthermore, concern

is recorded regarding the potential alteration of the character of teaching, the risk of weakening students' critical thinking, and excessive dependence on technological systems.

Participants place particular emphasis on the need for teacher training and development. Participants declare themselves willing to receive training in Artificial Intelligence, provided the training is targeted, practically oriented, and tailored to the needs of the subject domains.

Overall, the research concludes that teachers of the Greek language in secondary education maintain a realistically positive but cautious attitude towards Artificial Intelligence. AI is recognized as a tool with significant prospects for improving the educational process; however, its successful integration presupposes adequate knowledge, systematic training, institutional support, and clear ethical and pedagogical boundaries.

Poulimenou and Panitsidou (2025) investigated the readiness of teachers of all levels in Greece to integrate AI applications into the educational process. Concurrently, they examined factors influencing this readiness, as well as the key challenges and concerns raised using AI in education. The research adopted a quantitative methodological approach and was based on data collection from a sample of 508 teachers.

The results demonstrate that participants exhibit a high level of knowledge regarding Artificial Intelligence and that they understand its usefulness in education. Teachers believe that AI applications can enrich the learning experience, support differentiated instruction, facilitate the development of educational material, and enhance the educational process overall. On the other hand, teachers express skepticism regarding the adequacy of legal frameworks regulating the use of AI, as well as the assurance of privacy and personal data protection. Also, they articulate substantial concerns and fears related to personal data protection, excessive dependence on technology, and the potential negative impact on student skill development.

The research also showed that gender, level of education, and type of education differentiate participants' views. Male teachers appear more informed, while female teachers express higher levels of concern. Teachers with a higher level of education appear more informed and less anxious, while non-formal education educators perceive AI as more useful and less threatening compared to formal education teachers. Conversely, age and years of educational service did not appear to significantly influence readiness to utilize AI.

Overall, the research concludes that teachers in Greece exhibit a relatively high level of readiness to integrate Artificial Intelligence into their educational practice, as they possess sufficient awareness and a positive attitude towards its usefulness. At the same time, however, the existence of intense concerns and ethical dilemmas makes it clear that this readiness is not unconditional.

The study by Sakka (2025) investigated the utilization of Artificial Intelligence (AI) language models in written production within the framework of blended learning, focusing on the experiences, attitudes, and proposals of teachers teaching the Greek language in secondary education. The study followed a qualitative methodological

approach with focused semi-structured interviews and the sample consisted of 34 teachers teaching the Greek language.

The results of the research demonstrate that participants perceive the use of AI language models as a significant pedagogical challenge, but simultaneously as an opportunity for instructional and pedagogical transformation. The initial technological anxiety associated with the use of AI gradually shifts towards pedagogical and ethical concerns, which primarily concern the preservation of the authenticity of students' written expression, academic integrity, and the teacher's role in the learning process.

Participants place particular emphasis on the importance of guiding students in formulating appropriate prompts for language models. Teachers underline that the pedagogically correct use of AI does not lie in the indiscriminate production of text, but in the conscious and targeted interaction with the tool, which can function supportively in the process of designing, revising, and improving written discourse. Through this process, students enhance metacognitive skills and cultivate a critical stance towards the produced content.

Simultaneously, the findings highlight the need to redefine the role of the teacher teaching the Greek language. The teacher no longer functions exclusively as a knowledge transmitter or evaluator of the final product, but as a pedagogical mediator, guide, and coordinator of the learning process. This role includes shaping pedagogical frameworks for AI use, supporting the authentic voice of students, and ensuring that technology enhances – and does not replace – creative and critical thinking.

The pedagogical benefits from the use of AI language models, as recorded in the research, include enhancing written expression, vocabulary development, cultivating critical and creative thinking, as well as the possibility of personalizing the learning experience. Teachers recognize that, when AI is integrated into a clear pedagogical framework, it can function as a supportive learning tool and not as a threat to students' linguistic development.

However, substantial obstacles and implementation difficulties are also recorded, such as limitations in technological equipment and the absence of systematic training. Teachers emphasize that the effective integration of AI language models presupposes organized training, pedagogical design, and clear ethical and institutional boundaries.

Overall, the research concludes that the integration of AI language models into the teaching of written production within the framework of blended learning constitutes a multifaceted pedagogical challenge but also a significant opportunity for transformation. Their successful utilization does not depend on the technology per se, but on the way it is framed pedagogically, ethically, and institutionally. Under these preconditions, AI language models can contribute substantially to improving language education and shaping a modern student-centered school environment.

The study by Karagiorgou (2025) investigated the attitudes and views of Greek Primary and Secondary Education teachers regarding the utilization of Artificial Intelligence applications in educational practice, as well as the factors influencing their intention to integrate them into teaching. The study followed a quantitative research approach and

was based on data collection via a structured questionnaire from a sample of 494 teachers.

According to the findings, teachers exhibit a positive attitude towards Artificial Intelligence, recognizing its potential to support and enhance the teaching and learning process. The perceived usefulness of AI is recorded at high levels, a fact that indicates participants consider AI applications as tools that can contribute to learning personalization, improvement of teaching efficiency, and facilitation of educational practice.

Simultaneously, the perceived ease of use of AI applications is positive, but a portion of the teachers expresses reservations regarding the technical complexity of the tools and the adequacy of the skills they possess for their effective utilization. This finding underlines the importance of systematic training and the continuous professional development of teachers as basic prerequisites for the smooth integration of AI into educational practice.

Teachers also express ethical concerns and anxieties about the protection of students' personal data, the potential bias of algorithms, and the risk of excessive dependence on technology. These concerns do not lead to an overall rejection of AI, but function as factors that reinforce the need for clear institutional and pedagogical frameworks for use.

It was also revealed that certain demographic characteristics significantly influence teachers' attitudes and views. Gender, level of education, specialization, and engagement with Information and Communication Technologies (ICT) influence attitude towards AI. Teachers with a higher level of education and ICT knowledge exhibit a more positive attitude and a higher intention to use AI applications. Conversely, age and years of teaching experience do not influence teachers' attitudes, a fact that reveals that the acceptance of AI is not an issue of age but is more linked to digital familiarity and training. Furthermore, perceived usefulness and ease of use constitute the strongest predictors of teachers' intention to use AI.

Overall, the findings of the research conclude that Greek Primary and Secondary Education teachers maintain a positive but cautious attitude towards the utilization of Artificial Intelligence applications in educational practice. They recognize the pedagogical benefits and potential of AI, yet emphasize the need for adequate training, institutional support, and clear ethical boundaries.

Conclusion - Comparative Analysis of Research Findings

The comparative analysis of the studied research reveals a coherent and multi-dimensional framework for understanding the perceptions, attitudes, and readiness of Greek teachers for the utilization of AI in education.

A common finding in almost all studies is the positive attitude of teachers towards Artificial Intelligence. Whether it concerns primary and secondary education teachers (Batziakas, 2025; Kalota, 2024; Moschaki, 2025; Karagiorgou, 2025), teachers of Greek language (Pavlidou, 2025; Sakka, 2025), or educators from all levels and types of education (Poulimenou & Panitsidou, 2025), participants recognize the potential of

AI to support the learning process, enhance the personalization of learning, and facilitate the teacher's work.

On the other hand, positive attitude does not equate to high readiness for application. Kalota's research (2024) clearly highlights the gap between behavioral intention and actual readiness, a finding confirmed by the other studies as well. Teachers declare willingness to utilize AI, but simultaneously feel inadequately prepared in terms of knowledge, skills, and pedagogical design.

A central factor that differentiates teachers' attitudes and readiness is the perceived relevance of AI to the subject domain and teaching practice. In the studies by Kalota (2024) and Sakka (2025), this relevance emerges as a decisive predictive factor for intention and acceptance. Correspondingly, teachers of the Greek language in the studies by Pavlidou (2025) and Sakka (2025) appear more cautious, not due to technophobia, but because they question the pedagogical suitability of AI in fields where human interpretation, dialogue, and authentic writing are considered fundamental.

Another common finding concerns the decisive role of teachers' self-confidence and self-efficacy. As the studies by Kalota (2024) and Karagiorgou (2025) show, the perceived usefulness and ease of use of AI constitute strong predictors of intention to use. Correspondingly, in the qualitative studies (Pavlidou, 2025; Sakka, 2025), the lack of training and guidance is linked to insecurity and caution.

Of particular importance are the ethical and social concerns, which appear consistently across all studies. Issues such as personal data protection, algorithmic transparency, and the risk of excessive dependence on technology are recorded in both quantitative and qualitative studies.

Despite specific differentiations, all studies converge on the conclusion that teacher training constitutes a necessary and decisive prerequisite for the substantive integration of AI into education. Training is not understood exclusively as technical instruction, but as a multi-dimensional process encompassing pedagogical, ethical, and social dimensions.
In summary, the comparative analysis of the findings shows that Greek teachers are in a transitional phase of accepting Artificial Intelligence. AI is recognized as a tool with significant potential, but its successful utilization depends on its relevance to teaching practice, the enhancement of teacher readiness, as well as the existence of a clear pedagogical and institutional framework.

Research Limitations

Despite the contribution of the studies in mapping teacher attitudes, all research is subject to limitations. Firstly, an absence is observed of studies examining the long-term and systematic application of AI in educational practice. Most studies capture attitudes, intentions, and perceptions, without investigating the actual use of AI in the classroom and its pedagogical impact over time.

Furthermore, a limited focus is noted on the experiences and voices of students. Most of the research focuses exclusively on teachers, overlooking the role of students as

primary recipients and co-shapers of educational innovation. This fact deprives research of a holistic understanding of the dynamics of AI integration in schools.

Additionally, there is a lack of comparative studies between different subject domains, which could highlight with greater clarity the variations in the acceptance and utilization of AI depending on the scientific field.

Finally, most studies are limited to investigating attitudes and perceptions, without adequately examining the effectiveness of specific training interventions. There is a lack of empirical data regarding what type of training substantially enhances teacher readiness, self-efficacy, and pedagogical utilization of AI.

Suggestions for Future Research

Despite increasing research activity in this specific field, it is clear that further studies are required, which will deepen and broaden the understanding of the phenomenon. Primarily, it is deemed necessary to conduct longitudinal studies, which would examine the use of AI in educational practice over time, to record the transition from today's positive attitude and caution to systematic and pedagogically substantiated use.

Furthermore, the need emerges for studies focusing on actual teaching practice, and not only on teachers declared attitudes. Research in school units could reveal how specific AI applications are utilized in the classroom, what pedagogical strategies are developed, and what the learning outcomes are. Within the same framework of conducting research within schools, it is also recommended to develop comparative studies on the application of AI between different subject domains, as well as to record the students' perspective on the integration of AI into the school environment.

Finally, it is advisable for future research to also focus on evaluating the effectiveness of training interventions for the application of AI.

Overall, future research should move towards a holistic, interdisciplinary, and pedagogically oriented approach, which would transcend the study of attitudes and focus on the systematic application, learning impacts, and ethical and social dimensions of Artificial Intelligence in education.

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Big Data Time Series Analysis for Knowledge Mining and Prediction by Innovative Mathematical Models

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Abstract- The exponential growth of Big Data generated across digital ecosystems, including modern stock enterprises environments, necessitates advanced analytical and predictive methodologies capable of handling scale, uncertainty, and semantic complexity. Conventional deep learning approaches, typically operating on numerical vectors within Euclidean spaces, exhibit significant limitations with respect to explainability, semantic transparency, and knowledge interpretability (Aggarwal, 2015; Han et al., 2011; LeCun et al., 2015)—critical requirements in AI-driven education and decision support systems. This paper presents an innovative mathematical framework for Big Data time-series analysis aimed at knowledge mining and prediction. The proposed approach integrates Learning Analytics, granular computing, fuzzy lattice reasoning, and Type-1 Neural Networks (*T1NNs*) (Zadeh, 1996; Yager, 1997; Kaburlasos & Petridis, 2000; Kaburlasos et al., 2026), enabling neural computation directly on information granules rather than crisp numerical values. Time-series data are represented as Interval Numbers within a hierarchy of Hilbert spaces, allowing uncertainty-aware modeling and semantic reasoning. Real-world Big Data time-series are employed to validate the framework through experimental simulations, while an AI stock enterprise–oriented scenario demonstrates its applicability to learning analytics and predictive stock enterprise modeling. Experimental results indicate that the proposed granular deep learning paradigm enhances explainability (Babaei et al., 2025; Zadeh, 1996; Kaburlasos et al., 2026), preserves predictive performance, and offers a mathematically grounded alternative to conventional neural architectures. The study highlights the potential of innovative mathematical models to advance trustworthy, interpretable, and scalable AI systems for education and beyond.

Keywords—Big Data, Time Series Analysis, Knowledge Mining, Prediction, Innovative Mathematical Models, Granular Computing, Type-1 Neural Networks, Learning Analytics, Explainable AI.

I. Introduction

The rapid proliferation of Big Data across scientific, industrial, and socio-economic domains has elevated time-series analysis to a central position in contemporary data-driven modeling. Time series arise naturally whenever observations are collected sequentially over time, capturing temporal dependencies, trends, seasonality, and stochastic fluctuations. In modern Big Data environments, such series are characterized not only by large volume and high velocity but also by intrinsic uncertainty, heterogeneity, and semantic richness. These properties challenge conventional analytical and predictive methodologies that rely on processing vectors of real numbers in Euclidean spaces. (Aggarwal, 2015; Han et al., 2011)

Conventional statistical modeling and, more recently, deep learning approaches have demonstrated remarkable success by exploiting advances in computational power and data availability (LeCun et al., 2015). Neural computing models—often referred to as Type-0 Neural Networks (*T0NNs*)—operate in the Euclidean (*Hilbert*) space (R^N), where data are represented as numerical vectors and learning is typically achieved through gradient-based optimization. Despite their effectiveness, such models fundamentally process what may be described as flat data, i.e., arrays of numbers devoid of explicit semantic structure. When data are uncertain, aggregated, or inherently distributional—as is often the case in Big Data time-series—important information may be lost through premature numerical reduction. (LeCun et al., 2015)

The limitations of conventional approaches become particularly evident in knowledge mining tasks, where the objective extends beyond point prediction to the extraction of interpretable patterns, relations, and structures embedded in data. Knowledge mining presupposes that data representations preserve essential semantics, including uncertainty, partial order, and higher-order statistics (Aggarwal, 2015; Han et al., 2011). However, standard deep learning architectures typically handle uncertainty implicitly or post hoc, offering limited intrinsic explainability and restricted access to semantic content (Babaei et al., 2025).

In response to these challenges, alternative mathematical frameworks have been proposed that transcend the exclusive reliance on (R^N) (Birkhoff, 1967; Kaburlasos & Petridis, 2000). One such paradigm is Lattice Computing (*LC*), which provides a rigorous mathematical foundation for processing ordered data and computing with semantics. Within this paradigm, data elements are organized in mathematical lattices, where partial order relations can encode meaning, preference, inclusion, or uncertainty. LC enables the integration of numerical data with non-numerical percepts and supports reasoning mechanisms grounded in axiomatic logic. (Birkhoff, 1967)

A particularly significant development within LC is the use of Intervals' Numbers (*INs*) as fundamental data objects (Zadeh, 1996; Yager, 1997; Kaburlasos & Petridis, 2000). An IN may represent a real number, a fuzzy interval, or a probability distribution, thereby unifying multiple forms of uncertainty under a single mathematical construct. The set F_1 of Type-1 INs forms a complete lattice endowed with algebraic operations, metric distances, and order measures. Crucially, an IN can represent all-order statistics of data samples, making it especially suitable for Big Data time-series analysis, where summarization without loss of essential information is of paramount importance (Kaburlasos & Petridis, 2000).

Recent theoretical advances have further extended the LC paradigm by introducing a hierarchy of Hilbert spaces stemming from the real numbers (*R*) and culminating in the space of Generalized Intervals' Numbers (*GINs*). Within this hierarchy, the space F_1 of INs is embedded as a convex cone inside a Hilbert space G_1 (Kaburlasos et al., 2026). This construction preserves the analytical advantages of Hilbert spaces—such as inner products, norms, and similarity measures—while simultaneously enabling computation on information granules rather than scalar values. As a result, neural computing can be rigorously extended from processing vectors of numbers to processing vectors of distributions (Kaburlasos et al., 2026).

Building upon this mathematical foundation, Type-1 Neural Networks (*T1NNs*) emerge as an innovative class of neural architectures designed to operate in F_1 and related spaces (Kaburlasos & Petridis, 2000; Kaburlasos et al., 2026). Unlike T0NNs, which rely on numerical weights and activation functions, T1NNs process INs through monotone real functions, preserving order and semantic content throughout computation. This shift enables deep learning models to engage directly with uncertainty and distributional information, thereby enhancing knowledge mining capabilities and intrinsic explainability.

The motivation of this work is to investigate how such innovative mathematical models can be employed for Big Data time-series analysis, with a particular focus on knowledge mining and prediction. Real-world financial time-series datasets, including IBM and major technology stocks, are employed as representative Big Data streams. These datasets exhibit properties common to many large-scale temporal data sources, such as non-stationarity, noise, and complex temporal dependencies, making them suitable testbeds for the proposed framework (Bazinas et al., 2023; Vlachos et al., 2002).
The contributions of this paper are threefold. First, it presents a mathematically grounded framework for representing Big Data time series as information granules within a hierarchy of Hilbert spaces. Second, it demonstrates how T1NN-based models can be employed for knowledge mining and prediction by operating directly on distributions rather than scalar observations. Third, it provides experimental evidence, using real-world datasets, that the proposed approach constitutes a viable and conceptually richer alternative to conventional numerical deep learning models.
The remainder of this paper is organized as follows. Section II reviews related work on time-series analysis, Big Data modeling, and granular computing. Section III introduces the mathematical background, including lattices, valuation functions, order measures, and the hierarchy of Hilbert spaces.

II. Mathematical Background

This section presents the mathematical foundations underpinning the proposed framework for Big Data time-series analysis and knowledge mining. The exposition closely follows the lattice-computing paradigm and the hierarchy of Hilbert spaces introduced in recent works on granular semantics–enhanced deep learning. The objective is to establish a rigorous mathematical setting that enables neural computation on information granules, rather than on scalar numerical values.

A. Lattices, Valuations, and Metric Distances

A lattice is a partially ordered set ($L, \sqsubseteq$) such that any two elements x, y ∈ L admit both a greatest lower bound (*infimum*), denoted by x ⊓ y, and a least upper bound (*supremum*), denoted by x ⊔ y (Birkhoff, 1967). A lattice ($L, \sqsubseteq$) is called complete if every subset X ⊆ L has both an infimum and a supremum in L. The minimum and maximum elements of a complete lattice are denoted by o and i, respectively.

A key mathematical instrument in lattice computing is a positive valuation function v : L → R, which satisfies the properties $v(x) + v(y) = v(x \sqcap y) + v(x \sqcup y)$ and $x \sqsubset y \Rightarrow v(x) < v(y)$ (Birkhoff, 1967; Kaburlasos & Petridis, 2000). Given a positive valuation v, a metric distance $d : L \times L \rightarrow R^{+}_{0}$ can be defined as $d(x, y) = v(x \sqcup y) - v(x \sqcap y)$. This metric provides a quantitative notion of dissimilarity that is intrinsically consistent with the partial order of the lattice.

B. Order Measures and Fuzzy Lattice Reasoning

An order measure function $\sigma : L \times L \rightarrow [0, 1]$ is defined by the axioms: (1) $u \sqsubseteq w \Leftrightarrow \sigma(u, w) = 1$ and (2) $u \sqsubseteq w \Leftrightarrow \sigma(x, u) \leq \sigma(x, w)$, for all x ∈ L. Any systematic use of an order measure function $\sigma(\cdot, \cdot)$ is referred to as Fuzzy Lattice Reasoning (*FLR*) (Zadeh, 1996; Yager, 1997; Kaburlasos & Petridis, 2000). FLR enables axiomatic forms of reasoning, including inductive reasoning, deductive reasoning, reasoning by analogy, and abductive reasoning (Yager, 1997).

Two widely used order measures are defined via a positive valuation *v* as $\sigma_{\sqcap}(x, u) = v(x \sqcap u) / v(x)$ and $\sigma_{\sqcup}(x, u) = v(u) / v(x \sqcup u)$. These measures generalize classical Bayesian reasoning and have deep connections to Adaptive Resonance Theory.

C. Intervals and Intervals' Numbers

Let $\bar{R} = R \cup \{-\infty, +\infty\}$ be the extended real line. A Type-1 interval is defined as $[a, b] = \{x \in \bar{R} : a \leq x \leq b\}$. The collection I_1 of all Type-1 intervals, augmented by the empty interval ∅, forms a complete lattice ($I_1, \subseteq$). An Intervals' Number (*IN*) is defined as a function $F : [0, 1] \rightarrow I_1$ satisfying monotonicity and consistency conditions. The set F_1 of all Type-1 INs forms a complete lattice ($F_1, \preccurlyeq$). (Zadeh, 1996; Kaburlasos & Petridis, 2000)

D. A Hierarchy of Hilbert Spaces and Similarity Measures

A hierarchy of Hilbert spaces is constructed, stemming from the real numbers R and culminating in the space G_1 of Generalized Intervals' Numbers (*GINs*) (Kaburlasos et al., 2026). The space G_1 is endowed with an inner product that enables the definition of norms and similarity measures (Kaburlasos et al., 2026). The space F_1 of INs is embedded in G_1 as a convex cone. A cosine similarity measure is defined to quantify similarity between vectors of Ins.

Section I. Mathematical Formulas

$$\varrho([\alpha_1, b_1], [\alpha_2, b_2]) = \frac{a_1 a_2 + b_1 b_2}{\sqrt{(a_1^2 + b_1^2)}\sqrt{(a_2^2 + b_2^2)}} \quad (1)$$

$$\sigma_{\sqcap}([\alpha_1, b_1], [\alpha_2, b_2]) = \begin{cases} 1, & if\ [a_1, b_1] = \emptyset \\ 0, & \alpha_1 \vee \alpha_2 > b_1 \wedge b_2 \\ \dfrac{v\big(\theta(\alpha_1 \vee \alpha_2)\big) + v(b_1 \wedge b_2)}{v\big(\theta(\alpha_1)\big) + v(b_1)}, & otherwise \end{cases} \quad (2)$$

$$\sigma_{\sqcup}([\alpha_1, b_1], [\alpha_2, b_2])=\begin{cases} 1, & if\,[a_1, b_1]=\emptyset=[a_2, b_2] \\ \dfrac{v(\theta(a_2))+v(b_2)}{v(\theta(\alpha_1 \wedge a_2))+v(b_1 \vee b_2)}, & otherwise \end{cases} \quad (3)$$

$$d_1([a_1, b_1], [a_2, b_2])=\left[v(\theta(a_1 \wedge a_2))\text{-}v(\theta(a_1 \vee a_2))\right]+[v(b_1 \vee b_2)\text{-}v(b_1 \wedge b_2)] \quad (4)$$

$$\rho(E, F)= \int_0^1 \varrho_1(E_h, F_h; v, \theta)dh \quad (5)$$

$$D_1(E, F)= \int_0^1 d_1(E_h, F_h; v, \theta)dh \quad (6)$$

$$\sigma_{\curlywedge}(E, F)= \int_0^1 \sigma_{\sqcap}(E_h, F_h; v, \theta)dh \quad (7)$$

$$\sigma_{\curlyvee}(E, F)= \int_0^1 \sigma_{\sqcup}(E_h, F_h; v, \theta)dh \quad (8)$$

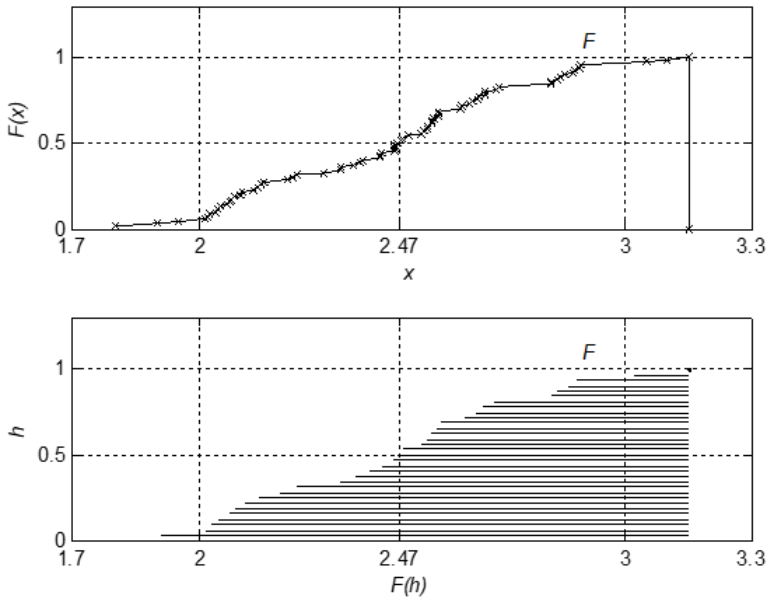


Image I. A hierarchy of Hilbert spaces, 'The figure depicts the embedding of the lattice F_1 of Intervals' Numbers into the Hilbert space G_1, extending the Euclidean space R to enable granular neural computation on distributions with well-defined inner products, norms, and similarity measures.'

III. Neural and Computational Framework

This section introduces the proposed neural and computational framework for Big Data time-series analysis, grounded in lattice computing and the hierarchy of Hilbert spaces.

A. Conventional Neural Computing in R^N

Conventional deep learning models, hereafter referred to as Type-0 Neural Networks (*T0NNs*), operate in the Euclidean space R^N. Data samples are represented as vectors of real numbers, neural links are associated with scalar weights, and learning is typically achieved through gradient-based optimization. (LeCun et al., 2015)

B. Granular Neural Computing and Type-1 Neural Networks

Type-1 Neural Networks (*T1NNs*) operate in the lattice (F_I, $\preccurlyeq$) of Intervals' Numbers (Kaburlasos & Petridis, 2000; Kaburlasos et al., 2026). Each input is an IN representing a distribution or information granule. Neural links are parameterized by monotone real functions rather than scalar weights, preserving order and semantic consistency.

C. Similarity-Based Processing and Learning

Similarity between IN vectors is quantified using a cosine similarity measure defined in the Hilbert space G_I (Vlachos et al., 2002; Kaburlasos et al., 2026). Learning can be guided by similarity maximization and order-preserving constraints, rather than relying exclusively on gradient descent.

D. Computational Architecture

Raw Big Data time-series are segmented, transformed into IN representations, and processed by a T1NN. Figure placeholders are introduced for the processing pipeline, Hilbert space hierarchy, and comparison between T0NN and T1NN architectures.

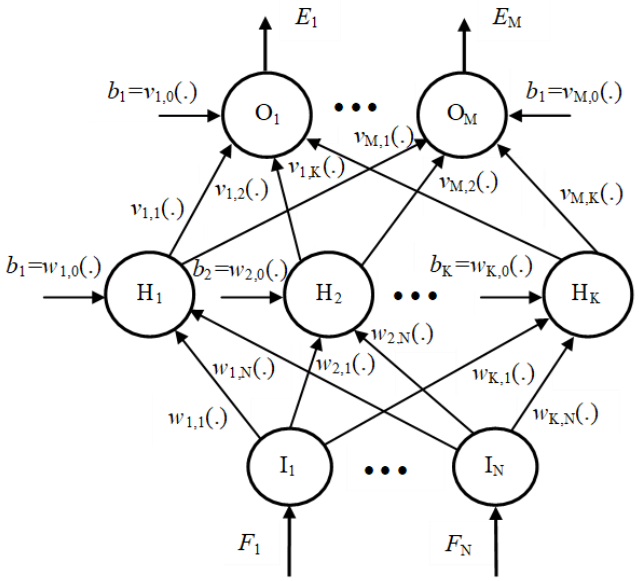


Image I. Type-1 Neural Network (T1NN), 'The figure illustrates a neural architecture that operates on Intervals' Numbers in the lattice F_1, where neural connections are defined by monotone real functions, enabling learning and similarity-based processing directly on distributions while preserving semantic order and uncertainty.'

IV. Experimental Design and Results

This section presents the experimental design, datasets, evaluation metrics, and results employed to validate the proposed granular framework for Big Data time-series analysis. Emphasis is placed on real-world datasets and knowledge mining capabilities rather than purely numerical forecasting accuracy.

A. Datasets and Big Data Characteristics

Real-world financial time-series datasets were employed as representative Big Data streams. The primary dataset consists of historical daily stock prices of IBM, complemented by a set of major technology stocks (*hereafter referred to as Big Tech*). These datasets exhibit key Big Data characteristics, including large temporal span, high variability, noise, and non-stationarity. (Bazinas et al., 2023; Vlachos et al., 2002)

Each dataset includes standard financial attributes such as Open, High, Low, Close prices and trading volume. Although originating from the financial domain, these datasets serve as generic exemplars of large-scale temporal data, sharing structural properties with time-series encountered in diverse application domains.

Table I summarizes the main characteristics of the datasets employed.

Table I. Summary of Time-Series Datasets

Dataset	Time Span	Sampling	Attributes
IBM	Multiple Years	Daily	Open, High, Low, Close, Volume
Big Tech	Multiple Years	Daily	Open, High, Low, Close, Volume

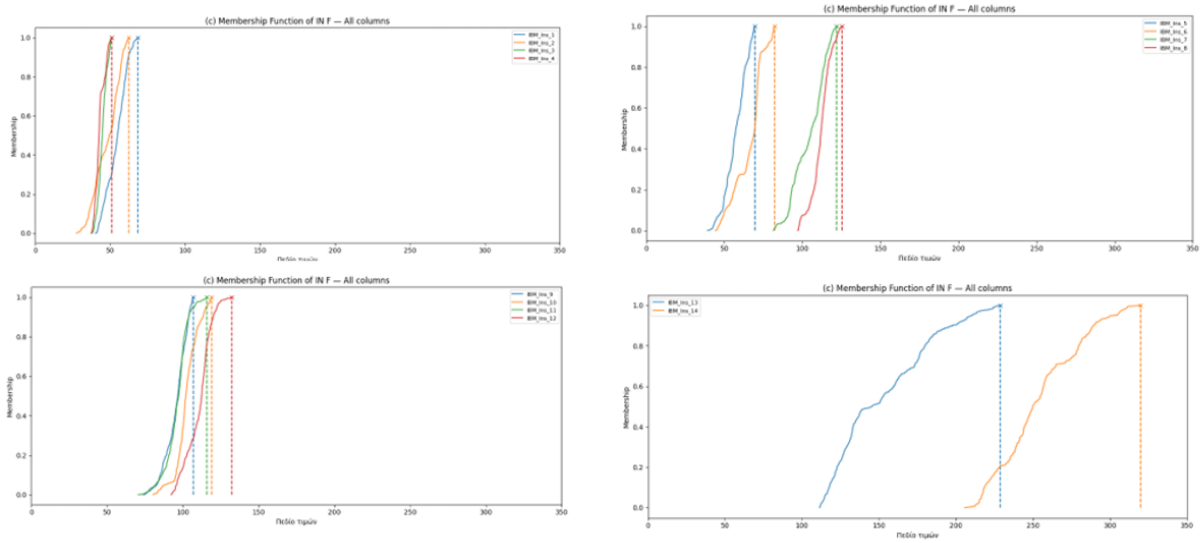


Image I. IBM, 'The figure represents the IBM historical time-series dataset used as a real-world Big Data exemplar, illustrating temporal dynamics that are analyzed through granular representations and similarity-based measures to support knowledge mining and prediction within the proposed mathematical framework.'

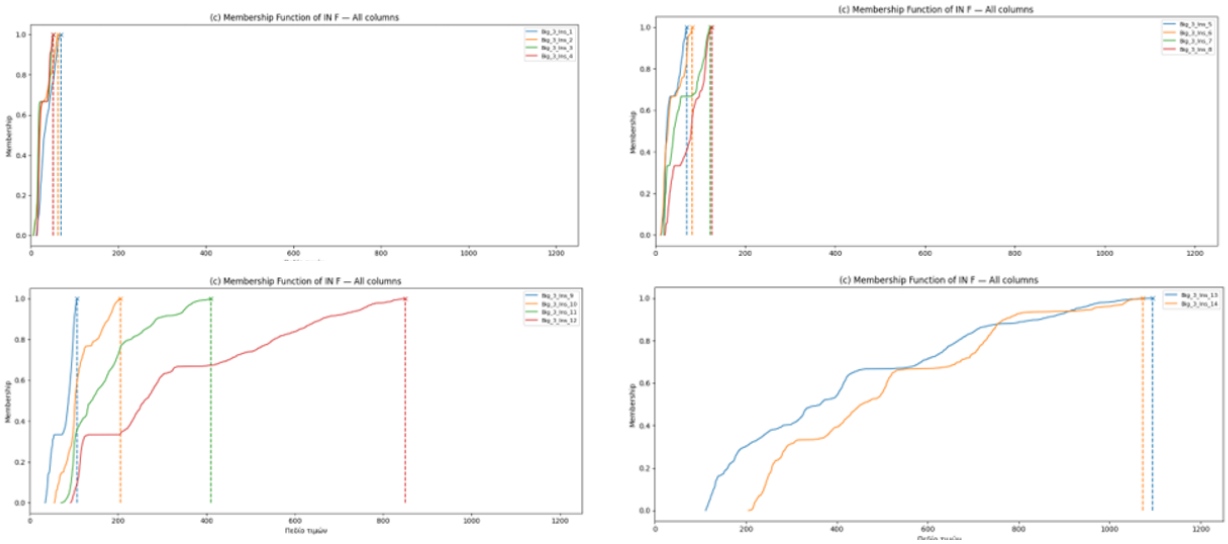


Image II. Big 3 Stocks, 'The figure depicts time-series data from three major technology stocks used as representative Big Data streams, enabling comparative granular analysis and similarity-based knowledge mining of distributional behavior within the proposed Hilbert-space.'

B. Time-Series Segmentation and IN Construction

The raw numerical time-series were segmented into fixed-length temporal windows. Each window was mapped to an Intervals' Number by inducing a distribution from the samples contained in the window. This process preserves statistical information while reducing data dimensionality.

Formally, given a window $W = \{x_1, x_2, \ldots, x_n\}$, an IN $F \in F_1$ was constructed such that $F(h)$ corresponds to the h-level interval containing the appropriate quantile of the data distribution. This representation captures all-order statistics of the window without resorting to scalar summarization. (Wang et al., 2020; Kaburlasos & Petridis, 2000)

C. Evaluation Metrics

Evaluation focused on metrics consistent with granular semantics. Similarity (Vlachos et al., 2002; Kaburlasos et al., 2026) between INs was quantified using the cosine similarity ρ defined in G_1. In addition, inclusion measures $\sigma\sqcap$ and $\sigma\sqcup$ were employed to assess partial order relations between distributions (Yager, 1997; Kaburlasos & Petridis, 2000).

Table II. Granular Evaluation Metrics

Metric	Description
$\rho(F, G)$	Cosine similarity between INs
$\sigma_\wedge(F, G)$	Inclusion via meet operation between INs
$\sigma_\vee(F, G)$	Inclusion via join operation between INs
$D_1(F, G)$	Distance between INs

D. Experimental Results

The experimental results demonstrate that the proposed granular framework captures meaningful similarities and differences among time-series segments. High similarity

scores correspond to windows with comparable distributional behavior, while lower scores indicate structural changes or regime shifts.

Table III. Representative Similarity Results

Window Pair	$\rho(F, G)$
IBM (t_1,t_2)	High
IBM (t_1,t_3)	Moderate
IBM (t_1,t_4)	Low

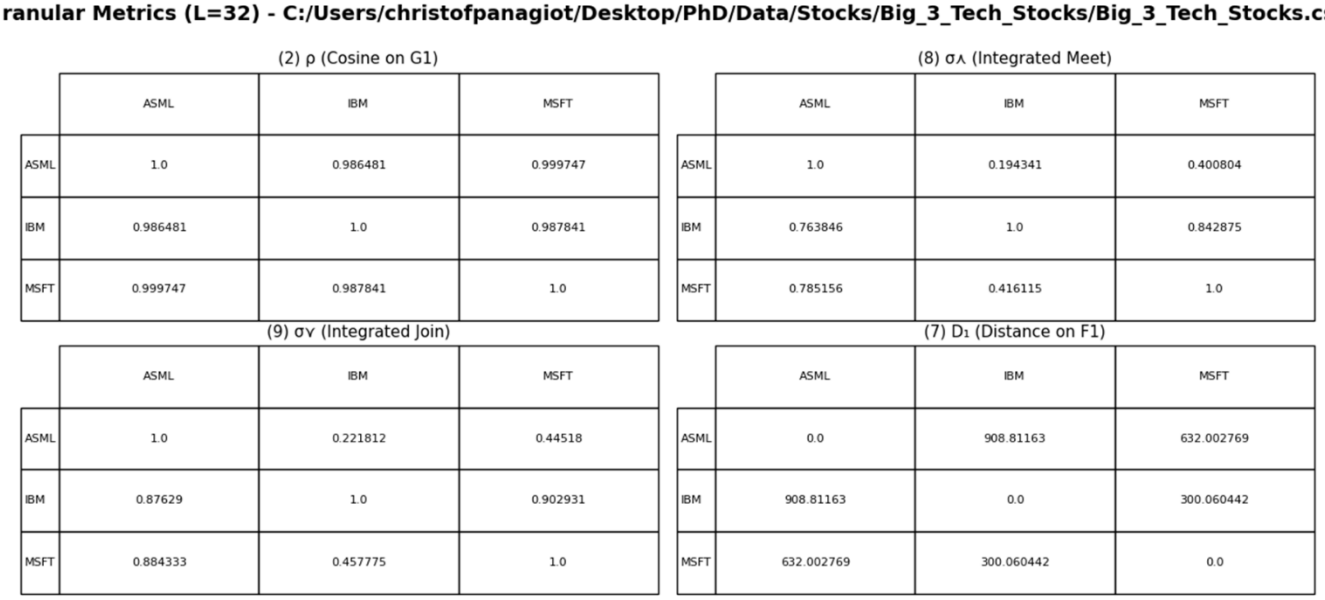


Image III. Representative Similarity Results of ρ, $\sigma_{\sqcap}$, $\sigma_{\sqcup}$, D_1 *,'The figure summarizes the outcomes of similarity and distance measures computed between Intervals' Number representations of time-series segments, illustrating how cosine similarity, order-based inclusion measures, and Hilbert-space distance jointly capture distributional resemblance, partial order relations, and structural differences in Big Data time-series.'*

The results indicate that knowledge mining based on IN representations enables detection of temporal patterns that may be obscured under conventional numerical representations. (Wang et al., 2020; Vlachos et al., 2002)

E. Discussion

Compared to conventional numerical approaches, the proposed granular framework offers enhanced interpretability by operating directly on distributions (Babaei et al., 2025; Zadeh, 1996; Kaburlasos et al., 2026). Rather than predicting a single future value, the model predicts and analyzes distributional behavior, providing richer information for decision-making and pattern discovery.

V. Conclusions and Future Research Directions

This paper investigated Big Data time-series analysis for knowledge mining and prediction through innovative mathematical models grounded in lattice computing and a hierarchy of Hilbert spaces. Departing from conventional numerical deep learning paradigms operating in R^N, the proposed framework represents temporal data as

information granules in the lattice (F_I, $\preccurlyeq$) of Intervals' Numbers and embeds them within the Hilbert space G_1. This shift enables neural computation on distributions rather than on scalar values, preserving semantic content, uncertainty, and all-order statistics inherent in large-scale temporal data (Kaburlasos & Petridis, 2000; Kaburlasos et al., 2026).

A granular neural computing architecture based on Type-1 Neural Networks (*T1NNs*) was presented and contrasted with conventional Type-0 Neural Networks (*T0NNs*). By parameterizing neural links as monotone real functions and employing similarity measures defined in G_1, the proposed approach supports knowledge mining tasks—such as similarity assessment, pattern discovery, and regime identification—beyond point-wise prediction. Experimental studies on real-world IBM and Big Tech time-series datasets demonstrated that the granular framework captures meaningful distributional behavior and temporal structure that may be obscured under purely numerical representations.

From a theoretical standpoint, the paper established a rigorous mathematical foundation for granular deep learning by integrating lattice theory, positive valuation functions, order measures, and Hilbert space embeddings. This foundation ensures semantic consistency, enables explainable reasoning through fuzzy lattice reasoning (*FLR*), and offers a principled path to extend deep learning models without sacrificing analytical tractability. From a computational perspective, the framework suggests the potential to reduce model complexity—by engaging fewer but more expressive components—while retaining or enhancing representational power.

Future research directions are multifold. First, the proposed framework can be extended to multivariate and high-frequency time-series, as well as to stochastic time-series modeled explicitly as sequences of distributions. Second, alternative learning strategies that exploit similarity maximization, order preservation, and lattice-theoretic constraints warrant systematic investigation and comparison with gradient-based optimization. Third, the integration of T1NNs with existing deep learning architectures, such as convolutional or transformer-based models, constitutes a promising avenue toward hybrid granular–numerical systems. Finally, large-scale empirical validation across diverse Big Data domains will further elucidate the scalability, efficiency, and generality of the proposed innovative mathematical models (Wang et al., 2020; LeCun et al., 2015).

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Ethical Issues Arising from the Use of Artificial Intelligence

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Abstract - Artificial intelligence (AI) is currently one of the most dynamic and rapidly developing fields of science and technology, with applications affecting almost every aspect of human life and work. The penetration of AI into areas such as healthcare, education, industry and public administration has created new possibilities, but at the same time it raises serious ethical and social issues that require careful analysis and constant vigilance (Ghosh, 2025).

The speed at which Artificial Intelligence is evolving raises concerns about privacy, security, algorithmic impartiality and social justice. In particular, the use of Artificial Intelligence in the workplace brings to the fore the fear of unemployment and the replacement of human resources by machines, as has happened in previous technological revolutions (Pasupuleti, 2024). At the same time, the conflict between scientific and technological progress and ethics is not a new phenomenon. Historically, similar confrontations have arisen at critical moments, such as in the case of cloning and euthanasia, where rapid scientific progress has led to the need to adapt ethics and society in order to set limits (Rafaiee et al., 2024).

This article focuses on the analysis of the key ethical issues arising from the use of Artificial Intelligence, with the aim of highlighting the challenges and needs for a clear and workable ethical and legal framework. Protecting human dignity, ensuring privacy, addressing bias in algorithms, accountability and responsibility for decisions made by automated systems, and social cohesion are central issues that need to be addressed. Only through continuous information, dialogue, and institutional interventions can technological progress serve people and promote social well-being (Voigt & Von dem Bussche, 2017; Kuner et al., 2021; Novelli et al., 2024).

Keywords—artificial intelligence, ethics, copyright issues

Introduction

The methodological approach of this article is based on a systematic review of the existing literature, as well as a thorough analysis of contemporary scientific sources, research studies and legal texts related to the ethical issues raised by artificial intelligence (AI). By collecting and synthesizing data from a multitude of academic publications, articles and official reports, the article attempts to shed light on the main challenges arising from the use of AI, such as the protection of privacy, the existence of algorithmic biases and the need for accountability, as well as the broader social implications of this technological development. This specific approach allows for an extensive and interdisciplinary investigation of the interactions between the technological, ethical and social dimensions, while providing a solid basis for the development of proposals regarding appropriate political and institutional measures.
In the remainder of the article, we first proceed to a multidimensional analysis of the ethical and social issues associated with Artificial Intelligence, such as unemployment and the replacement of human labor by automated systems, the protection of personal data and ensuring privacy, among others. We then present the findings of this analysis and conclude with the final conclusions.

A multidimensional approach to the ethical and social issues of Artificial Intelligence

Unemployment and replacement of human labor by Artificial Intelligence

Artificial intelligence is one of the most important technological trends of our time. Artificial intelligence technologies are a broad category of computer techniques that allow machines to perform tasks that usually require the assistance of human intelligence (Dwivedi et al., 2023).

The development of this technology raises various questions, the most crucial of which is whether artificial intelligence can replace human labor or whether its usefulness can be limited to its use as a tool, which will make it more efficient. Some consider artificial intelligence to be an assistant that contributes to the optimization and acceleration of work processes. Others see it as a competitor and potential replacement in the performance of their tasks.

This dynamic development and the increasing influence of artificial intelligence on the labor market make it necessary to analyze the aspects of this technology and its economic, social and ethical consequences. While some studies point to some positive effects of Artificial Intelligence, such as increased productivity, reduced operating costs or improved decision-making processes, others warn of possible negative consequences, including unemployment. Artificial intelligence, therefore, interferes with professional roles and the future of interpersonal cooperation in the workplace (PETROVÁ, 2025).

It is noteworthy that the labor market has been the subject of significant debate, precisely because the application and rapid development of artificial intelligence in various areas of daily life tends to become the norm in modern times. Consequently, the potential negative consequences of this application on human employment are of

considerable concern and raise questions among academics, employers and employees (Nigar et al., 2025).

In recent decades, social sciences have turned their attention to artificial intelligence, given the controversial impact of this type of technology on unemployment. According to Pentland et al. (2019 p.2) "future strategic advantage depends on the ability to exploit artificial intelligence in areas such as machine learning, computer vision and autonomous systems, but also on the prospect of integrating it into the workforce to create symbiotic human-machine teams" (Mutascu, 2021).

The roots of this concept can be traced back to the First World War period, when it was first mentioned in 1956 at a conference at Dartmouth College, during the session on artificial intelligence. As Nilsson (1984) notes, the process creates a "different class of machines – machines that can perform tasks requiring reasoning, judgment, and perception that previously could only be done by humans."

In modern times, artificial intelligence has led to the peak of automation processes, an element that deeply affects the labor market. According to Stevenson (2019), the use of artificial intelligence enhances economic growth by improving productivity and consequently future income, while he argues that this makes the positive side of this action apparent since the benefits generated by artificial intelligence can compensate for workers who have lost their salary (Mutascu, 2021).

Moreover, labor demand is necessarily adapted to the use of artificial intelligence by taking actions that affect it initially in the short term and then in the long term. As for the short-term effect, this consists, on the one hand, of the fall in labor demand in a multitude of jobs and, on the other hand, of the loss of professional positions. The long-term effect concerns the technological change which is expected to lead to the enhancement of human skills through the creation of new jobs. Essentially, artificial intelligence is responsible for the adoption of new ways of utilizing human skills. Therefore, the main concern regarding artificial intelligence concerns its effect on the level of unemployment (Mutascu, 2021).

In particular, artificial intelligence is said to lead to the displacement of ordinary jobs but at the same time creates new directions that require high specialization and which in turn generate the need for the implementation of urgent policies and the promotion of retraining.

In the modern world, human daily life is dominated by automation, which replaces unskilled labor in departments such as factories, stores and customer service centers. At the same time, artificial intelligence is responsible for fueling the demand for specialists in areas such as data science, cybersecurity and AI ethics.

More specifically, the rapid evolution of technology is changing the global labor market, as Artificial Intelligence is replacing industry sectors such as manufacturing, healthcare, retail and customer service, which has led to changes in job roles, skill needs and the way the labor market operates. As mentioned, automation, machine learning and robotics may replace some routine and low-skilled jobs, but they are also creating new highly skilled jobs that require advanced technical skills. This means disrupting traditional jobs and driving innovation, and for this reason it is important to understand

its implications across sectors of society and the economy. A multitude of studies have demonstrated that automation driven by Artificial Intelligence has already proceeded to replace humans in jobs that require repetitive tasks such as manufacturing and customer service with robots and chatbots taking on more roles (Kanagarla, 2024).

These changes may have positive effects on efficiency and productivity but raise concerns about unemployment and gaps in the labor market and incomes. This widening gap results in polarization in employment, as there is an increase in high-wage and highly skilled roles and a decrease in low-wage jobs (Jia,et al, 2024).

This situation has resulted in the widening of occupational inequality, especially in regions and sectors that are not easy to retrain. While those involved increasingly realize the need for retraining and skills upgrading programs, almost all of these initiatives face obstacles related to accessibility, scalability and affordability, especially in emerging economies (HK, 2026).

The fact remains that AI, in addition to its practical implications, has a significant impact on the quality of work. As on the one hand, there is automation of routine tasks and on the other hand, functions that require high-level processes, such as problem solving, decision-making and human-AI collaboration. This type of change demonstrates the importance of the need for lifelong learning, digital literacy and continuous adaptation of the workforce (HK, 2026).

Intellectual Property Protection in the Age of Artificial Intelligence

The rapid development of Artificial Intelligence leads, among other things, to the production of creative works by non-human creators. The emergence of these works raises a number of questions related to the application of existing copyright principles and infringement laws. The ability of Artificial Intelligence to produce works such as texts, images, graphics, voices and others, drawing from existing works available on the Internet raises the question of whether the works created by it should be protected by copyright (Al Busaidi et al., 2024).

As is well known, copyright is a kind of shield for creative works, allowing the creator to have control over how their work is used. This legal framework associated with intellectual property law grants the owner exclusive rights. More specifically, it is up to the creator to decide whether their work – a song, a painting, a book – can be shared or used by others. Simply put, copyright defines the way ideas and information can be expressed in tangible form, such as written down, recorded as music, or captured as an image.

Today, copyright legislation, which in its traditional form has as its main task the protection of the fruits of human creativity, is faced with a new challenge in the era of artificial intelligence (AI). AI is no longer used only in everyday tasks but is able to proceed to the production of creative products of music, art, literature and others. This perspective raises an essential question: How is it possible to adapt copyright principles to this innovation (Abbott & Rothman, 2023)?

Many discussions and negotiations have taken place around this issue, but so far no definitive decision has been made. All the traditional concepts of authorship, ownership

and liability require adaptation. Although AI is a useful tool in the management of intellectual property assets, contributing to licensing, enforcement, search and analysis, its use raises issues such as ownership, data protection, copyright infringement and patenting. In this context, ownership is a complex element, as copyright law gives authors exclusive rights to their creations and promotes artistic expression, which will affect AI (Milczarek, 2024).

The prevalence of AI, which leads to challenges regarding the protection of intellectual property rights, has necessitated the intervention of the legislator. He must take into account, on the one hand, that drastic regulation may impose restrictions on its development and have a negative impact on the competitiveness of the economy. On the other hand, the potential lack of respect for fundamental rights. Since the purpose of copyright regulations is precisely to protect and promote art and creativity, any regulation by the legislator regarding AI must also foresee the impact on "human" creators. The long-term goal of this situation is to remind that any action towards the development of AI should take into account that humans are at the center and therefore its applications must comply not only with the law but also with ethical principles and ensure that their applications do not cause unintentional harm (Milczarek, 2024).

Personal Data Protection and Privacy in the Age of Artificial Intelligence

Privacy as a concept has a wide range of implications and finds application in various fields of science from philosophy to computer science, politics and law (Rosadi, 2018). In the modern era, citizens continue to express their appreciation for privacy and integrity, but at the same time they seek to participate in a society that is becoming increasingly transparent and where they do not hesitate to share their personal information with people they (almost) know or give access to their personal data to any commercial company or social network that seems to offer advantages for their personal lives.

This situation raises a series of questions about Artificial Intelligence and robotic technology and how they will move when used by governments, industries and private households. Will personal robots have knowledge of all people's personal and family details? How valuable will human rights articles and conventions be in protecting human privacy? What about data protection rules? Is the General Data Protection Regulation an appropriate model and will it work well against AI (Genderen, 2017)?

In an attempt to provide answers, researchers have come to some interesting conclusions according to which Artificial Intelligence and autonomous robots will be part of our future society. It is also envisaged that Artificial Intelligence will be integrated with the human body, which will lead to a violation of the physical and informational integrity of the individual, regardless of his knowledge or consent. The disclosure of a large part of personal data to third parties already does not worry users. In addition, government agencies and the industrial sector are imposing the provision of an increased volume of personal data in order to regulate and ensure the functioning of the social system, as well as to limit the risks and costs associated with the provision of services and products. The General Data Protection Regulation cannot rise to the occasion, as it uses outdated terminology and traditional cognitive models and mental frameworks that are not sufficient for the protection of personal data in the era of Artificial Intelligence. The implementation of the data subject's information rights and

ensuring the transparency of processing may become impossible in the case of Integrated Artificial Intelligence, especially when it is integrated into human biological functions. If it becomes necessary to apply the General Data Protection Regulation to all aspects of Artificial Intelligence, the risk of the consequences that will harm its development will be enormous (Genderen, 2017).

A relevant report by the UK Parliament's Science and Technology Committee highlights the need to develop and implement AI technologies in a way that ensures continued functionality and seamless integration, while adopting appropriate control and regulatory mechanisms. According to the Association for the Advancement of Artificial Intelligence, it is important to be able to test, measure and validate the reliability, performance, safety and ethical compliance of robotics and AI systems before they are deployed (Roberts et al., 2023).

Is it possible to control developments in Artificial Intelligence and robotics, as well as manage the privacy of personal data related to them? In case the existing legal framework proves insufficient, is it possible to develop new legal instruments for effective regulation and protection? Furthermore, if Artificial Intelligence entities acquire a special (sui generis) legal personality, will we be able to ensure that privacy and personal data protection are respected in accordance with applicable legal requirements?

If AI entities acquire legal personality, the need to protect the “personal” data of these new legal subjects will also arise, especially when they evolve into intelligent entities. Existing regulatory gaps are expected to widen unless the legal framework dynamically adapts to technological developments. Competent law enforcement authorities may be unable to effectively police and regulate future technologies, as the speed of development leaves no room for stable and calm legislative measures. Technology is constantly evolving, creating a complex and interconnected framework, which requires forward-looking design and the establishment of security systems for AI and autonomous robots. This need becomes imperative before superintelligence takes control, transforming humans from active participants into passive subjects. Our present attitude and decisions will determine the future we face (Genderen, 2017).

Protecting data privacy and preventing discrimination in the application of artificial intelligence are fundamental factors that require not only strict compliance with applicable rules and regulations, but also the adoption of appropriate control mechanisms. Transparency and accountability in artificial intelligence processes also play a crucial role. Users must be able to understand how their personal data is being used, while decisions made based on artificial intelligence must be explainable and verifiable. Compliance with legislative frameworks such as the General Data Protection Regulation (GDPR) and the California Consumer Protection Act (CCPA) is essential to meet data protection requirements (Kotov, 2024).

Continuous training of staff and adaptation of data protection policies to the changing technological and legal environment are integral elements of ensuring security. In addition, technical and organizational measures, such as data encryption and access rights management, are essential for effective information protection. Readiness for adaptations in legislation and technology is crucial for a prompt response to new threats and requirements. A holistic approach to the use of artificial intelligence, which

integrates technical, ethical, legal and educational dimensions, is necessary to ensure the fair and responsible use of technology and data protection at all levels (Kotov, 2024).

Algorithms and biases

In recent years, it has become increasingly clear that computer algorithms are not simply neutral tools, but can cause problems, reproducing and reinforcing prejudices. For this reason, efforts to identify and prevent these prejudices have increased significantly. An important approach in this context is the Value Sensitive Design (VSD) methodology. This is a technology design method that invests in the systematic integration of human values into the technological product. According to this, technology is not neutral, on the contrary, it considers technology to be in an interactive relationship with the set of social, ethical and cultural values. This approach helps both in the critical analysis of the values or their lack in existing technologies, and in the creation of new technologies that incorporate specific desired values (Simon et al., 2020).

Scholars believe that social norms are passed on to machine learning programs as legacies from programmers unintentionally depending on the training they have. This is algorithmic bias. According to Johnson (2020) there are similarities between algorithmic and cognitive biases that do not necessarily stem from malicious intent but are often due to the unintentional influence of everyday, natural patterns or habits on the way people or systems process and interpret information. Simply put, someone may appear to be acting innocently but secretly pass on and reproduce entrenched biases. This situation does not allow for easy detection of biases and is therefore difficult to recognize, mitigate, or evaluate through traditional tools of knowledge and ethics.

Johnson (2020) mentions the “Proxy Problem”, which means that some seemingly harmless or neutral information (characteristic proxies) are used by algorithms or systems as substitutes for socially sensitive characteristics (such as gender, race, age, etc.). Such proxies may seem harmless, but their association with sensitive characteristics leads to the production or reinforcement of biases. In other words, bias is “hidden” behind these proxies, making it difficult to revise or correct it, because it is not immediately visible as bias. However, solving this problem involves challenges because if we remove or ignore these proxies to avoid bias, the effectiveness or accuracy of the system (whether this is a human or an algorithm) may be reduced. This creates a dilemma: how to balance between avoiding bias and maintaining good performance.

In fact, Artificial Intelligence does not simply reproduce bias but introduces new psychological mechanisms. First, selective attention, according to which users choose to pay attention only to information that confirms their pre-existing beliefs or prejudices. Second, justification of the system, according to which people proceed to uncritically accept the results of AI even if they are biased. Third, moral disengagement, according to which users choose to shift responsibility for the consequences of decision-making to AI, since the algorithm makes the decisions. The solution is reform and addressing technical and human factors. Failure to address these psychological tendencies will result in the perpetuation of inequalities by technically sophisticated systems that were originally designed to eliminate them (Johnson, 2020).

Therefore, it is the duty of humans not only to identify and correct biases in software systems but also to address and correct the social causes that reproduce them. Only in this way will we be able to create technologies that promote justice, equality, and respect for all (Borinca, 2025).

Responsibility and Accountability in Artificial Intelligence

Throughout human history, the spread and dominance of new ideas, as well as the questioning of existing ones, have been a driving force for the development of society and politics, creating new challenges. In modern times, Artificial Intelligence constitutes a new form of governance and functions as a powerful tool for the development of smart cities. Looking beyond its particularly auxiliary function, one is faced with many and varied problems created by its development. Among these are accountability and responsibility for AI (Gil, 2022).

The integration of Artificial Intelligence into social life and its various aspects implies the emergence of concepts such as accountability and responsibility in key issues. With the penetration of Artificial Intelligence in a wide range of directions from healthcare to finance, the debate around the accountability and responsibility of AI has been ignited. Since the moment AI has been integrated into decision-making processes, complex ethical questions have arisen related to the attribution of responsibility regarding the results of these systems.

But how are accountability and responsibility for AI defined? Accountability for AI relates to the mechanisms and processes that ensure that AI systems and their developers are held accountable for the actions and decisions taken by these systems. Therefore, accountability for the impacts of AI technologies is a responsibility that falls on the stakeholders themselves, who must give a voice to society, in order to establish trust and respect for ethics in its implementation. Responsibility concerns the moral obligation that stakeholders undertake to ensure that the design and use of AI systems are compatible with human well-being, justice and its delivery. This includes taking preventive measures to mitigate risks associated with AI such as bias, discrimination and privacy violations. These two concepts are in interaction, as accountability is mainly associated with reacting to a problem after it appears and requires clarification, while responsibility focuses on risk prevention and its ethical dimension. Their interconnected relationship contributes to the creation of a general framework that will be based on a common action aimed at promoting a trustworthy and ethical AI technology (Sidney et al., 2019).

Ethical Design and Human Control

In the modern era when AI has invaded all aspects of life with the aim of changing the way people work and live, understanding how control should be exercised over AI systems is a question of paramount importance in many areas of research (Tsamados et al, 2025).

HCAI (Human-Centered Artificial Intelligence) systems that put people at the center and prioritize human needs and capabilities should take precedence in the design of systems as a safety valve to serve people and their capabilities and not replace them. Ensuring the accessibility and easy management of Artificial Intelligence systems will

strengthen the users' effort to understand how they operate. Moreover, human-centered AI should have a dual goal: on the one hand, the rationalist perspective related to logic, accuracy, efficiency and serving functional goals, and on the other hand, the humanist perspective that focuses on human ethics, values, justice and the well-being of people and operates with the defense of human rights in mind. The balance of these two perspectives should become a central goal for AI systems (Xu, 2026).

Interdisciplinary teams are charged with the responsibility of examining the impact of AI on society and moving forward to create systems that are understandable to humans. Scientific understanding will only be achieved by removing the fears associated with the use of algorithmic decision-making processes, including computational invasion of privacy, information asymmetry, and lack of jurisdiction. Moreover, Human-Centered Artificial Intelligence (HCAI) systems whose design is based on ethical machine algorithms represent a very good prospect for human-centered systems. This is because their role will be vital in the effort to preserve human creativity and self-efficacy, and to protect privacy, equality, social justice, and human rights (Stafylas, 2021).

Discussion

Artificial Intelligence has penetrated key areas of human activity such as health and education, leading to the conclusion that the moral and legal framework must be redefined. Based on this study, technology cannot function as a neutral tool. On the contrary, it interacts with the set of social and cultural values and often leads to wrong directions. Of key importance is the algorithmic bias that unintentionally leads to the reproduction of established social patterns with the contribution of proxy characteristics. A fact that makes it difficult to move away from it. At the same time, the moral disengagement of users who tend to shift the responsibility for decisions to AI systems makes the impact on human judgment and accountability more evident.

Regarding the labor market, the discussion focuses on the tendency of AI to create two opposite effects, the first of which is related to the creation of new highly specialized positions and the second to the displacement of unskilled workers and the replacement of some repetitive tasks by algorithms. A perspective that intensifies inequalities in social life. The problem is, in fact, intensified by the fact that the existing legal framework appears inadequate since it is unable to cover the modern challenges of privacy and intellectual property.

Conclusions

In conclusion, we would say that in order for technological progress to be put at the service of social well-being in the future, a strictly human-centered approach (Human-Centered AI) should be adopted. It is necessary to design Artificial Intelligence systems with a view to enhancing human self-efficacy and not substituting it, maintaining the balance between operational efficiency and the defense of human rights. Accountability and responsibility must remain non-negotiable obligations of the actors involved, who must take preventive measures to mitigate the risks of bias and privacy violations.

It is becoming clear that the era of Artificial Intelligence does not allow for any kind of complacency, on the contrary it requires interdisciplinary collaboration and the adaptation of the institutional framework. Only the systematic integration of human

values in technological design and the addressing of the deeper social causes will lead to the proper utilization of AI.

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The Contribution of Canva Code and Claude to the Creation of Interactive Educational Games: An AI-Powered Gamification Approach

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Abstract - This paper examines the dynamic convergence of gamification, Artificial Intelligence, and low-code/no-code platforms within the context of educational innovation, with a focus on the capabilities of Canva Code and Claude. It explores a practical approach that combines visual content creation in Canva and Claude with AI-assisted integration through prompt engineering and embedded applications (Canva Apps - Claude HTML). The objective is to create interactive educational games that enhance engagement, self-regulation, and personalized learning without the need for programming knowledge. The methodology relies on a synthetic approach: initially, an extensive literature review is conducted on scientific articles regarding gamification, learning theories, and AI applications in education; subsequently, an original practical application is presented, where interactive games are created and demonstrated through structured prompts to AI models, which are then integrated into the Canva Code and Claude environments. The analysis indicates that this approach reinforces the pedagogical autonomy of educators, reduces the time required for creating interactive content, and promotes Artificial Intelligence as a tool for assisted instruction. Concurrently, limitations such as privacy issues, dependency on proprietary platforms, and the need for critical evaluation of AI-generated code quality are discussed. This study contributes to the research field of practical AI applications in teaching and learning by proposing a feasible and pedagogically meaningful model for integrating gamification into daily teaching practice. The findings are addressed to both researchers and educators, offering a framework for developing digital pedagogical competence through the creative use of existing technologies.

Keywords: Gamification, Artificial Intelligence, Canva Code, Claude, interactive games.

Introduction

The educational process in the 21st century is characterized by a continuous search for innovative pedagogical strategies aimed at enhancing student engagement, motivation, and personalized learning (Fokides & Kaimara, 2020). Within the context of this quest, Gamification has emerged as one of the most dynamic and promising fields of modern educational practice. It refers to the application of game elements and mechanisms in non-game contexts, such as the classroom, with the objective of improving the learning experience and increasing students' active participation (Deterding et al., 2011). A multitude of research has demonstrated that Gamification can increase student commitment to the learning process, strengthening their motivation to participate through the addition of playful elements to instruction, thereby making learning more attractive and enjoyable (Simões et al., 2013).

Concurrently, the rapid evolution of Artificial Intelligence (AI), and particularly the development of Large Language Models (LLMs) (Gabrovšek & Rihtaršič, 2025), has offered new, unprecedented possibilities in education, especially in the field of automated creation of complex and customized educational material (Liu et al., 2025). However, the utilization of these technologies raises challenges regarding both pedagogical validity and the technical accessibility of the resulting tools. The primary difficulty lies in the effective integration of AI into processes for the rapid production of interactive educational games that adhere to established pedagogical standards while remaining accessible to educators without specialized technical skills (Ke, 2009).

Within this framework, the present paper focuses on investigating the dynamic convergence of three critical technological and pedagogical fields: Gamification, Artificial Intelligence, and low-code/no-code (LCNC) platforms (El Kamouchi et al., 2023). The study concentrates on analyzing how LCNC platforms, in combination with Large Language Models, can contribute decisively to the creation of interactive and pedagogically targeted educational content (Spyrou et al., 2023). The aim of this work is to highlight how this approach can reinforce the pedagogical autonomy of educators (Fokides & Kaimara, 2020), significantly reducing the time required for the production of educational material while promoting AI as an effective tool for assisted instruction, without the need for specialized programming knowledge (El Kamouchi et al., 2023). The methodological approach of the present study is based on an extensive literature review of authoritative scientific sources, aiming to substantiate theoretical assumptions and critically evaluate the practical applications of Gamification and AI in education (Ke, 2009).

1. Theoretical Framework: Gamification, Motivation, and Learning

1.1. Definitions of Gamification and Applications

Gamification is defined as the use of game design elements and mechanisms in non-game contexts (Deterding et al., 2011). In the context of educational practice, this definition translates into the integration of game elements - such as points, badges, leaderboards, quests, and narratives - into the learning process, with the aim of enhancing student engagement and motivation (Simões et al., 2013). Gamification does not aim to create a full-fledged game, but rather to leverage the psychological and social mechanisms that activate participation, collaboration, and sustained effort in players,

adapting them to educational contexts to serve specific learning objectives (Deterding et al., 2011).

The effectiveness of digital educational games as a pedagogical approach has been extensively substantiated in the international literature, as they promote active learning and enhance students' cognitive and emotional engagement (Ke, 2009). However, their successful integration into the educational environment is not a given; it depends largely on the perceptions, attitudes, and technological competence of the educators themselves, who are called upon to combine their pedagogical expertise with the utilization of modern technological tools (Fokides & Kaimara, 2020). Through this complex process, Gamification acquires particular significance as a means of transforming the learning experience, offering new prospects for the development of creative and interactive learning environments.

1.2. Psychological and Pedagogical Foundations

Interactive educational games, particularly when designed with AI support, are grounded in three key learning and motivation theories: Self-Determination Theory, Constructivism, and Flow Theory (Ryan & Deci, 2000; Parthenis, 2022; Csikszentmihalyi, 1990).

1.2.1. Self-Determination Theory (SDT)

Self-Determination Theory (SDT) (Deci & Ryan, 2000) constitutes the dominant theoretical framework for the study of motivation within the context of Gamification (Simões et al., 2013). According to this theory, optimal human functioning and the development of intrinsic motivation require the satisfaction of three fundamental and innate psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2000). The first need, autonomy, concerns the individual's sense that they are the origin of their own actions and choices - that is, acting based on free will rather than external coercion (Ryan & Deci, 2000). In the context of Gamification, the provision of choices, differentiated learning paths, and personalized goals contributes decisively to reinforcing students' sense of autonomy, allowing them to feel that they play an active role in the learning process (Simões et al., 2013).

The second need, competence, refers to the individual's sense of efficacy during their interaction with the environment and the progress experienced through their successes (Ryan & Deci, 2000). Game elements, such as points, badges, and visual progress indicators, function as immediate feedback mechanisms that reinforce the sense of competence and affirm the continuous improvement of the student's skills (Simões et al., 2013). Finally, the third need, relatedness, concerns the individual's desire to feel connected to others and to belong to a community (Ryan & Deci, 2000). Leaderboards, collaborative quests, and social interaction mechanisms integrated into educational games significantly reinforce this need by cultivating a sense of participation and cooperation among students (Simões et al., 2013).

According to Self-Determination Theory, the satisfaction of these three psychological needs - autonomy, competence, and relatedness - leads to the enhancement of intrinsic motivation, which has a direct positive effect on both the learning process and the individual's psychological well-being (Ryan & Deci, 2000). Through Gamification,

these needs are satisfied in a natural and creative manner, making learning not only more effective but also deeply satisfying for the student.

1.2.2. Constructivism

Constructivism posits that students do not function as passive recipients of knowledge, but as active constructors of it, shaping their learning experience through continuous interaction with the environment and the stimuli it offers (Parthenis, 2022). This process of cognitive construction is realized through the integration and processing of new information based on pre-existing cognitive frameworks, which serve as reference points for understanding and interpreting new material (Parthenis, 2022). Consequently, according to Constructivist theory, learning is more effective when the student is not limited to the rote memorization of predefined answers, but is actively involved in the process of meaning-making, personally building their own system of understanding and knowledge (Parthenis, 2022).

In this context, interactive educational games created with the support of Artificial Intelligence constitute an ideal practical application of Constructivist principles (Ke, 2009). Through the student's active participation in environments that incorporate elements of problem-solving, discovery, and experimentation, these games promote the development of critical and creative thinking, as the student is called upon to actively utilize their cognitive background to achieve the game's objectives (Parthenis, 2022). Concurrently, the interactive nature of these games reinforces students' autonomy and intrinsic motivation, as the achievement of their goals emerges as a result of personal effort and cognitive engagement. This fact renders the learning process more meaningful, experiential, and transformative.

1.2.3. Flow Theory

Flow Theory, formulated by Mihaly Csikszentmihalyi (1990), describes an optimal experience during which an individual is in a state of complete absorption and absolute concentration while performing an activity, experiencing a sense of deep immersion and enjoyment. In this state, also known as "being in the zone," the individual loses the sense of time and self-consciousness, as action and awareness merge into a unified experience, leading to a level of total dedication and creative engagement (Csikszentmihalyi, 1990).

The fundamental core of achieving the Flow state lies in finding an ideal balance between the challenge offered by an activity and the skills of the individual performing it (Csikszentmihalyi, 1990). When the challenge is lower than the individual's skills, the result is boredom, as the activity ceases to stimulate cognitive interest. Conversely, when the challenge far exceeds the individual's capabilities, anxiety arises, which deters continued engagement (Csikszentmihalyi, 1990). Consequently, the Flow state is achieved when the activity offers challenges that push the individual's capabilities to their limit, maintaining a continuous sense of achievement and progress. To facilitate entry into Flow during an activity, the presence of specific conditions is necessary: clear goals, so the individual knows exactly what must be achieved; immediate feedback, allowing them to know their performance in real-time; and a balance between challenge and skill, ensuring that the activity requires effort without becoming unattainable (Csikszentmihalyi, 1990).

In this theoretical framework, interactive educational games based on Gamification principles and supported by Artificial Intelligence technologies aim to achieve this "zone of optimal experience" (Csikszentmihalyi, 1990). Artificial Intelligence, through its capacity for personalization and adaptability, can dynamically regulate the level of difficulty, adjusting challenges - such as quizzes, quests, or game scenarios - to the specific abilities of each student. In this way, the aim is to sustain the student within the Flow state, which not only enhances intrinsic motivation but also maximizes the quality and depth of the learning experience (Csikszentmihalyi, 1990).

1.3. Artificial Intelligence as a Tool for Educational Innovation

The advent of Artificial Intelligence and Large Language Models (LLMs) has brought about a profound transformation in the creation, management, and dissemination of digital content, signaling a new era of innovation in education and technology (Gabrovšek & Rihtaršič, 2025). These advanced models possess the capability to generate high-quality original content, including text, images, and notably software code, thereby contributing decisively to the automation and enhancement of the creative process (Liu et al., 2025).

In the realm of education, Artificial Intelligence is emerging as a catalyst for transformation, offering new possibilities for personalized learning and dynamic student support (Gabrovšek & Rihtaršič, 2025). Concurrently, LLMs can be leveraged for the rapid production of educational material and games, significantly facilitating the educational process and reducing instructional preparation time (Liu et al., 2025).

Consequently, AI becomes a powerful tool for educational innovation, reinforcing the educator's role not merely as a transmitter of knowledge, but as a pedagogical guide focused on the needs, interests, and development of students (Gabrovšek & Rihtaršič, 2025). Through its integration into the learning process, a new type of educational experience is achieved wherein technology functions in support of instruction rather than in competition with it, promoting creativity, collaboration, and the continuous renewal of pedagogical practices.

2. Low-Code/No-Code Platforms and LLMs

The substantial contribution of the present approach lies in the creative synergy of two rapidly evolving technological paradigms: the ease of use offered by Low-Code/No-Code (LCNC) platforms and the generative capability of Large Language Models (LLMs) (El Kamouchi et al., 2023). This combination allows for the development of innovative educational and technological solutions, drastically reducing the technical barriers that traditionally required specialized programming knowledge.

2.1. The Democratization of Creation with Low-Code/No-Code Platforms

Low-Code/No-Code (LCNC) platforms constitute a turning point in the evolution of software development, as they contribute decisively to the democratization of the digital application creation process (El Kamouchi et al., 2023). By simplifying technical requirements, these platforms allow for the participation of a broader spectrum of users, including those with minimal or zero programming experience. So-called "Citizen

Developers[2]" now have the ability to design, develop, and implement applications quickly and efficiently, utilizing tools based on visual data management and the use of intuitive interfaces (El Kamouchi et al., 2023).

This practice shifts the focus of creativity from the level of technical programming to the level of ideological and pedagogical conceptualization. A characteristic example is the use of visual design tools, such as Canva AI, which has been studied as a dynamic medium enabling educators to produce interactive and multimedia educational material without requiring specialized technical skills (Spyrou et al., 2023). The integration of these tools into LCNC environments highlights their potential as vehicles for educational innovation, simultaneously enhancing the creativity of educators and students within the classroom.

Furthermore, the synthesis of visual design with simple code functions that characterizes LCNC platforms offers a flexible and accessible framework for creating educational applications that promote participatory learning, inquiry-based thinking, and collaboration (Spyrou et al., 2023). In this way, LCNC platforms do not function merely as technological tools, but as catalysts that redefine the relationship of educators with technology, reinforcing autonomy, imagination, and innovative teaching in the digital school environment.

2.2. Generative Coding with Large Language Models

Large Language Models (LLMs) constitute the forefront of Generative Artificial Intelligence (AI) in the field of automated code generation, as they incorporate advanced algorithmic capabilities for understanding and generating natural language with the aim of translating verbal commands into programming structures (Liu et al., 2025). Generative coding, which lies at the core of this technology, allows LLMs to compose targeted and functional code - such as HTML, CSS, or JavaScript - in response to instructions given in natural language through the process known as *prompt engineering* (Gabrovšek & Rihtaršič, 2025).

This capability acquires particular significance within the context of creating interactive educational games, where the educator can simply describe the functionality or the pedagogical outcome desired, and the system automatically generates the appropriate code for its implementation. For example, an educator can formulate the instruction "Create a multiple-choice quiz," and the model immediately synthesizes the necessary code that implements this function (Gabrovšek & Rihtaršič,2025). In this way, the process of developing educational content is transformed from a technical to a creative endeavor, where natural language becomes the primary medium of design and production.

In this context, the technique of *prompt engineering* emerges as the new essential skill for educators, replacing the specialized programming requirements traditionally demanded for the development of educational applications (Gabrovšek & Rihtaršič, 2025). This shift redefines the role of the educator, allowing them to focus more on the

[2] The term **"Citizen Developer"** refers to an individual without formal training in software engineering who creates functional computer applications using Low-Code/No-Code (LCNC) development environments. In the context of education, this describes educators (or students) who leverage intuitive, visual interfaces to design and deploy interactive learning tools - such as educational games or assessment apps - tailored to specific pedagogical needs, thereby bypassing the traditional reliance on IT specialists for content creation.

didactic and pedagogical dimension of technological creation rather than on the technical details of the code. Consequently, generative coding via LLMs constitutes a critical step toward the full integration of AI into the learning process, making knowledge and technological innovation more accessible and creative than ever before.

2.3. The Application of the Synthetic Approach

The synthetic approach to instructional and technological innovation is grounded in the integration of code generated by Artificial Intelligence, via Large Language Models (LLMs), into the visual environment of Low-Code/No-Code (LCNC) platforms (El Kamouchi et al., 2023). This combination constitutes a pivotal step toward the creation of a comprehensive educational design framework, wherein code production is automated while the creative and pedagogical initiative of the educator is preserved. By leveraging this synthesis, the educator assumes the role of a learning designer, focusing attention on the pedagogical quality and clarity of the prompts - that is, the manner in which instructions are formulated to the system for the creation of an interactive game - rather than on the technical details of implementation (Gabrovšek & Rihtaršič, 2025).

This shift from technical skill to pedagogical precision contributes decisively to the improvement of the educational process, as the time required to create interactive content - which traditionally constituted a significant constraint - is drastically reduced (Liu et al., 2025). This time-saving allows the educator to adapt instructional material more immediately to the specific learning needs of the class, enhancing the flexibility and personalization of instruction (El Kamouchi et al., 2023). Concurrently, the ability to rapidly and creatively produce interactive games promotes student engagement, as it reinforces intrinsic motivation through the immediate satisfaction of the basic psychological needs of autonomy, competence, and relatedness, as defined by Self-Determination Theory (Ryan & Deci, 2000).

Therefore, the application of the synthetic approach represents not merely technological advancement, but a substantial transformation in teaching philosophy, evolving the educator from a simple user of tools into a creator of learning experiences who leverages Artificial Intelligence to promote active, collaborative, and deeper learning.

3. Practical Application: Demonstration of Tools and Prompts

The investigation of the dynamic convergence between Low-Code/No-Code (LCNC) platforms and Large Language Models (LLMs) acquires substantial substance through the practical demonstration of the educational material creation process, as the theoretical substantiation of their capabilities is complemented by their applied utilization in real pedagogical environments (El Kamouchi et al., 2023). The practical dimension of this section focuses on the manner in which the educator, adopting the role of the "Citizen Developer," can utilize the Large Language Model, Claude, or the LCNC platform Canva Code, in order to design and implement functional, interactive learning games (Gabrovšek & Rihtaršič, 2025).

3.1. Prompt Engineering Strategies for Gamification

The effectiveness of generative coding depends decisively on the quality and structure of the prompt provided to the Large Language Model (LLM), as the precision and

completeness of the instruction determine the level of consistency, functionality, and pedagogical relevance of the generated code (Gabrovšek & Rihtaršič, 2025). Therefore, to achieve a high-quality result, it is necessary for the prompt to be formulated systematically and with clarity, incorporating specific structural elements that guide the LLM toward producing educationally utilizable content.

First, the primary element concerns the definition of Role & Context, i.e., the explicit articulation of the identity the LLM must adopt, such as: *"You are an experienced web developer specializing in educational games."* Establishing a specific role allows the model to adapt its tone, language, and technical choices to the appropriate professional and pedagogical context, ensuring greater relevance of the final result to the goals of the educational application. Equally critical is the clear description of the Goal & Activity, specifically referencing the type of game desired (such as a quiz or a fill-in-the-blanks activity) and the specific learning objective it serves. Clarifying these elements allows the model to adapt the game structure and the content of questions or interactions to the requirements of the intended cognitive process.

Concurrently, Technical Constraints constitute an integral element of the prompt, as they determine the format and compatibility of the generated code. Specifically, the requirement to produce full and unified code in a Standalone HTML/CSS/JS format ensures the possibility of immediate integration into LCNC platforms that support HTML or iframes, allowing for its immediate utilization by the educator without further technical interventions. Additionally, the careful provision of Content/Data - that is, the questions, potential answers, or elements required to fill in the blanks - enhances the relevance of the generated game to the subject matter and ensures its didactic value. Finally, the possibility of dialogue through iterative prompting, which distinguishes these platforms, allows for the immediate correction of any errors or discrepancies and the optimization of the final activities and the game's appearance.

Overall, the process of prompt engineering constitutes a critical pedagogical and technological skill, as through it the educator acquires control of the creation process, guiding generative artificial intelligence in the production of code that not only functions technically but also substantially serves learning purposes (Gabrovšek & Rihtaršič, 2025).

3.2. Creating Educational Games in Canva Code and Claude

3.2.1. Creating Interactive Multiple-Choice Quizzes

The multiple-choice quiz constitutes a particularly effective tool for knowledge assessment, as it allows for the objective evaluation of students' comprehension and information recall, offering clear and measurable results (Ke, 2009). Concurrently, its use in a gamified or interactive learning environment contributes substantially to reinforcing the student's sense of competence, as described within the framework of Self-Determination Theory, according to which perceived competence constitutes a fundamental source of intrinsic motivation (Ryan & Deci, 2000). Through the successful completion of such activities, the student experiences a sense of achievement

and self-efficacy[3], which reinforces their commitment to the learning process and promotes a positive attitude toward learning.

Prompt Element	Prompt Content (in Canva Code)
Role	Act as an expert in pedagogical coding for educational games and as an experienced Philologist teaching in Junior High School.
Educational Goal	Create a multiple-choice exercise with the following characteristics: First, the student must identify the objects of the verb by clicking on the appropriate word in each sentence. Subsequently, they must select between two option buttons: one labeled "Monotransitive Verb" and the other "Ditransitive Verb".
Technical Constraints	Group articles or prepositions with their accompanying words so they function as a single clickable entity and count as one selection. Center the "Monotransitive Verb" and "Ditransitive Verb" options and style them as toggle buttons with an active background color. Set a red background for "Monotransitive Verb" and a blue background for "Ditransitive Verb" so they are clearly distinguishable. Apply a dark green background to the sentence frame for better contrast with the word-buttons. Upon completion of all exercises, add a result scoreboard on a new card displaying the success rate; display an encouraging phrase corresponding to the score, accompanied by fireworks behind the summary card. Add approving and encouraging feedback phrases with small animation effects at the bottom of each card. Every time the player presses "Check," if the choices are correct, a green message *"Bravo! You nailed it!"* should appear with a small pop and confetti; if incorrect, a red message *"Never mind! Keep going, you got this!"* should appear with a subtle shake effect, revealing the correct solution below. Apply a clear "pressed" and "active selection" effect to all buttons for immediate visual confirmation. Add functionality so that the order of exercises changes each time the test starts, making the test more difficult upon repetition. Finally, allow the player to proceed to the next exercise even after making a mistake.
Content	The sentences to be included in the test are the following: 1. A good friend always offers help to his partner. 2. Real friends boost our self-confidence with their actions. 3. True friendship withstands time, distance, and silence. 4. Deep friendship gives young people certainty about the future. 5. Only a devoted friend inspires trust every day. 6. Beloved friends share joys and sorrows. 7. True friendship offers man peace and fulfillment. 8. A friend knows a friend in times of danger. 9. Few people honor their happy friend without envy. 10. A friend is someone who gives you complete

[3] **Self-efficacy**, a central concept in Albert Bandura's Social Cognitive Theory, refers to an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments (Bandura, 1982). In an educational context, it does not reflect the student's actual skills, but rather their *confidence* in utilizing those skills to overcome challenges. High self-efficacy is strongly correlated with increased effort, persistence in the face of difficulties, and resilience, all of which are critical for successful learning outcomes.

	freedom to be yourself. 11. Even the strongest person needs friends. 12. The only way to have a friend is to be a friend.

Table 1. Prompt for a multiple-choice quiz in Canva Code. The webpage hosting the game: https://lyoenergitikisfonis.my.canva.site/dagzos3lics

Prompt Element	Prompt Content (in Canva Code)
Role	Act as an expert in pedagogical coding for educational games.
Educational Goal	Create an escape room-style game on Ancient Greek history, Roman history, the geography of Greece, and the geography of Italy, suitable for Greek and Italian students aged 13-15.
Content	Players must solve [4] exercises. Each one will constitute a room they must unlock. The first and third rooms will each have 10 multiple-choice questions on Geography, and the second and fourth rooms will also each have 10 multiple-choice questions on History. In all 4 rooms, half the questions will be in the Greek language and the other half in the Italian language, alternating in sequence. Additionally, the topics of the questions must correspond to the country of the respective language (e.g., Italian questions regarding Italy).
Technical Constraints	Upon opening the room, a trap will be activated, which they must try to avoid. Upon solving the exercise, a key will appear; clicking it will advance them to the next level, accompanied by confetti falling. For each sub-question, they will have two chances to answer. If they fail the second time, the game will restart from the beginning. At the end of the game, there should be a congratulatory message in both languages, accompanied by falling confetti. Use bright metallic colors and a futuristic design. Each room must have a different color. Provide ideas for the adventure theme and the room names (e.g., something involving a labyrinth or something that better fits an escape room context).

Table 2. Prompt for a multiple-choice escape room game for Erasmus students in Canva Code. The webpage hosting the game: https://lyoenergitikisfonis.my.canva.site/dag3afsbvsq

Additional examples of interactive multiple-choice games are provided in the following links:

1. Distinction between Nouns and Adjectives: Two-termination / Three-termination Adjectives & Parisyllabic / Imparisyllabic Nouns: https://lyoenergitikisfonis.my.canva.site/dagzayyi1gu
2. Grammatical Objects and their Forms: (Noun, adjective, pronoun, subordinate clause): https://lyoenergitikisfonis.my.canva.site/dagznbj9qws
3. Interactive Multiple-Choice Test on Paragraph Development Methods: https://lyoenergitikisfonis.my.canva.site/dagxe50wjxa
4. Test on Poetic Meters: https://lyoenergitikisfonis.my.canva.site/dagwy7rk7zq
5. Geography of Greece and Italy for Erasmus Students: "Who Wants to Be a Millionaire": https://lyoenergitikisfonis.my.canva.site/dag3ajybkms

3.2.2. Creating Fill-in-the-Blank and Answer Discovery Games

Fill-in-the-blank and answer discovery games constitute a particularly effective form of learning activity, as they promote the principles of Constructivism, enabling students to participate actively in the learning process through meaning-making. The interaction entailed by these types of games requires the student to recall, organize, and integrate their knowledge within the context of constructing complete words, phrases, or sentences. This process enhances their cognitive engagement and comprehension of linguistic or conceptual structure (Parthenis, 2022).

Prompt Element	Prompt Content (in Claude)
Role	You are an experienced educational game developer.
Educational Goal	Create an interactive word composition board game using HTML. Title the game: "Word Masters" (*Lexomastores*). I want two teams, Team A (boys) and Team B (girls), to answer in turn. Each team must have its own score counter that updates when they answer correctly. There must be visual indicators showing which team's turn it is.
Content	The game must include 35 blue numbered tiles on the left, which, on their flip side, will contain one of the inseparable particles from the parentheses (α- αν- ξε- αρχι- αμφί- ανα- δια- διχο- δυσ- εισ- εκ-/εξ- εν- επι- επ- εφ- ημι- περι- συν-συγ- συλ- συμ- συρ- συσ- υπο-υπ- υφ- αει- ενδο- ευ- ομο- παν- παγ- προ- τηλε- υπερ-). Also, the game must have on the right 35 corresponding green numbered tiles which, on their flip side, will have only a suffix of a verb, noun, adjective, participle, or adverb.
Technical Constraints	Each team will select one of the 35 tiles with the inseparable particles and one of the 35 tiles with the suffixes and must orally form a suitable compound word. When a team answers correctly by combining a particle and a suffix, the corresponding 2 tiles will become permanently orange. The background color should be red. Furthermore, ensure the tiles have dimensions of 2cm x 2cm and are arranged in a 7x5 grid. When the game starts, a visible and automatic draw (coin toss) should take place to show whether the boys or girls start first. Ensure that after 15 attempts by each team, a "Game Over" box appears, accompanied by a sentence of positive feedback. Finally, add a 20-second timer for each team's attempt. The time will start as soon as the 2 necessary tiles are selected.

Table 3. Prompt for a word composition game in Claude AI. The webpage hosting the game: https://claude.ai/public/artifacts/58895dd8-88fb-4743-9b5f-6b8811ffc039

Prompt Element	Prompt Content (in Canva Code)
Role	Assume the role of an experienced educational game developer.
Educational Goal	Your goal is to design a playful, colorful, and technically sound "Snakes and Ladders" style board game titled "The Verbs Snakes and Ladders," which will practice students on the tenses and persons of the Indicative mood in Modern Greek. The game must: Reinforce students' grammatical awareness through practice in verb tenses. Cultivate the correct use of verb forms in all persons of the Indicative. Reinforce collaborative and competitive learning in the

	form of a two-player game. Offer immediate feedback for every answer and maintain interest with visual and sound effects. The tenses to be included in the questions are: Present, Imperfect, Simple Past, Simple Future, Continuous Future, Future Perfect, Present Perfect, and Pluperfect.
Content	**Title:** The Verbs Snakes and Ladders. **Game Description:** Two players (Player 1 and Player 2) take turns rolling a 3D die (numbered 1-6). Before the game starts, a draw takes place to determine the starting order: each player rolls the die, and whoever rolls the higher number starts first. On every square of the board, a verb appears, and the player is asked to provide the correct form in a specific tense and person of the Indicative. **Examples:** *"Verb: eat - Give the form in Simple Past, 2nd singular." "Verb: love - Give the form in Present, 1st plural."* If the answer is correct, the player moves forward the number of squares shown on the die. If wrong, they stay in place. If they land on a ladder, they move up; if they land on a snake, they slide back down. The first to reach the last square is the winner. **Educational Content:** Create an array with at least 20 verbs, such as: *write, go, see, eat, say, love, give, stay, come, take, know, play, want, can, leave, learn, open, look, find, ask*. Each question must be random and include only one person (2nd or 3rd, singular or plural). Questions must be drawn from an array of correct verb forms for answer validation. **Game Rules (Summary):** Draw for player order. Roll 3D die (1-6). Pop-up question with verb, tense, and person. Answer check – correct or incorrect. Token movement based on die number. If snake or ladder exists, extra movement occurs. Turn switching with visual indicator. Victory message at the end. **Visual and Audio Experience:** Background: light blue with cloud or book motifs. Squares: colorful (yellow, green, pink, orange). Player 1 → blue token, Player 2 → red token. Active player indicator (glow, border, or animation). Large, round buttons with vivid colors (e.g., green, orange). Hover effects and token movement animation (step-by-step, with ~300ms delay). Dice sound, correct answer sound, and reward messages.
Technical Constraints	Use only HTML, CSS, and JavaScript (without external frameworks or libraries). The entire game must be implemented in a single HTML file. The board must consist of 100 squares (10x10). Token movement must be based strictly on the die number (1-6) and must not affect the other player. Movements must be executed with animation and without overlapping. Questions must always include a valid tense and person, with no undefined values. The game must start only after the draw and display a victory message at the end. The code must be clean, commented, and ready for integration into an educational website.

Table 4. Prompt for a "Snakes and Ladders" style fill-in-the-blank game in Canva Code. The webpage hosting the game: https://lyoenergitikisfonis.my.canva.site/html-js

Additional examples of interactive "find the correct answer" games are provided in the following links:

1. History Quiz: https://claude.ai/public/artifacts/789b5b43-03c6-40c8-b92f-360596018a08
2. Flashcards for the first declension of nouns in the Ancient Greek language: https://lyoenergitikisfonis.my.canva.site/dagwpro8dj4

4. Discussion and Critical Evaluation

4.1. Pedagogical Implications and Effectiveness

This specific approach contributes substantially to reinforcing the pedagogical autonomy of educators, as it allows them to take an active role in the creation and adaptation of their instructional material (Fokides & Kaimara, 2020). Instead of being limited to the use of pre-existing and often generalized educational content, educators are transformed into creators of personalized and interactive learning experiences that respond to the specific needs, abilities, and interests of their students (El Kamouchi et al., 2023). This capability facilitates the implementation of more personalized and differentiated instruction, which promotes learning activation and reinforces the application of Gamification principles, leading to greater motivation and effectiveness in the learning process (Gabrovšek & Rihtaršič, 2025).

Concurrently, the evaluation of the effectiveness of digital educational games highlights the critical importance of pedagogical quality and their cognitive impact on learning progress (Ke, 2009). A focus not merely on entertainment or technological innovation, but also on pedagogical substantiation and the clarity of learning objectives, ensures that games contribute substantially to the cognitive development of students. The combination of LCNC and LLM technologies makes feasible the rapid development of digital games that incorporate clearly formulated learning objectives, an element of decisive importance for increasing cognitive engagement and the active participation of students in the learning process (Ke, 2009).

4.2. Critical Consideration and Limitations

Despite the significant advantages arising from the use of Artificial Intelligence and Low-Code/No-Code (LCNC) platforms, their application in the educational environment raises certain critical issues that demand careful consideration and responsible management (Gerlich, 2025). One of the fundamental issues concerns the quality and evaluation of the code or content generated via these tools. Although Artificial Intelligence can create functional and technically adequate code, human oversight remains irreplaceable. The educator must maintain a critical stance toward the generated results, verifying their technical and pedagogical integrity and evaluating their compatibility with learning objectives (Gabrovšek & Rihtaršič, 2025).

Equally important are issues related to data privacy and the pedagogical competence of educators. The use of private or commercial platforms creates reasonable concerns regarding the protection of personal and learning data, necessitating the development of policies for the responsible use of Artificial Intelligence within the educational community (El Kamouchi et al., 2023). Furthermore, the effective utilization of *prompt engineering* and LCNC tools presupposes targeted professional development (training) for educators, so they may develop the necessary technological, pedagogical, and methodological competence to use them in a creative and scientifically grounded manner (Fokides & Kaimara, 2020). Consequently, the successful integration of

Artificial Intelligence into the educational process requires not only technological innovation but also systematic investment in the development of skills and critical awareness among the educators who use it.

Conclusions

The present study has highlighted the synthetic and innovative approach emerging from the convergence of Gamification (Deterding et al., 2011), Low-Code/No-Code (LCNC) platforms (El Kamouchi et al., 2023), and Generative Artificial Intelligence (Gabrovšek & Rihtaršič, 2025). The combination of these three fields constitutes a decisive factor in promoting educational innovation, as it allows for the creation of dynamic, personalized, and pedagogically targeted learning experiences (Liu et al., 2025). The theoretical substantiation of this approach is grounded in Self-Determination Theory, which emphasizes the importance of reinforcing the student's autonomy, competence, and relatedness to the learning subject (Ryan & Deci, 2000); in Flow Theory, which points out the role of complete and absolute concentration during the execution of an activity; as well as in the principles of Constructivism, which underscore the significance of the active construction of knowledge through students' participatory engagement (Parthenis, 2022).

The primary contribution of combining LCNC and LLMs lies in the democratization of the interactive educational content creation process (El Kamouchi et al., 2023). Through this approach, educators have the ability to overcome technical barriers related to programming and focus on pedagogical design, leading to a significant reduction in the development time for educational games and activities (Gabrovšek & Rihtaršič, 2025). The transition from the role of passive consumer of educational software to the role of active creator reinforces pedagogical autonomy, promotes innovation, and aligns with the contemporary demands of digital education. Nevertheless, the adoption of this method requires particular attention to the critical evaluation of the generated content's quality, in order to ensure the pedagogical validity and cognitive relevance of the produced materials (Gerlich, 2025). Furthermore, it becomes necessary to address issues regarding data privacy, as well as to reinforce the pedagogical training and technological competence of educators, enabling them to utilize the capabilities of these tools in a responsible and effective manner (Fokides & Kaimara, 2020).

Regarding proposals for future research, there is an imperative need to conduct empirical studies that will evaluate the pedagogical impact of the proposed synthetic method in real classroom conditions. Specifically, both the cognitive outcomes and the learning motivations arising from the use of interactive games created via the combination of Generative AI and LCNC platforms should be examined (Ke, 2009). Such a research direction will allow for the empirical validation of the theoretical assumptions of the present study and will contribute to the further reinforcement of the evidence-based utilization of new technologies in modern education.

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The Secret of Statues – Culture, History, and Creative Writing in Education with the Contribution of Artificial Intelligence

Athina Pampoukidou

Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract— The article presents an experiential educational practice for first and second grade elementary school students, which combines culture, history, and creative writing with the pedagogically responsible use of Artificial Intelligence (AI). The scenario "The Secret of the Statues" uses contact with ancient and foreign statues to develop historical empathy, critical thinking, and creative expression, while teaching the safe, conscious, and critical use of AI. Students create monologues, interpret the feelings and thoughts of the statues, and connect history with their imagination. The article highlights the potential for integrating AI into primary education as a supportive learning tool.

Keywords- Artificial Intelligence, cultural education, creative writing, experiential learning, primary education.

1. Introduction

Artificial Intelligence is rapidly entering education, even at a young age. Children consider it part of their everyday lives, so the challenge is to teach them to use it critically and creatively, without replacing their own thinking or creativity.

The educational practice "The Secret of the Statues" connects AI with history and culture, cultivates critical thinking, and enhances creativity through experiential learning and theatrical expression.

2. Theoretical Framework

The pedagogical approach is based on three main axes:
-Creative writing and experiential learning: Student writing is based on research, personal expression, and imagination (Graham & Perin, 2007).
-Learning through art and historical empathy: Children understand history "through" works of art (Eisner, 2002).
-Artificial intelligence as a support tool: It is used only for information retrieval and enrichment of ideas, not to replace student creativity (Luckin et al., 2016).

3. Educational Practice

3.1 Educational Challenge

Students learn to:
-Check and cross-reference information,
-Recognize errors or distortions,
-Understand that AI has no emotion,
-Realize that creation and interpretation belong to humans.

3.2 Central Idea

Each student gives a "voice" to a statue from Greek history and culture (e.g., Aphrodite of Milos, Nike of Samothrace, Discobolus, Parthenon Sculptures). The statues become "windows" into another era, allowing children to connect historical events with emotional experience.

3.3 Learning Process

A. Historical research
-Searching for information in books, museums, and reliable websites.
-The TN is used as a supplementary source for additional information.
B. Evaluation of information
-Identify inaccuracies or omissions in the internet.
-Cross-check information and correct errors.
C. Creative composition
-Composing a monologue with strong emotional charge and imagination.
-Introducing poetic or fictional language, interacting with characteristics of the statues (e.g., wings of Nike, thunderbolt of Zeus).

3.4 The symbolic use of TN

TN functioned as a "research tool," teaching children to:
-Seek information with a critical eye,
-Cross-check data,
-Not settle for easy answers,
-Develop responsibility and autonomy in learning.
Symbolically, AI became a "friend of learning," enhancing historical empathy and imagination without replacing human creativity.

4. Theatrical Presentation

-The students played the roles of the statues, bringing stories, thoughts, and feelings to life.
-Construction objects (wings of Nike, discus of Discobolus, thunderbolt of Zeus, sceptre of Athena) were used for a multisensory experience.
-The theatrical presentation was linked to International Museum Day, honouring culture.

5. Ethical dimension of using TN

-No personal data of students was collected.
-TN did not replace student creativity.
-Students were taught to use TN critically, responsibly, and creatively.

6. Conclusions – Pedagogical Responsibility

The activity proved that children can:
-Utilize technology without becoming dependent on it,
-Understand the limits of TN,
-Create authentically and creatively,
-Respect cultural heritage and connect the past with the present.
IT is a tool when its use does not eliminate human creativity. Education should aim to produce critical users, creative producers, and responsible digital citizens.

7. Self-assessment – Reflection

-Young children can understand complex concepts through experiential learning.
-Differentiation according to class dynamics is crucial.
-In the future, the use of construction elements and collaborative activities will be enhanced.

8. Transferability

The scenario can be applied:
-In other classes and age groups,
-With different cultural objects,
-Even without ICT, using books, museums, and images.

9. Scenario – The Secret of the Statues

(Brief description)

-The children "talk" to statues: Athena, Nike, Discobolus, Zeus, Aphrodite, Alexander the Great.
-They create monologues, evaluate and critically enrich information through TN.
-Construction objects are used to enhance the theatrical presentation.

The Secret of the Statues – Script

Prologue – Educational context
This scenario is designed for first and second grade elementary school students with the aim of experiential learning, creative writing, and theatrical expression. Each statue becomes a "window" into a period of Greek history and culture. Students take on roles, create monologues, use their imagination and props (wings of Nike, discus of Discobolus, thunderbolt of Zeus, sceptre of Athena, etc.) to bring the stories to life. Artificial intelligence is used only as a supportive tool for searching for information and enriching ideas, without replacing student creativity.

Scenario: "The Secret of the Statues"

Author: Athina Nana Pampoukidou

Foreword for teachers

This scenario is aimed at first and second grade elementary school students and aims to connect:
-The history and culture of Greece
-Creative writing and theatrical expression
-The critical and creative use of Artificial Intelligence.
The activity is based on experiential learning: children "talk" to the statues, interpret historical events and emotions, make props (e.g., wings, discs, thunderbolts), and present the story live.
The script is flexible: the roles and statues can be increased or decreased depending on the number of students and the time available.

Statue / Role Description Props / Construction elements Notes

Athena Goddess of wisdom and strategy Spear, shield, helmet The child represents Athena's wisdom and achievements.
Zeus Father of the gods, powerful and majestic Thunderbolt (paper or cardboard), crown Represents power, wisdom, and leadership
Aphrodite Goddess of beauty and harmony Flower wreath, scarf The child expresses beauty, friendliness, charm
Nike of Samothrace Goddess of victory, winged Wings made of paper Speaks of the importance of victory and freedom
Discus thrower Athlete, symbol of the Olympic Games Cardboard discus Teaches discipline, strength, and technique
Alexander the Great General, conqueror Sword, helmet Emphasizes leadership, strategy, and courage
Hermes Messenger of the gods, swift Winged sandals, scarf Carries messages and secrets of the gods

Dionysus God of wine and celebration Bunch of grapes (plastic or paper), cup Teaches joy, revelry, and social life
Caryatid Column in the form of a woman, symbol of civilization Nothing specific—may hold a small book Whispers stories of the past to children
Additional statues Optional: Poseidon, Iris, Hercules, Apollo Depending on the statue Can be used for larger groups of students

Procedure

1. Preparation

-Each student chooses or is assigned a statue/role.
-Gather information about the statue from books, museums, and online sources.
-Use ICT only for supplementary information (e.g., historical context, myths).
-The children note down the basic characteristics and stories of the statue.

2. Creating monologues

-Each student creates a short monologue, incorporating elements of history, emotion, and imagination.
-Add theatrical elements: voice, movement, interaction with other statues.
-Optional: add poetic or fictional speech.

3. Construction objects

-Wings for Nike and Iris
-Discus for Discus Thrower
-Thunderbolt for Zeus
-Spear and shield for Athena
-Grapevine for Dionysus
-Wreath or scarf for Aphrodite
The objects enhance the experiential experience and the feeling of a "living statue."

4. Theatrical presentation

-The students are placed in the space as "statues."
-The teacher guides the flow of the story.
-Each statue speaks in turn, performing its monologue.
-Add interaction between statues (e.g., Greece talks to Nike, Caryatid, Zeus).
-The presentation can be short (~15–20 minutes) or extended if there are more roles.

5. Instructions for using AI

-Use AI to search for images or basic information.
-Do not copy texts verbatim—children compose their own monologues.
-AI is used to enhance imagination and accuracy, not to replace creativity.

6. Suggested extension

-Add additional gods or heroes (Hercules, Apollo, Poseidon).

-Connect with local museums or exhibitions (e.g., National Archaeological Museum).
-Group creation of a "digital museum" with photos of props and short narratives.

7. Learning Objectives

After completing the activity, students will:
-Understand basic elements of Greek history and culture.
-Express emotions and imagination through creative writing.
-Use ICT critically and creatively.
-Develop collaboration and theatrical expression skills.
-Appreciate the importance of cultural heritage.

THE SECRET OF THE STATUES

Theatrical performance

The script I am submitting is an example of many years of creativity and inspiration in school practice.
It has been adapted for children in the first and second grades of elementary school, with simple, understandable, and poetic language, so that children can actively participate, express themselves, and connect with cultural heritage through theater.
This adaptation allows young children to experience their roles with joy and confidence, to understand concepts such as history, art, beauty, and the value of heroes, and to develop their creativity through play and expression.

PROLOGUE

(The statues are already on stage, arranged in a circle.
Greece sits further back. Soft lighting.)

Narrator:

Once upon a time, in a land full of light, stone, and sea,
a civilization was born that spoke with marble, color, and dreams.
This land was called Greece.

It was full of heroes, philosophers, poets, and craftsmen who brought stone to life, building temples and statues that still whisper stories through the centuries.
Traveling through the history of Greece, you don't just see statues.
You see figures that once lived, thought, fought, or loved.
Statues do not speak.
And yet...
if you stand before them with respect and love, they whisper something.
They are the children of Greece. She is proud of them.

(There may be more narrators.)
(Greece slowly rises, walks among the statues, and stands in the center.)

SCENE 1 – ATHENS

(Greece stands still. She sees Athena. She kneels.)
Athena:
Greece, do not be afraid. My spear is not meant to hurt,
but to protect. Wisdom and strategy build cities
and keep a people alive.
When you think before you act, then you are truly strong.

SCENE 2 – CARYATID

(Greece approaches the Caryatid.)
Narrator:
There are people whose souls remain behind when their bodies travel far away.
There are hearts that stand upright in foreign lands, holding on to memories, homeland, and nostalgia. Like hers.

Caryatid:
I have stood here for centuries. Motionless, but never silent. I carry more than just stone.
I carry the culture of an entire world.
I carry weight because I am strong.
And as long as I stand upright, memory does not falter.
But my heart aches.
I am a stranger.
I miss my sisters.
(Greece wipes a tear from the Caryatid's face and moves on.)

TRANSITION – BEFORE THE DISCUS THROWER

Narrator:

Before the games, before the olive wreaths, people first learned to respect.
They respected the body as a gift, the spirit as light, and the opponent as a mirror.
The contest was not a battle.
It was a celebration of balance.

(Greece observes him for a moment.
She walks slowly around him,
looking at him with admiration.)

SCENE 3 – DISCUS THROWER

Discus thrower:
There is movement in my body, but moderation in my spirit.
Power without control is noise. Speed without thought
is chaos.
Our competitions were not born for victory, but for harmony of body and soul.
This is how the Olympic Games were born.

TRANSITION – BEFORE ZEUS

Narrator:

And above them all stood the father of the gods.
Not only as a force, but as a judge.
Because in Greece, even the gods were accountable to justice.

SCENE 4 – ZEUS
Zeus:
I am power, but also responsibility.
Whoever holds power must also uphold justice.
The gods are judged just like humans.

TRANSITION – BEFORE APHRODITE
Narrator:
And then beauty was born.
Not to be admired, but to teach.

SCENE 5 – APHRODITE

(Greece approaches slowly.
He looks at her proudly and gently caresses her hair.)

Aphrodite:
Beauty is not just what you see. It is what you feel.
It is born within you and reflected outside.
Love, kindness, tenderness — these are what make the world human.
When the soul is beautiful, the whole world is illuminated.

SCENE 6 – VICTORY OF SAMOTHRAKI
Narrator:
She was born out of waves and smoke.
Out of naval battles for freedom.
She stood at the bow of a ship, her wings spread wide.

(Greece moves forward, takes deep breaths
and opens her arms like wings.)

Victory:
I am not a cry.
I am a breath after the battle.
I am not noise.
I am silence full of meaning.
I flew away from my homeland, but my heart remained here.
Victory has value only when it returns to its roots.

SCENE 7 – HERMES
Narrator:
There are messages that do not remain static.
They travel through time, cross borders, and seek someone to keep them alive.

(Hermes gives a papyrus scroll to Greece.)
Hermes:
With my wings, I carry stories.
I am the messenger of time.
And today, I carry the voice of Greece from statue to statue.

SCENE 8 – DIONYSUS

Narrator:
And there were celebrations. Laughter, singing, dancing around the light.
Because culture is also born out of joy.

(Greece sits with him and they share grapes.)

Dionysus:
Life needs joy and celebration.
It needs song and sharing.
A people that sings will never be lost.

SCENE 9 – ALEXANDER THE GREAT
Narrator:
And then came the one who did not fit within borders.
Young as spring, bold as a dream, he carried Greece
not as a weapon, but as a light.

(Greece stands proud.)
Alexander the Great:
I did not just conquer places... I brought culture.
And wherever I went, Greece traveled with me.

FINAL SCENE
(Greece walks among the statues. With gentle movements, she calls them close to her and embraces them.)
Narrator:
The statues have souls.
And if they were given life,
they would give us endless stories.
Because all these statues... whether they are here...
or abroad... carry a common secret:
(**All together in a whisper**):

The soul of a civilization that has not been lost and will never be lost.

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Μουσεία και καταλόγους αγαλμάτων-Museums and catalogs of statues:

-Εθνικό Αρχαιολογικό Μουσείο, Αθήνα
-Μουσείο Ακρόπολης, Αθήνα
-Βρετανικό Μουσείο, Λονδίνο – Γλυπτά Παρθενώνα
-Μουσείο Λούβρου, Παρίσι – Αφροδίτη της Μήλου
-Μουσείο Σαμοθράκης – Νίκη της Σαμοθράκης

The Role of Artificial Intelligence in Enhancing School Life: Innovative Approaches for Effective Classroom Crisis Management Crisis Management and Enhancement of School Climate

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Abstract- The integration of AI into education is among the most important axes of pedagogical and institutional change concerning the effective management of complex social and emotional dynamics within current school environments (UNESCO, 2023; European Commission, 2022). The present scientific article examines the ways in which Artificial Intelligence (AI) can function both as a tool and as a catalyst for empowering secondary school teachers and educational institutions in addressing classroom crises as well as social and emotional challenges. The analysis is situated within the specific context of Greece, as shaped by national and European legislation and policy frameworks governing digital learning and teaching (Ministry of Education, 2024; Law 5029/2023).

More specifically, the article aims to explore how AI-informed practices can support a shift in school practice from reactive and fragmented crisis management approaches toward systematic, preventive, and evidence-based strategies that promote social and emotional development and stress management. This perspective aligns with well-established frameworks of Social and Emotional Learning (SEL), which emphasize the positive impact of structured, whole-school interventions on students' academic achievement, psychosocial well-being, and teachers' professional resilience (Durlak et al., 2011; CASEL, 2020).

Within this framework, the school is conceptualized as a dynamic pedagogical environment in which challenges such as interpersonal conflicts, externalizing behaviors, disruptions to academic processes, teacher stress and heightened emotional intensity are not treated solely as problems requiring immediate control. Instead, they are reframed as pedagogical opportunities for fostering social and emotional competencies. The strategic integration of AI tools can facilitate this transformation by providing data-informed insights, early identification mechanisms and tailored pedagogical interventions, thereby supporting a culture of prevention, empowerment and sustainable social and emotional growth within the school community. Thus, AI is perceived as a pedagogical intervention and its usefulness is conceived in the context of the wider ecological organization of a democratic, socially and emotionally safe, pedagogically supportive and inclusive school context. Particular emphasis is placed on pedagogical processes supported by AI-based tools that foster prevention and early intervention, self- and co-regulation, and systematic pedagogical reflection, within

clearly defined ethical, data protection, and humanistic pedagogical boundaries (UNESCO, 2023). The paper draws on theories of Social and Emotional Learning (SEL) and behavior change, as well as self-regulation frameworks, to examine how AI-enabled tools can enhance emotional awareness, self-awareness, empathy, emotion regulation, and collaborative problem-solving skills.

The findings suggest that pedagogically meaningful applications of AI-supported tools have the potential to positively influence school climate and student well-being, provided that teachers are positioned as the central agents of change within the school context and that coherent, long-term institutional structures are designed and implemented to support educators.

In conclusion, the study argues that AI can serve as a constructive and effective enabler of pedagogical transformation in the area of crisis prevention and management in schools, on the condition that human-centered organizational frameworks suited to the digital era are established and sustained, that ongoing and supportive teacher professional development initiatives are maintained, and that transparent and pedagogically grounded practice frameworks are consistently applied (European Commission, 2022; Law 5029/2023; UNESCO, 2023).

Keywords- Artificial Intelligence in Education, Classroom Crisis Management, School Climate, Social-Emotional Learning, School Violence Prevention, Pedagogical Innovation

Introduction

School violence and bullying constitute predominant socio-pedagogical phenomena of the contemporary educational landscape, with multifaceted implications for both the teaching–learning process and the psychosocial development of students. These phenomena are associated with adverse academic outcomes, increased emotional distress, diminished sense of school belonging, and long-term risks for students' mental health and social adjustment (Olweus, 2013; Espelage & Swearer, 2010).

Within school settings, incidents of violence and bullying often manifest through interpersonal conflict, externalizing behaviors, emotional dysregulation, and disruptions of instructional continuity, placing significant pressure on teachers and school leadership. As a result, educators are frequently required to manage complex classroom crises while simultaneously sustaining a safe, inclusive, and emotionally supportive learning environment. Traditional responses to such challenges have largely focused on reactive disciplinary measures, which, while necessary in certain cases, have been shown to be insufficient in addressing the underlying social and emotional factors that contribute to aggressive and exclusionary behaviors (Smith, 2016).

In Greece, school violence directly affects the pedagogical climate, psychological security and the interpersonal relationships in the school, with consequent effects on the quality of education (Katsakiori, 2023; Hellenic Statistical Authority, 2025). Recent educational research concludes that the "reactive" approach to school violence and crisis management, the one focused mainly on disciplinary measures, is limited in understanding the resilience of such phenomena. School should instead adopt preventive, holistic and participative strategies, based on emotional competences, on relationship skills and on fostering a positive school climate (Durlak et al., 2011; CASEL, 2020). Within the scope of school pedagogy, Social, Emotional Learning (SEL) has been already established as an essential context to develop resilience, empathy, critical thinking and rational decision making and constructivist conflict resolutions. At the same time, the rapid development of AI technology has provided a field of multi dimensions possibilities to support pedagogical processes, decision making and personalized learning. Nowadays, AI is approached more and more as an aid to education that can complement practices that strengthen prevention, early interventions and reflexivity of educators, when developed reliably and ethically (UNESCO, 2023; European Commission, 2022). The purpose of this scientific article is to investigate the contribution of AI as an empowerment and support tool to manage crises in the classroom, in particular in the context of secondary education in Greece, where the pedagogical framework of the implementation of the Greek education system is aligned with all the current policies and practices prevailing in the United States as well as in the European digital pedagogical policies (Ministry of Education, 2024; Law 5029/2023). More specifically, the study seeks to examine how AI-assisted pedagogical practices can facilitate the identification and constructive management of social and emotional challenges within school settings, transforming moments of crisis into meaningful learning experiences and opportunities for personal development, civic participation, and democratic engagement. By situating the use of AI within broader pedagogical and institutional frameworks that prioritize human-centered values, responsible governance, and the protection of teachers' professional autonomy, the research aspires to enhance the contribution of AI to pedagogically sound, ethically grounded, and socially responsible educational practice.

1. Institutional Measures and Pedagogical Practices

1.1 Law 5029/2023

Law 5029/2023 (Government Gazette 55/10.03.2023), entitled *"Living Together in Harmony – Breaking the Silence"*, constitutes a significant development in Greek educational legislation and policy concerning the prevention and management of school violence and bullying. The law builds upon and further strengthens the institutional framework initially established by Law 4823/2021, adopting a systemic approach that prioritizes the identification of underlying causes and the implementation of preventive intervention mechanisms, rather than relying primarily on disciplinary or punitive responses (Law 5029/2023, Art. 1).

As articulated in Article 2, the primary objective of the law is to enhance relationships of trust among all members of the educational community, including students, teachers, administrative staff, and parents. This objective is pursued through a range of preventive pedagogical measures, the introduction of digital early-warning and reporting mechanisms, and the implementation of targeted, restorative, and supportive interventions for all parties involved in incidents of school violence and bullying (Law 5029/2023, Art. 2). The guiding principle underlying these provisions is a clear shift from a punitive logic toward a culture of prevention and shared responsibility, emphasizing care, accountability, and collective engagement within the school community.

Of particular significance is the law's recognition of the multidimensional and complex nature of school violence and bullying, as defined in Article 3. The forms of violence identified encompass physical aggression (e.g., assault), verbal abuse (e.g., insults), psychological violence (e.g., social exclusion), social violence (e.g., defamation), as well as racist and sexist violence and cyberbullying. This comprehensive conceptualization reflects an understanding of school violence as a multifaceted phenomenon requiring coordinated, inclusive, and pedagogically grounded responses.

All these types of violence or intimidation, also including the exertion of force and coercion to impose behavior or behavior regulations, are regarded as school violence which disturbs the smooth conduct of the educational process and undermines the safe environment of the schools (Law 5029/2023, Art.3). Such a multidimensional categorization maintains the response sensitive, contextual, differentiated, less biased, and proportionate to the severity and nature of occurrence. At the policy level, emphasis is placed on the responsibility of the Ministry of Education and Religious Affairs, the Institute of Educational Policy (IEP), and the Computer Technology Institute and Press 'Diophantus' in the development and application of national prevention schemes, pedagogical sessions and professional development events addressed to teachers and students, respectively, for the construction of culture and shared responsibility regarding collaboration, conflict management, and cyber rights and responsibilities (Law 5029/2023, Art. 5). Furthermore, all educational levels will deploy digital pedagogy contents to promotion of consciousness and prevention activities (Law 5029/2023, Art. 5). Significantly, Article 6 institutes the operation of a new digital platform through which reports of school violence and bullying are submitted and collected. This platform can be used anonymously or not by teachers and students alike,

also acts as a national registry, allowing sort, analyses by time span, thematic issues, and study of practices (Law 5029/2023, Art.6). Its usage falls within the limits of the General Data Protection Regulation (GDPR), and it immediately involves authorities for the case management (Law 5029/2023, Art.6). On the school level, Agency 7 calls for the School Principal and the responsible teachers to be the primary recipients of reports and pass them along to the school review committees within 24 hours (Law 5029/2023, Art.7). This preliminary review by four, member school committee (School Principal, responsible teacher, psychologist or social worker or if absent one day aweek, a random teacher from the school) takes five working days and results in a formal report with suggestions for intervention strategies (Law 5029/2023, Art.8). Incidents that are considered of lower severity will involve mitigation and pedagogical interventions (e. g. mediated group communication, reconciliation actions, one to one or between groups' discussion), whereas serious recurrent incidents will call for action teams formed with the consent of the Province's education directorate to provide action support, staff training, and ongoing monitoring with annual reporting (Law 5029/2023, Arts 9, 10). Furthermore, Articles 12 and 13 institutionalize an anti-victimization approach through the establishment of an anonymous helpline and a Scientific Committee. The latter is entrusted with the responsibility of issuing national guidelines for the handling of school violence cases, informed by the systematic analysis of data generated through the digital reporting platform and grounded in international best practices and contemporary research evidence.

Although Law 5029/2023 introduces a more advanced and coherent institutional framework compared to earlier legislative provisions, its effective implementation remains contingent upon the continuous professional development of all stakeholders involved. Moreover, as highlighted by the Institute of Educational Policy (IEP, 2024), the law's impact can be further strengthened through the integration of emerging and collaborative educational technologies, including the responsible use of Artificial Intelligence to support the early identification of potential risk indicators and the timely implementation of preventive interventions.

1.2 Alternative Pedagogical Practices and School Mediation

Alternative pedagogical practices constitute important additions to the measures put in place by the institutional tools of Law 5029/2023, both in terms of redirecting the policies of the school towards prevention, experiential learning and restoration of relationships experienced in schools, instead of repression and punishment, and in terms of pedagogical approaches promoting students' empowerment and responsibility, social cohesion and empathy, and avoiding discrimination, marginalization and stigmatization (Gournelou & Semitekou, 2021). Thus, within this framework, school mediation constitutes one of the best documented practices, which has been studied systematically in the Greek educational system, through Thanos' (2017) model, supported by the University of Ioannina. These practices aim to create an inclusive school culture founded on dialogue, respect and cooperation, not focus on individual cases of violence. School mediation is an educational intervention, which has been characterized by the research as a socio, emotional oriented activity with a focus on improving school life. According to Thanos' (2017) model of school mediation, there are five core principles, discretion, confidentiality, respect, equality of the participants, neutrality of the mediator, and participation in the process is voluntary, as it is based on the proposal and the agreement of the students involved; it is functional, because it does

not involve any form of authority or judgment; and the mediator teacher acts simply as a facilitator of dialogue. School mediation refers to the construction of a school culture conducive to problem solving, through the development of skills like participation, responsibility, negotiation and conflict regulation and not to individual incidents, and contributes to the empowerment of students in their capability to regulate feelings and behaviors, but also negotiate in cases of specific difficulties, as these could be associated both with universal social and emotional skills, as well as with situations of bullying. Finally, the model can provide high cost/benefit ratio, because, involves only 20 to 30 hours of training and the pedagogical outcomes can be lasting (Thanos, 2017). With respect to the implementation process, the initiation comprises a preparatory phase, during which the students are selected and trained, a referral phase, where conflicts are proposed to the mediators, a sixth phase, in which students are brought together for their interaction, and a final phase, where the success of the settlement is checked and mediated relationships are evaluated. School mediation can be fully aligned with the aims and methods defined in Articles 8, 10 of Law 5029/2023, supporting the establishment of the four school member committees and the development of peer mediation practices, transforming the school into a space of democratic, education, where conflicts cease to be punished and are only a pedagogical opportunity for growth and social participation.

1.3 Deep Democracy and Education

Deep Democracy is a participatory intervention procedure in groups, inspired by the Process Oriented Psychology of Arnold and Amy Mindell (Mindell, 1995; IAPOP, 2025), focusing on transforming tensions, conflicts, and disagreements into pedagogical opportunities for learning and democratic development. In education, it serves both as a method for implementing participatory decision-making in groups and as a pedagogical theory with practices aimed at turning disagreements into rich learning experiences and active democratic education (Lewis, 2015).

Core Principles

It recognizes the need to include all voices, even the "weak or silent" ones, as "all voices matter" and "every voice bears the wisdom of a teacher for the group's growth" (Ammann, 2022). When voices are excluded, polarization and alienation emerge, potentially leading to violence. According to the "Conscious-Unconscious Iceberg Model," observable views reflect only a minor part of the dynamic, while the unconscious holds "ghost roles" (unspoken restrictions), unexpressed minority voices, and invisible relational aspects. Deep Democracy aims to zero the Resistance Line until the dissenting minority is heard.Four-Step Process

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Educational Tools

In schools, techniques include check-in/check-out for safety and awareness, Dynamic Dialogue for empathy via role-playing, the four-step decision-making procedure, and the Soft Shoe Shuffle tool to expose group dynamics and escalate conflicts (Bouckaert, n.d.; Hosting Transformation, n.d.). This facilitates early detection of latent conflicts, preventing school violence and bullying, promotes a culture of collaboration and trust, and aligns with Law 5029/2023 and four-member school committees (ΦΕΚ Α' 55/2023). The classroom becomes a "microdemocracy," preparing students for responsible participation in society (Mindell, 2014).

1.4 CASEL, Social and Emotional Learning (SEL), and Pedagogical Integration in Greek Education

Social and Emotional Learning (SEL) constitutes one of the most evidence-based and internationally recognized pedagogical frameworks for fostering students' holistic development, as it systematically addresses not only cognitive but also emotional, social, and ethical dimensions of learning. According to the Collaborative for Academic, Social, and Emotional Learning (CASEL), SEL is a structured and ongoing educational process through which children and adolescents develop five core, interrelated competencies: self-awareness, the ability to recognize one's emotions, values, and strengths; self-management, encompassing the regulation of emotions, thoughts, and behaviors; responsible decision-making; relationship management through cooperation and conflict resolution; and social awareness, which involves empathy, respect for diversity, and active engagement in the community (CASEL, 2020).

The revised CASEL framework extends across the entire developmental trajectory—from early childhood to adulthood—acknowledging that social and emotional skills are cultivated throughout life. Particular emphasis is placed on equity and inclusion, recognizing that SEL is not solely the responsibility of schools but results from holistic collaboration among schools, families, and the wider community. Through this systemic approach, SEL contributes to the creation of supportive learning environments that enhance students' sense of belonging and psychosocial resilience.

The efficacy of SEL is strongly supported by international empirical evidence. A meta-analysis by Durlak et al. (2011), encompassing 213 SEL programs, demonstrated substantial improvements in academic achievement (11 percentile points), reductions in problem and aggressive behaviors (approximately 9%), and enhanced positive social attitudes. Subsequent research confirms the long-term benefits of SEL, including higher secondary school graduation rates, increased access to tertiary education, and improved employment prospects and social integration in adulthood (Taylor et al., 2017).

In the Greek educational context, SEL has begun to be systematically implemented primarily through pilot and approved programs under the scientific supervision of the Institute of Educational Policy (IEP). For example, the Youth Power program, implemented with 617 students aged 10–12 in schools in Athens, Thessaloniki, and Ioannina, showed significant improvements in participants' social and emotional skills regardless of socioeconomic background. Similarly, the ENABLE program, involving

508 students aged 11–14, effectively contributed to reducing bullying through the reinforcement of peer support. Additionally, anti-hate speech initiatives have trained over 3,500 primary and secondary school students, yielding highly positive feedback from both students and educators (IEP, 2024).

A key feature of SEL is that it is not an isolated or extracurricular activity but is pedagogically embedded within existing structures and institutions of the Greek education system. In Skills Labs, activities aim to enhance self-regulation, emotional recognition and management, and social skills through experiential and collaborative methods. Moreover, IEP-approved programs, such as "Me & You… Growing Stronger Together" (University of Patras), cultivate SEL through arts-based activities, drama, and group dynamics, fostering expression, collaboration, and empathy (IEP, 2024).

Active Citizenship initiatives represent another domain in which CASEL's core principles are meaningfully integrated, promoting responsible decision-making, democratic participation, and social responsibility. According to the 2024 Teachers' Guide, these activities connect school-based learning to real-world social issues, enhancing students' critical thinking and civic engagement (Ministry of Education, 2024). Additionally, SEL is incorporated across various school programs: in Health Education, the focus is on stress resilience and self-management; Cultural Programs emphasize empathy, teamwork, and intercultural respect; and Environmental Programs promote responsible decision-making and acceptance of diversity.

Particular importance is given to the application of SEL in extracurricular clubs and activities, where peer mediation practices, social skills workshops, and collaborative projects are developed. Model and Experimental Schools, due to their enhanced pedagogical autonomy, pioneer innovative SEL interventions, serving as laboratories for best practices within the national education system. Concurrently, IEP and the "Diophantus" Institute contribute to the production and dissemination of digital educational materials that support systematic classroom implementation of SEL.

Finally, Law 5029/2023 indirectly but substantially incorporates SEL principles within the four-member school committees addressing in-school violence, particularly in Articles 8–10, complementing the framework established by Law 4823/2021. Emphasis on emotion management, dialogue, and relationship restoration positions SEL as a central pillar of school violence prevention. Despite increasing interest, over 80% of teachers report the need for systematic professional development and enhanced digital infrastructure to ensure the consistent and sustainable implementation of SEL. Overall, Social and Emotional Learning constitutes a critical instrument for creating resilient, democratic, and inclusive schools fully aligned with the contemporary demands of the digital and social era.

2. Artificial Intelligence in Education

2.1 Theoretical Paradigm of AI in School Violence Prevention

Over the past decade, Artificial Intelligence (AI) has emerged as a rapidly evolving innovation within the repertoire of complementary measures for the prevention and management of school violence, strengthening pedagogical and psychosocial interventions grounded in Social and Emotional Learning (SEL). At a global level, the

integration of AI within the CASEL framework signals a paradigm shift in educational care, moving schools from reactive crisis management approaches toward predictive, preventive, and personalized models of support. These models are rooted in large-scale data analysis, continuous feedback loops, and timely, context-sensitive interventions aimed at mitigating the escalation of violent behaviors (CASEL, 2020).

The theoretical model underpinning the use of AI in school violence prevention is structured around three interdependent core pillars. First, it involves data-driven predictive analytics, including training in the identification, interpretation, and anticipation of emotional states through sentiment analysis, alongside the implementation of adaptive digital interventions. Second, these processes are embedded within an integrated, self-regulating system that enables early risk detection, the timely de-escalation of emotionally charged situations, and the systematic cultivation of social and emotional competencies at both individual and group levels. Third, the model incorporates advances in machine learning and statistical analysis to identify early indicators and precursors of violent escalation within large and heterogeneous educational datasets, such as academic performance, attendance records, teacher evaluations, digital activity logs, and indicators of social interaction. In parallel, natural language processing (NLP), multimodal pattern recognition, and speech analysis techniques are employed to analyze textual, auditory, and visual data streams, generating real-time, dynamically evolving emotional profiles of students and enhancing educators' emotional awareness through discreet early-alert signals (CASEL, 2020; Taylor et al., 2017).

Within this conceptualization, the systematic use of AI is not construed as an invasive surveillance mechanism but rather as a pedagogical and emotional empowerment tool. Textual or visual alerts are designed as low-stigma, non-intrusive triggers that activate gentle preventive responses, such as self-regulation applications, augmented reality tools that enhance self-awareness, and structured collaborative dialogue facilitated through digital communication channels. Through these mechanisms, core SEL competencies—particularly emotional recognition and stress management—are fostered authentically and seamlessly within natural, real-time learning environments.

A third fundamental component of the model is the deployment of digitally mediated, adaptive, rapid-response interventions. These interventions consist of short, individualized, and unobtrusive pedagogical strategies that respond to the immediate social and psychological needs of students. They incorporate proactive conversational techniques to address emotional intensity and anxiety, personalize emotion regulation pathways, and employ flexible group configurations to strengthen social bonding and community formation. Drawing on established practices from digital mental health interventions and adapted to educational contexts, this AI-mediated model aims to prevent the immediate escalation of distress and to promote resilience and social-emotional competence development (Institute of Educational Policy [IEP], 2024).

Through the convergence of SEL and AI, the model seeks to support all five core CASEL competencies in an integrated and augmented manner. Self-awareness is fostered through context-sensitive self-observation and reflective self-assessment; self-management through digital mood monitoring and self-regulation coaching; responsible decision-making through intelligent scenario-based simulations and recommendation systems; social awareness and empathy through emotion recognition

and culturally responsive stimuli; and relationship skills through conflict alerts and relational mapping tools that support constructive interpersonal engagement. As the system evolves, it continuously adapts, enhancing predictive accuracy and expanding opportunities for personalized student and classroom experiences (CASEL, 2020).

Crucially, the model positions teachers as the central agents of change. Educators are empowered as facilitators of transformation through reflective and deep pedagogical engagement, supported rather than replaced by AI. Automation of data processing, transcription, and observational documentation reduces the burden of repetitive administrative tasks, thereby freeing cognitive and emotional resources for creative, mindful instruction, relational work, and holistic guidance (Ministry of Education, 2024).

In conclusion, the theoretical framework of AI-assisted school violence prevention envisions the school as a forward-looking learning community grounded in predictive pedagogy. Within this model, AI functions as an enabling infrastructure that amplifies human pedagogical capacity, supports ethical and human-centered educational practice, and reinforces—rather than substitutes—the professional role of educators in fostering safe, inclusive, and emotionally responsive school environments.

2.2 Integration of CASEL Competencies in the School Environment with AI Support, Gamification, and Interactivity

The pedagogical implementation of the five core Social and Emotional Learning (SEL) competencies, as conceptualized by CASEL (2020), can be enhanced through the integration of Artificial Intelligence (AI), gamification, and interactive learning strategies. In contemporary schools, this integration operates within a hybrid pedagogical framework, in which SEL-oriented activities are complemented by AI-driven predictive analytics, adaptive interventions, and gamified learning sequences. Such an approach constitutes a holistic, learner-centered process that personalizes experiential learning based on metacognitive modalities and guides students through immersive, interactive, and animated educational experiences. These strategies aim to achieve two primary pedagogical outcomes: (a) effective, individualized classroom learning via scaffolding and adaptive support, and (b) the autonomous transfer of acquired skills to students' broader academic and extracurricular contexts (Mourtzaki & Mavridis, 2022; Durlak et al., 2011).

Within this framework, the five SEL competencies serve as the pedagogical scaffolding upon which human-centered AI functionality is constructed. AI facilitates the gamified recognition, simulation, and feedback of internal emotional states and behaviors in lifelike environments, thereby enhancing learner engagement, transferability of skills, and overall pedagogical efficacy (CASEL, 2020). The competencies are operationalized as follows:

1. Self-Awareness: This competency emphasizes the learner's reflective capacity, including awareness of innate emotional states, recognition of internal triggers for behavioral responses, and opportunities for strategic adaptation. AI supports the development of self-awareness by providing real-time, individualized feedback that fosters intrapersonal insight and conflict prevention without functioning as an external overseer of the learner (Durlak et al., 2011).

2. Self-Management: Focused on the mastery of self-regulation in diverse contexts, this competency involves developing flexible coping strategies to navigate stress and challenging scenarios. AI-enabled pedagogical tools—through guided simulators, gamified exercises, and dual-feedback mechanisms—promote resilience, strategic judgment, and emotion regulation. Acting as a pedagogical co-player, AI enhances students' ability to apply self-regulation techniques, such as mindfulness, breathing exercises, or self-monitoring, in authentic school contexts (Taylor et al., 2017).
3. Social Awareness: This competency targets the development of empathy, intercultural sensitivity, and social perception. AI can individualize socio-ethical dilemmas, providing a safe virtual space for experimentation, reflection, and learning, while promoting cooperative team activities and responsible engagement. By tailoring scenarios to student-specific profiles, AI supports the internalization of social competencies and the application of empathetic understanding in academic and social interactions.
4. Relationship Skills, Responsible Decision-Making, and Social Responsibility: These remaining competencies build on the first three by engaging students in the identification and resolution of social friction, collaborative problem-solving, role negotiation, and conflict resolution. Gamified collaborative tasks, matrixed simulations, and interactive challenges foster social cohesion, active listening, negotiation, and interpersonal competence, aligning with the objectives of Law 5029/2023 on school violence prevention (Ministry of Education, 2024).
5. Responsible Decision-Making: This competency is reinforced through predictive scenarios, moral dilemmas, ethical questioning, and reflective exercises, in which students evaluate possible actions, outcomes, and alternative solutions. These activities enhance critical thinking, consensus-building, and the transfer of SEL competencies to practical, real-world decision-making contexts.

The integration of AI and gamification within SEL is guided by the principles of Self-Determination Theory (Deci & Ryan, 2000), emphasizing autonomy, competence, and relatedness as essential dimensions for fostering psychologically guided, intrapersonal and interpersonal behavioral development. Dynamic adjustment of task difficulty, multimodal feedback, achievement recognition, and continuous metacognitive scaffolding supports the mastery of SEL competencies in authentic learning contexts. Simultaneously, educators assume the role of pedagogical facilitators or "conductors," leveraging AI dashboards, analytics, and real-time feedback to orchestrate learning experiences while preserving human-centered guidance, reflection, and relational engagement.

Over the past decade, AI has emerged as a rapidly evolving tool for supporting pedagogical and psychosocial interventions grounded in SEL. Globally, AI integration within the CASEL framework represents a shift from reactive crisis management toward predictive, preventive, and personalized educational care, leveraging large-scale data analysis, continuous feedback, and timely interventions to mitigate the escalation of violent behaviors (CASEL, 2020).

The theoretical model of AI for school violence prevention is anchored on three interdependent pillars:

1. Data-Driven Predictive Analytics: AI systems analyze student behavior, emotional states, and contextual indicators through techniques such as sentiment analysis, multimodal pattern recognition, and natural language processing.

Predictive algorithms identify early risk patterns, enabling timely, individualized interventions.

2. Integrated, Self-Regulating Systems: These systems enable early detection of risks, de-escalation of tense situations, and the systematic cultivation of social and emotional skills at both individual and group levels. Adaptive learning and feedback mechanisms allow AI to support emotional regulation, empathy, and collaborative problem-solving without supplanting teacher judgment (Taylor et al., 2017).

3. Machine Learning and Statistical Modeling for Early Warning: AI leverages large, heterogeneous educational datasets—including academic records, attendance, digital activity, and social interaction parameters—to predict potential escalation of violence. These models, combined with real-time analysis of textual, auditory, and visual input, enhance teachers' situational awareness while remaining discreet and non-intrusive (CASEL, 2020; IEP, 2024).

In this framework, AI functions not as a surveillance tool but as a pedagogical and emotional empowerment mechanism. Alerts are designed to be low-stigma, discreet triggers that promote self-regulation, collaborative dialogue, and experiential SEL interventions. Short, adaptive, and individualized strategies respond to students' immediate socio-emotional needs, fostering resilience, emotional competence, and positive classroom climates.

2.3 Challenges and Ethical Issues of Artificial Intelligence in Education

The integration of Artificial Intelligence (AI) in education, particularly in applications addressing school violence prevention and supporting Social-Emotional Learning (SEL), presents multiple technological, pedagogical, and ethical challenges. These challenges make careful design, implementation, and regulatory oversight of such systems imperative (UNESCO, 2023). The criticality of these challenges lies in the risk of exacerbating existing inequalities, undermining core pedagogical principles, and potentially degrading the quality of school relationships, necessitating human-in-the-loop architectures and the development of coherent frameworks for managing ethical and technological issues.

Data protection and compliance with the General Data Protection Regulation (GDPR) constitute primary challenges in educational AI use, as these systems require extensive collection of sensitive personal data, including biometric features (e.g., voice patterns, physiological indicators, emotional profiles) and behavioral data (e.g., interactions, digital footprints, participation in platforms). The processing of such data often conflicts with key GDPR principles, such as data minimization and purpose limitation, exposing students to potential risks of leakage or misuse. Furthermore, the absence of parental consent mechanisms for systems collecting real-time data creates legal liability for educational institutions. To mitigate these risks, federated learning architectures are recommended, which maintain data locally, reduce the need for central aggregation, and ensure higher levels of data protection (Institute of Educational Policy [IEP], 2024).

Algorithmic bias and fair assessment represent an additional critical dimension, as machine learning models may amplify social inequalities through bias amplification, leading to misclassification of students, particularly those from vulnerable groups, such as migrant students or those from low socioeconomic backgrounds. Studies indicate

that false-positive rates in sentiment analysis can be significantly higher for minority students, leading to stigmatization and excessive interventions. The limited availability of educational datasets reflecting the Greek context exacerbates this issue, making the implementation of bias auditing protocols, explainable AI (XAI) methods, and transparent decision-making processes essential (Durlak et al., 2011).

The digital divide and accessibility are also determining factors, as unequal distribution of technological infrastructure intensifies educational disparities. In particular, rural schools or institutions with limited technological resources risk cognitive offloading, i.e., reduced critical thinking and learning autonomy, disproportionately affecting students from lower socioeconomic backgrounds. The transition to low-resource AI models and hybrid deployment strategies, such as on-premise cloud solutions, is necessary to promote inclusive and equitable practices (Ministry of Education, 2024).

Over-surveillance and psychological pressure constitute further challenges, as the constant surveillance culture embedded in AI tools creates panopticon effects, increasing anxiety, self-censorship, and inhibition among students. Excessive quantification of emotions may reduce emotional authenticity, and inappropriate use of gamification mechanisms, such as leaderboards and badges, may foster unhealthy competition. Research highlights the privacy paradox, wherein students accept monitoring for perceived benefits while disregarding potential long-term psychosocial consequences (Taylor et al., 2017).

The potential replacement of human relationships and pedagogical alienation emerges as a fundamental concern, as AI risks substituting empathic human judgment with algorithmic approaches, reducing authentic pedagogical interactions and mentoring opportunities. The deskilling of educators through automated monitoring systems limits pedagogical creativity and the capacity for personalized guidance, underscoring the need to develop symbiotic AI–human frameworks that empower rather than replace teacher judgment (CASEL, 2020).

Plagiarism, misinformation, and deepfakes are emerging challenges associated with generative AI. Misuse can facilitate academic dishonesty, produce deepfake harassment, and threaten academic integrity, while hallucination risks in natural language processing (NLP) models generate misinformation. Moreover, emotional manipulation via bots poses serious threats to student mental health, making the integration of AI literacy curricula and detection mechanisms essential for responsible technology use (UNESCO, 2023).

The regulatory and institutional framework is foundational for the safe and ethical use of AI in education. The absence of clear national guidelines creates a regulatory vacuum and exposes schools to liability risks. Alignment with the EU AI Act (2024) requires risk-based classification of AI tools as high-risk systems, enforcing conformity assessments and post-market surveillance. In the Greek educational context, Law 5029/2023 provides partial guidance, emphasizing the need to develop a national strategy for AI implementation in education and to adapt tools to safe, ethical, and pedagogically sound practices (IEP, 2024).

Overall, these challenges require multi-stakeholder governance, where educators, technologists, legislators, and parents collaborate to balance innovation, protection, and

pedagogical reliability, ensuring that AI functions as an augmentation tool that enhances, rather than replaces, human judgment and pedagogical relationships within the educational process.

6. 3. Practical Applications of Artificial Intelligence in School Violence Prevention

The integration of Artificial Intelligence (AI) into educational practice, particularly in the context of preventing school violence and promoting Social and Emotional Learning (SEL), represents a paradigmatic shift from traditional top-down disciplinary approaches to experiential, individualized, and proactive pedagogical interventions (CASEL, 2020; Durlak et al., 2011). Whereas conventional interventions often respond reactively to incidents of aggression or conflict, AI-enabled tools allow educators to anticipate, prevent, and mediate social and emotional challenges in real time. The application of AI occurs across multiple levels of the school ecosystem—ranging from the individual student to classroom, group, and school-wide contexts—allowing for a multilayered and systemic approach to both preventive and intervention practices. A variety of AI platforms, including Mizou, TeachQuest, Napkin AI, Musely.ai, ClassMana, and NotebookLM, exemplify the integration of predictive, personalized, and collaborative AI interventions within contemporary educational settings.

3.1 Individual Level: Personalized Student Support with Mizou

At the individual level, Mizou functions as a digital SEL tutor, providing one-on-one guidance and support for students identified as being at risk for aggression, anxiety, or other behavioral challenges. For instance, in a pilot intervention, a student exhibiting impulsive behaviors such as conflict with peers or minor infractions, including lunchroom disputes or classroom disruptions, engages with Mizou through interactive dialogue sessions. During these sessions, the digital avatar provides personalized exercises in self-regulation, mindfulness, emotion recognition, and breathing techniques.

Through continuous engagement, Mizou assists students in identifying emotional triggers, practicing adaptive coping strategies, and applying these skills proactively to prevent escalation of frustration or aggressive responses. In parallel, Mizou collects de-identified affective and usage data, enabling educators to receive early warning signals regarding heightened anxiety, stress, or frustration. For example, prior to an exam, if a student exhibits elevated stress indicators, Mizou can recommend targeted interventions, such as brief relaxation exercises, reflective journaling, or pre-emptive teacher-led support, minimizing the likelihood of conflict and promoting proactive socio-emotional regulation (Durlak et al., 2011).

Importantly, this individualized approach preserves student autonomy, positioning AI as a supportive facilitator rather than a surveillance mechanism, while simultaneously providing teachers with actionable insights to guide pedagogical decision-making.

3.2 Group Level: Collaborative Learning and Conflict Resolution with TeachQuest and Napkin AI

At the group level, AI tools such as TeachQuest and Napkin AI support collaborative learning and socio-emotional skill development by structuring classrooms as interactive

problem-solving ecosystems. TeachQuest introduces scenario-based “missions” in which students engage with avatars representing different behaviors in contexts such as cyberbullying, peer conflict, or group decision-making dilemmas. Students collaboratively analyze the scenarios, debate possible interventions, and select appropriate conflict resolution strategies, thereby practicing social awareness, empathy, and cooperative problem-solving.

Napkin AI enhances these activities by generating dynamic visualizations, including mind maps, emotional wheels, and relationship diagrams. These tools enable students to identify the sources and consequences of emotions, track reactions, and conceptualize strategies for resolving conflicts. By combining TeachQuest with Napkin AI, educators facilitate a learning environment in which collaborative skills, perspective-taking, and emotional intelligence are explicitly developed and reinforced. Students are encouraged to understand group dynamics, anticipate potential triggers of conflict, and engage in collective problem-solving, fostering classroom cohesion and proactive violence prevention.

3.3 Classroom Level: Management and Prevention with Musely.ai and ClassMana
At the classroom level, AI applications such as Musely.ai and ClassMana provide comprehensive support for the design, delivery, and monitoring of SEL curricula tailored to violence prevention. Musely.ai automatically generates lesson plans aligned with the five core CASEL competencies, integrating role-play exercises, group discussions, and reflective activities that address both individual and collective needs. The platform adapts lessons to the specific composition of the classroom, providing additional scaffolding for students identified as more prone to conflict.

ClassMana operates as a real-time classroom climate monitoring system. Through dashboards and analytics, teachers can visualize trends in student behavior, detect early signs of tension or social exclusion, and implement proactive interventions before escalation occurs. For instance, if the system identifies patterns of hostility or group segregation, it may suggest targeted collaborative exercises, reflective discussions, or peer-mediated problem-solving tasks. The combination of Musely.ai and ClassMana ensures that classroom management strategies are evidence-based, data-informed, and continuously responsive to evolving socio-emotional dynamics.

3.4 School Level: Strategic Planning and Policy Alignment with NotebookLM

At the institutional or school-wide level, NotebookLM functions as a research, planning, and policy alignment tool. Educators, counselors, and school administrators can synthesize incident reports, institutional guidelines, and research-based best practices to develop comprehensive, data-informed prevention plans. NotebookLM supports the continuous development of pedagogical resources, aligning SEL curricula and intervention measures with cultural, social, and contextual factors specific to the school community.

By integrating behavioral data from individual students, classroom-level analytics, and group-level insights, NotebookLM enables the design of holistic, participatory, and safeguarded learning ecosystems. Schools are empowered to monitor, evaluate, and iteratively refine their SEL and violence prevention strategies, ensuring that

interventions remain culturally sensitive, ethically grounded, and pedagogically effective.

3.5 Integrated Implementation Strategy

The application of AI in school violence prevention can be conceptualized as a multilayered, iterative process that integrates tools across individual, group, classroom, and school levels. A representative framework includes:

1. Detection and Observation: NotebookLM captures and organizes behavioral incidents, linking them with ongoing monitoring from Mizou to provide a continuous evidence-based overview.
2. Individualized Intervention: Digital avatars and AI-guided lessons (e.g., Mizou, Musely.ai) deliver personalized support targeting students' socio-emotional needs.
3. Reinforcement and Collaborative Learning: TeachQuest and Napkin AI facilitate collaborative reflection, conceptualization of emotions, and group-based problem-solving.
4. Monitoring, Evaluation, and Adjustment: ClassMana dashboards provide continuous feedback on behavioral trends, enabling educators to assess intervention effectiveness, adapt strategies, and ensure long-term sustainability.

3.6 Educational Benefits and Impact on School Violence Prevention

The integrated deployment of AI tools fosters the development of a resilient, SEL-oriented school ecosystem. Key educational benefits include:

- Customized Instruction: Tailored interventions for individual students (Mizou) and differentiated group learning experiences (TeachQuest).
- Content Creation and Categorization: Adaptive generation of SEL curricula and learning resources (Napkin AI, Musely.ai).
- Behavior Monitoring and Assessment: Continuous tracking of student behavior trends and classroom climate (ClassMana).
- Strategic Planning and Iterative Improvement: Evidence-based institutional planning and ongoing refinement of interventions (NotebookLM).

This multilayered approach empowers teachers to act as AI coordinators, leveraging digital resources to implement differentiated, data-informed, and ethically sound interventions. As a result, schools can proactively prevent violent behavior, cultivate SEL competencies, and align practices with regulatory frameworks, including Law 5029/2023, GDPR requirements, and national digital education guidelines (Institute of Educational Policy [IEP], 2024).

4. Conclusion

In conclusion, the integration of Social and Emotional Learning (SEL) principles, as articulated by CASEL, with the systematic, strategic, and personalized deployment of Artificial Intelligence (AI) tools offers a multi-dimensional, experiential, and adaptive framework for addressing socio-emotional challenges and preventing school violence in contemporary educational settings. When applied within a human-in-the-loop pedagogical architecture, AI functions not as a substitute for the teacher but as a mediator, translating abstract SEL principles into targeted, context-sensitive, and

individualized interventions that support students' emotional and social development (CASEL, 2020; Durlak et al., 2011).

Through this approach, learners can progressively cultivate core socio-emotional competencies, including self-awareness, self-regulation, social awareness, relationship skills, and responsible decision-making, within a supportive and reflective learning environment. The strategic use of AI platforms—such as Napkin AI, Musely.ai, Mizou, TeachQuest, ClassMana, and NotebookLM—facilitates interventions across multiple ecological levels: individual, group, classroom, and school-wide. These tools enable the creation of a comprehensive, dynamic, and evidence-informed learning ecosystem that integrates continuous monitoring, predictive analytics, and reinforcement of positive social behaviors within a safe and legally compliant framework (Law 5029/2023; GDPR; IEP, 2024).

Practically, AI tools support the early identification of socio-emotional concerns or potential conflict episodes through continuous observation of behavioral and affective indicators, providing data-driven insights while preserving privacy and ethical safeguards. Personalized and adaptive interventions can then be delivered via digital avatars, gamified learning missions, mission maps, dynamic feedback systems, or individualized video and interactive assignments. These mechanisms allow students to engage in realistic simulations of conflict scenarios, experiment with collaborative problem-solving strategies, and achieve consensus in a structured, scaffolded environment (Taylor et al., 2017). Simultaneously, teachers remain central facilitators, guiding reflection, reinforcing SEL competencies, and shaping a proactive classroom culture that reduces reliance on repetitive disciplinary practices.

In such a digitally augmented educational ecosystem, socio-emotional learning, cooperation, and relational competencies are fully embedded into everyday pedagogical routines. Each lesson, interaction, and classroom activity becomes an opportunity to nurture emotional intelligence, ethical behavior, and social cohesion, transforming the school into a proactive environment where preventive, rather than reactive, strategies prevail (IEP, 2024). Importantly, this model safeguards the professional pedagogical role of teachers, preventing the mechanization or surveillance-oriented misuse of AI, while leveraging technological innovations to enhance, rather than constrain, the teacher's humanistic and relational functions (Selection, 2021).

Ultimately, the convergence of AI-assisted pedagogical tools and SEL provides a foundation for sustainable, participatory, and learner-centered learning ecosystems. These systems are designed to address contemporary challenges—including the prevention of school violence and the promotion of social-emotional competence—while simultaneously preserving students' safety, well-being, and autonomy. By embedding SEL competencies into both digital and physical school environments, this integrated framework transforms socio-emotional development into a lived, practical, and enduring component of everyday schooling, cultivating resilient, empathetic, and socially responsible learners prepared to navigate the complexities of contemporary society.

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Instructional Design and Artificial Intelligence in Special Education

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Abstract - The rapid development of Artificial Intelligence (AI) and its integration into education have significantly reshaped contemporary teaching practices. In Special Education, where inclusion and differentiation are essential, AI emerges as a powerful pedagogical tool capable of supporting diverse learning needs. This paper presents a best-practice case study of a micro-teaching intervention implemented with students diagnosed with Mild Intellectual Disability (MID) in a Unified Special Vocational Junior–Senior High School. The instructional unit focused on the topic "Forms of Vegetable Consumption" within the Floriculture curriculum. The lesson design combined principles of Active and Inquiry-Based Learning with the strategic use of AI and ICT tools: Gemini for content adaptation and simplification, Gamma for visually structured presentations, and AnswerGarden for real-time formative assessment and anonymous participation. Data from classroom observation and pedagogical reflection revealed increased student motivation, improved conceptual understanding, and enhanced learner autonomy. The findings suggest that AI can function as a cognitive and pedagogical scaffold, promoting inclusive and meaningful learning environments.

Keywords— Artificial Intelligence, Special Education, Instructional Design, Inclusion, Generative AI

Introduction

The rapid development of Artificial Intelligence (AI) and its widespread integration across numerous sectors of human activity is decisively influencing the educational reality of the 21st century (Holmes et al., 2019). Within the context of the digital transition, education faces the challenge of the pedagogically sound utilization of generative AI tools. AI is no longer a simple technological tool but a catalyst that can reshape traditional teaching practices, fostering differentiation, creativity, and active student participation (Luckin et al., 2016).

Special Education is a field with specific requirements, as it aims for full inclusion, support, and the adaptation of content for students with diverse learning profiles and disabilities. The complexity of the classroom, the heterogeneity of students, and the need for personalized curricula make the search for innovative methods imperative (Zawacki-Richter et al., 2019). In this context, AI can function as a powerful enhancement mechanism for personalization, allowing for the adjustment of instructional material, pace, and presentation style with unprecedented effectiveness. Recent research from the Special Olympics Foundation highlights that the majority of educators perceive AI as a potentially powerful mechanism for promoting more inclusive learning for students with intellectual and developmental disabilities (Shriver, 2024).

The literature already emphasizes AI's potential to create adaptive learning environments, provide real-time feedback, and support students with learning difficulties (Holmes et al., 2019). Recent studies show that AI tools can significantly enhance accessibility, inclusion, and the academic performance of students with disabilities, functioning as a "cognitive prosthesis" that complements and strengthens students' cognitive functions (Dumitru et al., 2025). However, there is still a lack of empirical studies presenting specific best practices for applying generative AI tools within a specialized educational context, particularly for students with Mild Intellectual Disability (MID) attending Unified Special Vocational Junior–Senior High Schools. The need for practical examples that combine pedagogical principles with technology is critical, enabling educators to integrate AI tools in a pedagogically sound manner (Selwyn, 2023).

This paper presents such an application, focusing on a micro-teaching session in the "Floriculture" course for the 12th grade of a Unified Special Vocational Junior–Senior High School, on the topic of "Forms of Vegetable Consumption." The aim of the study is to demonstrate how the combination of modern pedagogical principles (Active and Inquiry-Based Learning) with AI and ICT tools (Gemini, Gamma, AnswerGarden) can lead to more meaningful learning, improved understanding, and increased participation of students with MID. Consequently, the paper seeks to answer the following research questions:

- In what way can AI tools support instructional design for students with MID, enhancing accessibility and differentiation?
- How does the use of AI tools (Gemini, Gamma) affect students' active participation, understanding, and self-directed action?

Theoretical Framework

The integration of Artificial Intelligence (AI) into education, particularly in Special Education, presupposes a deep understanding of both the technological capabilities of the tools and the pedagogical principles governing their use. A systematic review of research on AI in higher education, although focusing on a different level, confirms the necessity of linking technology with teaching methodology (Zawacki-Richter et al., 2019). The present practice is based on a threefold theoretical foundation: the function of AI as a differentiation mechanism in Special Education, the integration of AI tools through recognized pedagogical models, and the application of Active Learning principles.

Artificial Intelligence in Special Education (SE)

Special Education is characterized by the effort toward inclusion and personalization, aiming to support students with diverse learning profiles (OECD, 2024). AI is emerging as a particularly effective factor in achieving these goals. In SE, AI is directly linked to adaptability and personalization (Holmes et al., 2019). Recent research from Uruguay shows that AI can facilitate the production of accessible digital educational books that support inclusion by breaking down communication barriers and providing personalized support to students with special needs (UNICEF Innocenti, 2025).
AI can function as an enhancement mechanism for adapting instructional content, solving the "one size fits all" problem that often plagues traditional teaching. AI applications support students with learning difficulties by allowing for the differentiation of pace, content, and the manner of presenting the material. According to a recent comprehensive review, AI-enhanced assistive accessibility technologies can shape personalized learning experiences and increase the participation of students with disabilities in higher education (Dumitru et al., 2025). Content generation tools (such as Gemini) allow the educator to create:

- Simplified or visualized versions of complex texts, enhancing accessibility.
- Comprehension questions adapted to each student's cognitive level, providing immediate feedback.
- Differentiated activities that respond to different learning styles.

Furthermore, AI strengthens formative assessment by providing real-time feedback (UNESCO, 2023). The ability of tools to immediately analyze student responses (as is the case with AnswerGarden) allows the educator to readjust their teaching instantly, transforming assessment from a simple measurement into an integral part of the learning process. The integration of AI in special education represents a significant advancement in supporting student diversity and promoting equal learning opportunities (Fitas, 2025).

Pedagogical Models for Technology Support

To utilize AI tools in a pedagogically sound manner (Selwyn, 2023), the use of appropriate theoretical models that bridge technology with teaching practice is required. The two primary frameworks used in this paper are the TPACK model and the SAMR model, in combination with the principles of Universal Design for Learning (UDL).

The TPACK Model

The TPACK (Technological Pedagogical Content Knowledge) model is a classic framework for synthesizing the knowledge required of modern educators (Mishra & Koehler, 2006). TPACK describes educator knowledge as the intersection of three core components: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). The effective utilization of AI is achieved only at the intersection of these three components, namely TPACK. The educator must know how to use AI tools (TK) to teach specific content (CK) using the most appropriate methods (PK), such as creating personalized content for students with MID. This practice constitutes an application of TPACK, as it combines specialized knowledge of AI with the principles of Special Education.

The SAMR Model

The SAMR (Substitution, Augmentation, Modification, Redefinition) model provides a framework for evaluating the extent to which technology transforms learning (Puentedura, 2014). Utilizing AI tools can enrich the stages of the model, leading instruction from simple technological substitution to transformative learning experiences. Using Gemini for producing and adapting differentiated instructional material (e.g., simplifying definitions) places the practice at the Modification level, as it changes the way knowledge is accessed. Using AnswerGarden for anonymous, simultaneous, and visualized collection of ideas pushes the practice toward the Redefinition level, as it enhances collaboration and formative assessment in ways that were not possible in a traditional SE classroom.

Universal Design for Learning (UDL) and AI

Universal Design for Learning (UDL) is a fundamental framework for enhancing accessibility and inclusion in education. UDL is committed to inclusion by providing multiple ways for students to access, interact with, and demonstrate understanding of content (Saborío-Taylor & Rojas-Ramírez, 2024). The convergence of UDL principles with the capabilities of AI emerges as a transformative force shaping education in the digital age.

The three core principles of UDL include multiple means of representation, multiple means of engagement, and multiple means of expression. AI can support each of these principles in innovative ways. For example, AI tools such as text-to-speech and speech-to-text systems, enhanced with AI, become more accurate and natural in reproduction, supporting multiple means of representation (CAST, 2025). Furthermore, AI can reduce cognitive load by helping individuals understand and process information more quickly.

Recent studies highlight the importance of integrating UDL principles with generative AI in adult and continuing higher education. The targeted alignment of UDL principles with generative AI capabilities in content creation, personalization, and accessibility allows educators to design uniquely flexible, inclusive, and rigorous learning experiences (Mallary, 2025). However, it is important to recognize challenges related to academic integrity, algorithmic bias, and data privacy.

Active and Inquiry-Based Learning

The present practice was based on the principles of active learning, the inquiry-based approach, and student-centered instruction. According to Dewey (1938), learning is experiential and must be connected to the students' own experiences. Active learning, as proposed by Biggs & Tang (2020), focuses on the student's active participation in the construction of knowledge, rather than passive reception. In Special Education, this translates to enhancing the student's self-directed action and engagement. AI tools support the educator in this new role, as they take on the burden of creating differentiated material, allowing them to focus on facilitating and enhancing the learning process. AI functions as a "pedagogical scaffold" that facilitates social interaction and the development of cognitive skills (Vygotsky, 1978).

Methodology

The present work followed the case study methodology, focusing on a specific instructional intervention within a real educational context. The case study was selected as the most appropriate method, as it allows for an in-depth analysis of the application of AI tools in teaching, the recording of interactions between students and technology, and the pedagogical reflection of the educator (Cohen et al., 2018).

Context and Participants

The micro-teaching session took place in a class of five (5) students in the 12th grade of a Unified Special Vocational Junior–Senior High School, aged 17-18, who presented with Mild Intellectual Disability (MID). The students are enrolled in the Floriculture specialization and possess varying levels of cognitive, social, and communication skills. The heterogeneity of the class necessitated a personalized approach and differentiated instructional material.

Instructional Design and AI Tools

The instructional intervention lasted three teaching hours and was organized into three phases: preparation, implementation, and evaluation. In the first phase (preparation), Gemini was used to create differentiated instructional material. Specifically, Gemini was utilized for:

- Simplifying texts and adapting vocabulary to the students' cognitive level.
- Creating comprehension questions tailored to the students' needs.
- Generating ideas for interactive activities and real-life examples.

In the second phase (implementation), Gamma was used to create a visualized presentation with images, videos, and diagrams. The visual presentation of content helped students with MID better understand the concepts, as it supports the multiple means of representation of UDL. Additionally, AnswerGarden was used for real-time formative assessment, allowing students to express their views anonymously and participate actively in the discussion.

Objectives and Instructional Strategy

The intervention was designed through the lens of Differentiated Instruction, with the instructional strategy focusing on Active and Inquiry-Based Learning (Dewey, 1938). The objectives were categorized as follows:

- **Cognitive:** Understanding and recognizing the basic forms of vegetable consumption.
- **Skills:** Development of digital skills, categorization, and critical thinking.
- **Affective:** Enhancing self-directed action and self-confidence, while promoting cooperation.

Detailed Description of the Intervention

Preparation Stage: AI as a Design Assistant (Gemini)

The educator used Gemini to generate and adapt instructional material, ensuring compatibility with the needs of students with MID. The use of Gemini places the practice at the **Modification** stage of the SAMR model.

- **Simplification of Definitions:** Gemini was used with prompts such as: "Provide very simple definitions for the terms 'raw', 'cooked', 'canned', and 'frozen' vegetable..."
- **Material Production:** Multiple-choice comprehension questions were created, based on simplified language and visualized scenarios.

Implementation Stage: Teaching with ICT and AI (AnswerGarden, Gamma)

- **A. Inquiry & Motivation (20'): AnswerGarden:** Students, anonymously and simultaneously, answered the question: "Which vegetables do we eat raw?". This phase constitutes an application of Inquiry-Based Learning and the **Redefinition** level of the SAMR model.
- **B. Presentation (45'): Gamma:** Presentation of core content, featuring the simplified versions and images generated by Gemini. The use of Gamma enhanced differentiation through intensive visualization.
- **C. Application & Consolidation (50'): Experiential Activity (Group):** Card categorization. Use of Gemini by the educator for immediate feedback on any student errors or queries, reinforcing **Active Learning**.

More specifically, the instruction was organized into a multisensory strategy across four stations:

- **Station 1 (Fresh):** Recognition through touch and smell (e.g., a real tomato).
- **Station 2 (Frozen):** Exploration of the concept of freezing and the need for electricity.
- **Station 3 (Canned):** Examination of packaging durability and labels.
- **Station 4 (Dried):** Comparison of weight and volume to understand suitability for travel.



Figure 1: Fresh Vegetables Station

Evaluation Stage: Formative Assessment

The assessment was formative in nature. Questions generated by Gemini were utilized for this purpose. The evaluation was conducted using the **"Nutritional Runner"** method, a kinesthetic activity where students had to run to the correct station based on statements provided by the educator. The statements were categorized into:

- **Recognition Questions:** e.g., "I absolutely need electricity and a freezer!" (Frozen).
- **Application Questions (Decision Making):** e.g., "I choose this because I don't have a refrigerator and it's hot!" (Dried) or "Because I ‘m in a hurry!" (Frozen).



Figure 2: Nutritional Runner

Results and Pedagogical Reflection

The evaluation of the intervention was based on the quantitative and qualitative recording of learning behaviors through systematic observation (Cohen et al., 2018).

Quantitative Findings: Assessment of Understanding

The analysis of the responses (12 questions) showed high student performance. The average success rate of the class reached 82%, with all students achieving scores above 70%. Specifically, the category of questions concerning the recognition of consumption forms had a correct response rate of 90%, suggesting that the visualization of the

material via Gamma and the simplification of definitions via Gemini effectively contributed to the consolidation of concepts (UNESCO, 2023).

Qualitative Findings: Observation and Reflection

Pedagogical reflection highlighted significant qualitative changes:

- **Active Participation and Motivation:** The introduction of AI tools functioned as a powerful motivator. Even students who typically exhibit low self-confidence participated willingly. Anonymous contribution through AnswerGarden reduced the fear of making a mistake (Holmes, 2019).
- **Improved Concept Understanding:** The use of Gamma, combining images with simplified text, helped consolidate core concepts.
- **Self-directed Action and Collaboration:** Students showed increased self-directed action during group work. The educator's use of Gemini as a "rapid knowledge source" enhanced their inquisitive disposition.
- **Development of Digital Skills:** Students became familiar with the use of cloud-based tools, which is a critical element for digital inclusion (OECD, 2024).

Results and Analysis

Differentiation and Accessibility

The use of Gemini allowed for the creation of simplified and adapted content that rendered the lesson accessible to all students. Simplified definitions and real-life examples helped students connect theoretical content with practical experience. The visual presentation via Gamma enhanced understanding, as students with MID benefit significantly from the visual representation of concepts. This approach aligns with the principles of UDL, providing multiple means of representation that support learning diversity (Saborío-Taylor & Rojas-Ramírez, 2024).

Active Participation and Motivation

The use of digital tools significantly enhanced students' active participation. AnswerGarden, as an interactive idea collection tool, allowed students to express their views anonymously, which reduced anxiety and boosted their self-confidence. Students showed increased interest and motivation throughout the instructional intervention, participating actively in discussions and group activities. The educator's use of AI as a "rapid knowledge source" enhanced their inquisitive disposition and self-directed action.

Recent research confirms that AI can function as assistive intelligence, reducing cognitive load and helping students understand and process information more effectively (CAST, 2025). Furthermore, students became familiar with using cloud-based tools, which is a critical element for digital inclusion and their preparation for the future work environment (OECD, 2024).

Pedagogical Reflection and Interpretation

The educator's reflection concludes that the use of AI improved the quality of teaching and the learning experience in Special Education. The practice confirmed the effectiveness of the SAMR model at the Modification/Redefinition levels, as AI tools

allowed for content differentiation and the creation of new forms of interaction. AI acted as a technological ally for the educator, reducing the time required to produce differentiated material and allowing the teacher to focus on their pedagogical role as a guide (UNESCO, 2023). However, it is important to note that successful AI integration presupposes appropriate teacher training and the ethical use of tools, taking into account issues such as privacy protection and the avoidance of algorithmic bias (Linsenmayer, 2025).

Conclusions and Pedagogical Recommendations

This case study highlighted the decisive role that the integration of Generative Artificial Intelligence can play in the instructional methodology of Special Education. The systematic utilization of Gemini, Gamma, and AnswerGarden functioned as a lever for inclusion and pedagogical empowerment. The main findings of the research include:

- **Enhancement of Accessibility:** AI allowed for meaningful content differentiation at the Modification level (SAMR), making learning accessible to all students.
- **Increase in Active Participation:** The use of digital tools boosted student motivation and self-directed action (Dewey, 1938).
- **Support for the Educator:** AI functioned as a technological ally, reducing workload and allowing the educator to focus on their pedagogical role (UNESCO, 2023).

Limitations of the Study

The research sample was limited, as it included only five (5) students, which reduces the generalizability of the findings. Additionally, the duration of the intervention was particularly short, taking place over only three instructional hours, a factor that does not allow for safe long-term conclusions. Finally, there was no control group using traditional teaching methods, making direct and reliable comparison of the results more difficult.

Proposals for Pedagogical Policy and Future Research

Formulating effective policies and research directions requires, first and foremost, the continuous and systematic training of educators through specialized programs focusing on the ethical, pedagogical, and practical utilization of AI (Zawacki-Richter et al., 2019). Educators need support in understanding AI tools, their limitations, and the core principles for their effective use, as well as guidance regarding legal compliance with provisions for the education of students with disabilities and privacy protection (Aboulafia, 2025).

Simultaneously, state care is necessary for the development of Greek-language and accessible AI tools designed according to UDL principles to meet the needs of all students. The participation of students with disabilities in the design of AI tools is critical to ensuring these technologies are truly inclusive and free from "hidden barriers" (CAST, 2025).

Furthermore, future large-scale and long-term research using control groups is required to systematically investigate the long-term impact of AI on the skill development of

students with MID. In conclusion, the successful integration of AI in Special Education requires a combination of technological competence with pedagogical empathy and the principles of inclusion. AI will never replace the central importance of genuine human connection in teaching—the essential element for our students' well-being in the classroom (Shriver, 2024).

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Teachers' Perceptions and Practices of Artificial Intelligence in Education: Opportunities and Challenges

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - Artificial Intelligence (AI) is reshaping educational practices by offering new opportunities for personalization, efficiency, and learner engagement. Yet the integration of AI into classrooms depends largely on teachers' readiness, perceptions, and capacity to use these tools effectively. This study investigates how teachers use AI in education, their perceptions of its usefulness, and the challenges they face in adopting AI-based approaches.

A mixed-methods questionnaire was administered to a sample of teachers from the lower and upper secondary educational level, collecting both quantitative and qualitative data on AI awareness, usage, perceived benefits, and barriers. Respondents reported their experiences with various AI tools such as adaptive learning systems, automated assessment platforms, and content generators. The instrument also explored their confidence in using AI, ethical concerns, and training needs.

Preliminary findings indicate that while a large proportion of teachers acknowledge AI's potential to enhance teaching and learning, its use in everyday practice remains limited. Teachers tend to use AI mainly for preparatory purposes, such as generating materials, planning lessons, and much less for evaluating students' work. In addition, most teachers avoid using AI for direct classroom interactions. Consistent with recent research, teachers appreciate AI's potential to save time and support differentiation, but they express concerns about ethical issues, data security, and the possible reduction of human interaction in education.

Differences also emerged across experience levels and educational sectors. Younger teachers demonstrate greater confidence and experimentation with AI, aligning with findings that they tend to integrate emerging technologies more readily. In contrast, more experienced educators emphasize the importance of affiliating AI use with pedagogical goals and curriculum standards. Across all groups, the main barriers identified include insufficient professional development, lack of institutional support, and limited access to reliable AI tools.

These findings underscore the urgent need for targeted professional learning programs that build teachers' AI literacy and pedagogical understanding of AI's role in education. Empowering teachers through training and reflective practice is essential to move from curiosity to confident, ethical implementation. Beyond technical competence, teachers

must be supported to critically evaluate AI's educational, social, and ethical implications.

This study contributes to the growing body of research on AI in education by providing empirical insights into teachers' real-world practices and perceptions. It emphasizes that for AI to become a sustainable part of educational innovation, teachers must be empowered as informed co-designers of AI-enhanced learning environments rather than passive users of technology.

Keywords— Artificial Intelligence in Education, Teachers' Perceptions, Educational Innovation, AI Literacy, Ethical Challenges

Introduction

Artificial Intelligence (AI) is rapidly emerging as a transformative force with the potential to fundamentally reshape the educational landscape. By offering advanced tools for personalized learning (Laak & Aru, 2025; Luckin et al., 2022), task automation (Fügener, Walzner & Gupta, 2025), and data-driven insights (Sajja et al., 2025) AI promises to enhance efficiency (Xu, 2024) and create more engaging, student-centered learning environments (Barrett & Miller, 2024). However, the ultimate success of this technological integration does not rest on the sophistication of the tools themselves, but on the perceptions, readiness, and skills of the educators tasked with implementing them (Mehdaoui, 2024). Teachers remain the central actors in the educational process, and their willingness and ability to adopt, adapt, and critically evaluate AI are paramount to realizing its benefits.

Despite the growing discourse about AI's potential, a significant gap persists between its theoretical promise and its practical application in schools. This gap is largely driven by teacher-related factors, including their existing beliefs about technology, their confidence in using new tools, and the institutional support they receive. As highlighted by Holmes, Bialik, & Fadel (2019), educator capacity is a key determinant of effective EdTech integration. Furthermore, research by Zawacki-Richter et al. (2019) emphasizes that without understanding the educator's perspective, efforts to implement AI risk remaining superficial. Therefore, this study aims to address this gap by investigating a critical set of questions:

1. How are secondary school teachers in Greece currently using AI tools?
2. What are their perceptions of AI's utility and its potential impact on their professional role?
3. And what are the primary challenges and barriers preventing its wider adoption?

By understanding these factors, this paper argues that for AI to become a sustainable component of educational innovation, teachers must be empowered as informed "co-designers" of AI-enhanced learning environments rather than mere passive users of commercial technology.

Method

To develop a comprehensive understanding of educator perceptions and practices, this study employed a mixed-methods approach. This framework was chosen because it allows for both the quantitative measurement of trends and the qualitative exploration of the underlying reasons for those trends.

We developed a questionnaire and distributed it to secondary teachers in Greece. Respondents reported their experiences with various AI tools, adaptive learning systems, automated assessment platforms, and content generators. The questionnaire was structured to capture two distinct types of data:

- Quantitative Data: 39 closed-ended questions were used to systematically measure teachers' self-assessed digital confidence, the frequency of their AI tool usage, and their attitudes and perceptions regarding AI's benefits and risks.
- Qualitative Data: 2 open-ended questions invited participants to elaborate on their specific professional development needs, the barriers they encounter in their daily practice, and their ethical concerns. Qualitative data were analyzed

using thematic analysis (Braun & Clarke, 2006).

Through this dual approach, the study aimed to not only identify what teachers are doing with AI but also to understand why they are doing it and what support they require to deepen their engagement.

Results

The findings of the study are presented in four main parts. First, we outline the demographic profile of the participants, followed by a detailed analysis of their self-reported patterns of AI-usage, an exploration of their perceptions and attitudes toward AI, and finally, an examination of the specific barriers and professional development needs they identified.

Participant Demographics

In the study 73 educators participated. The respondents were predominantly female (74%) and comprised mostly senior educators, with 68.5% over 50 years old (Figure 1).

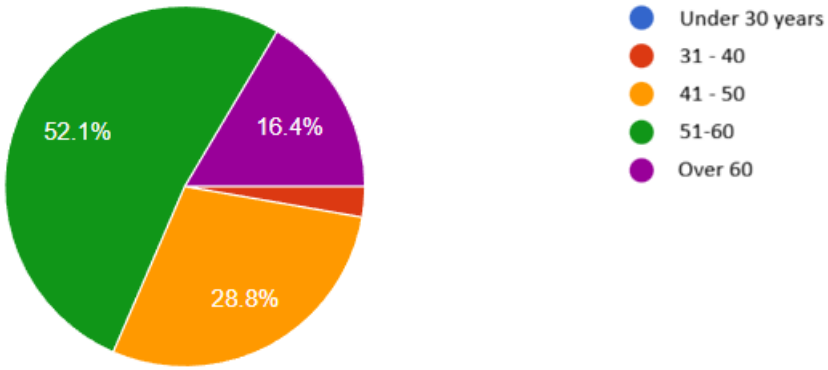


Figure 1: Age groups of the participants.

The study sample is mostly composed of senior teachers, with 79.5% reporting over 16 years of teaching. Furthermore, most respondents (78%) were Engineers of the construction sector, representing a technically-oriented discipline. They teach across a cross-section of Greek secondary schools, with 56.2% from Gymnasium (lower secondary), 41.1% from EPAL (vocational upper secondary), and 9.6% from Lyceum (general upper secondary) – some of the teachers teach both in a lower and upper secondary school, therefore the sum exceeds 100%.

When asked how they would describe their digital skill level, 16,4% stated very high and 43.8% high, adding up to 60.2%. Thus, this is not a group of technological novices; a clear majority (60.2%) self-assessed their digital proficiency as either "Good" (43.8%) or "Very Good" (16.4%), framing their hesitant AI adoption not as a product of technophobia, but of calculated professional judgment. The participants' pedagogical experience and existing digital confidence make their cautiousness towards AI particularly significant.

Patterns of AI Usage and Integration

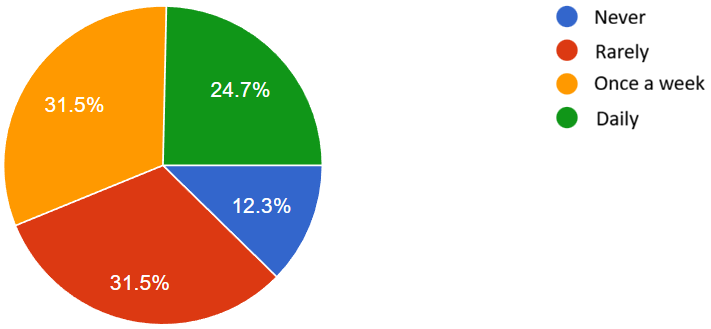


Figure 2: Usage of AI tools for educational purposes.

The frequency of AI-tools varies largely: while 24.7% report daily use and 31.5% use AI about once a week, an equal proportion (31.5%) use it rarely, and even less (12.3%) state never (Figure 2). Additionally, of those who use AI-tools for educational purposes, more than half (52.1%) spend less than an hour weekly, 28.8% 1-3 hours, while only 13.7 spend 4-6 hours, and 5.5% over 6 hours.

When teachers use AI, their application is mainly focused on their personal workflow for lesson preparation, as depicted in Table 1, a trend that reveals a clear "preparation vs. practice" dichotomy.

Application Category	Specific Use Cases	Percentage of Respondents
Dominant Uses	Inspiration/Ideas for Activities	74.0%
	Creating Educational Materials	65.8%
	Lesson Planning	49.3%
Infrequent Uses	Differentiated Instruction	19.2%
	Student Assessment	13.7%

Table 1: Usage of AI tools

Analysis of AI-adoption reveals cautious and selective engagement, with usage heavily tilted toward preparatory tasks rather than live classroom implementation. This pattern is further confirmed by data on in-class practices. A large majority of educators (72.6%) reported that they do not use AI directly in the classroom with their students. Similarly, teachers are hesitant to encourage students to use AI. Only 17.8% "often" encourage their students to use AI tools, while 42.5% only "sometimes," indicating that AI has not yet become an integrated part of the student learning experience.

Educator Perceptions and Attitudes Toward AI

When asked to what extent they believe that AI will replace other sources (books, internet, etc.), 48% answered positive (38% much and 11% very much so). Most of them are aware that AI tools can be used for all subjects.

Perceptions of teachers on AI	**1**	**2**	**3**	**4**	**5**

1 AI can improve the quality of my teaching	2.7	4.1	13.7	56.2	23.3
2 AI can assist with personalized learning for students	2.7	1.4	24.7	56.2	15.1
3 I understand the potential of AI in education	2.7	4.1	16.4	61.6	15.1
4 I feel that the use of AI is ethically acceptable	2.7	9.6	32.9	50.7	4.1
5 AI is a threat to the teaching profession	12.3	39.7	41.1	4.1	2.7
6 AI will radically change the way students learn	5.5	8.2	19.2	45.2	21.9
7 I am willing to experiment with new AI tools	1.4	4.1	9.6	46.6	38.4
8 I trust the accuracy of the information provided by AI	8.2	30.1	38.4	20.5	2.7
9 I believe that the use of AI increases students' creativity	4.1	19.2	43.8	30.1	2.7
10 AI can help reduce my workload	5.5	5.5	26.0	45.2	17.8
11 I feel that AI is a tool that enhances equality in education	4.1	19.2	47.9	21.9	6.8
12 AI helps me plan my lessons more efficiently	2.7	4.1	27.4	49.3	16.4
13 AI inspires me to be more creative in teaching	2.7	2.7	20.5	58.9	15.1
14 AI helps me adapt teaching to the needs of my students	4.1	5.5	26.0	49.3	15.1
15 AI can improve student learning	1.4	9.6	34.2	50.7	9.6
16 AI can lead to misinformation among students	4.1	9.6	30.1	39.7	16.4
17 AI can limit students' authentic effort	2.7	9.6	27.4	41.1	19.2
18 AI needs a clear ethical framework in education	2.7	5.5	8.2	37.0	46.6
19 I am confident that I can tell when a student has used AI for their assignment	4.1	15.1	26.0	47.9	6.8
20 I believe that AI will be integrated into school curricula in the coming years	2.7	6.8	23.3	52.1	15.1
21 I believe that my students should be trained in the use of AI	2.7	8.2	13.7	45.2	30.1

Table 2: Perceptions of teachers on AI in education (1=disagree strongly, 2=disagree, 3=neutral, 4= agree, 5 = agree strongly) in percentage

In Table 2, we present the perceptions of teachers on AI in education. This table measures the readiness and professional stance of educators, moving from general awareness to specific classroom application. The data show the current state of the teachers as "Cautious Optimism". The distribution of percentages across the 1–5 scale suggests that although the teachers acknowledge AI's utility, its practical classroom integration is still ongoing. Teachers perceive AI as an assistant that reduces their workload, primarily in lesson preparation. A significant portion of responses falls into the "Neutral" category regarding AI's impact on learning outcomes. This reflects a lack of empirical conviction; while teachers value AI for speed, they remain sceptical of its ability to improve learning quality.

Data show a sharp decline between high scores for "Perceived Usefulness" and lower scores for "Ease of Use" or "Intention to Use", suggesting that systemic barriers like technical complexity and lack of institutional support hinder active classroom adoption. Additionally, scores clustering around "Disagree" and "Neutral" regarding ethics and reliability indicate concerns over data privacy and algorithmic accuracy (hallucinations).

The study of teachers' perceptions revealed a complex set of attitudes among educators, characterized by a blend of professional optimism about AI's potential, significant skepticism regarding its reliability and ethical implications, and a firm belief in the irreplaceable role of the teacher. Teachers are broadly optimistic about the value AI can bring to their work, with high agreement that it can improve teaching quality, reduce administrative workload, save valuable time, and help them design lessons more efficiently.

This optimism, however, is tempered by significant reservations and ethical concerns. Many educators express a clear lack of trust in the accuracy of AI-generated information, fearing it could lead to student misinformation. Further anxieties relate to data security and the potential for a reduction of human interaction in education. An even greater concern is the challenge of maintaining academic integrity, with high levels of anxiety about detecting AI-assisted plagiarism. This culminates in an overwhelming consensus that a clear and robust ethical framework governing the use of AI in education is not just desirable, but necessary.

Despite these concerns, teachers do not perceive AI as an existential threat to their profession. On the contrary, they strongly disagree with the notion that AI poses a threat to their role. Educators overwhelmingly view AI as a supportive tool designed to augment their capabilities, not a technology that will replace their function as mentors, guides, and pedagogical experts.

Identified Barriers and Needs for Professional Development

When asked to identify the primary obstacles preventing wider AI adoption, educators pointed to a clear set of systemic and personal challenges, with the lack of training and support emerging as the most critical factor. 61.6% of the teachers reported never having received AI training, and an overwhelming 87.7% feel that they need more.

Furthermore, in Table 3 the teachers expressed their perceptions regarding the barriers in the use of AI in education.

Barriers of the use of AI	**1**	**2**	**3**	**4**	**5**
1 Lack of access to technological equipment	19.2	17.8	21.9	19.2	21.9
2 Lack of appropriate training and support	4.1	8.2	17.8	32.9	37.0
3 Concerns about privacy and data protection	4.1	9.6	23.3	30.1	32.9
4 Doubts about the reliability of information produced by AI	1.4	4.1	24.7	43.8	26.0
5 Fear that the use of AI will reduce the value of teaching	12.3	16.4	41.1	13.7	16.4
6 Fear that AI will make my job harder	21.9	31.5	35.6	8.2	2.7
7 The cost of access to advanced AI tools	4.1	17.8	30.1	28.8	19.2
8 Difficulty in managing academic integrity	4.1	17.8	35.6	27.4	15.1

Table 3: Barriers of the use of AI in education (1 = not at all, 5 = very much) in percentage

The results presented in Table 3 corroborate and deepen the insights regarding the barriers teachers perceive in relation to the use of AI in education. Overall, the distributions of responses across the Likert scale indicate that teachers' concerns are selective and nuanced, rather than uniformly resistant to AI adoption.

Theme	Categories
Pedagogical Integration of AI in Teaching and Learning	• Classroom use of AI • Subject-specific pedagogy • Personalized instruction
Instructional Design and Educational Content Creation	• Lesson planning support • Educational material production • Assessment design
Practical AI Tools and Applied Use by Discipline	• Tool selection • Task-specific AI applications • Subject relevance
AI Literacy, Prompting Skills, and Critical Use	• Prompt formulation • Information evaluation • Operational understanding of AI
Ethics, Reliability, and Responsible Student Use	• Ethical concerns • Academic integrity • Student guidance
Professional Development and Training Needs	• Training demand • Confidence gaps • Practical skill development
Infrastructure and Institutional Constraints	• Technological infrastructure • Learning spaces • Organizational barriers
Innovation, Engagement, and Educational Enhancement	• Student engagement • Teaching innovation • Learning improvement

Table 4: Thematic Analysis of Teachers' Responses on the Use of Artificial Intelligence in Education

In table 4 we present the Thematic Analysis of Teachers' Responses on the Use of AI and their need. By comparing Table 3 and 4 one can notice that the most salient barrier is the lack of appropriate training and support, with 69.9% of respondents selecting high agreement (4–5). This finding aligns directly with the qualitative data (Table 4), in which teachers repeatedly emphasized the need of practice-oriented, pedagogically grounded professional development. The convergence of results suggests that insufficient training is not perceived as a minor inconvenience but as a structural obstacle that limits teachers' confidence and capacity to integrate AI meaningfully into teaching practice.

Similarly, concerns about privacy and data protection emerge as a significant barrier, with 63.0% of respondents indicating strong concern (4–5). This quantitative pattern (Table 3) reinforces qualitative references (Table 4) to ethical uncertainty and responsibility, indicating that teachers perceive data protection not as a technical issue, but as an unresolved institutional risk that discourages classroom-level implementation.

Doubts about the reliability of AI-generated information are also strongly supported by the data, by 69.8% of the respondents. This finding is consistent with teachers' qualitative expressions of mistrust toward AI outputs and fear of misinformation. The prominence of this barrier highlights teachers' concern with maintaining epistemic authority and instructional credibility, particularly in assessment and knowledge construction processes.

In contrast, fear that AI will reduce the value of teaching presents a more moderate profile. While 41.1% of respondents selected the neutral midpoint (3), only 30.1% expressed high concern (4–5). This suggests ambivalence rather than strong resistance, supporting the qualitative interpretation that teachers do not fundamentally perceive AI as a threat to their profession – they see it as a supportive tool.

Likewise, fear that AI will make teaching more difficult appears to be a relatively weak barrier. 53.4% of respondents selected low agreement levels (1–2), indicating that most teachers do not associate AI-use with increased workload or complexity. This finding reinforces the qualitative theme of cautious openness and suggests that resistance is not driven by fear of operational burden.

Regarding access to technological equipment, responses are relatively evenly distributed across the scale, with no dominant trend toward high or low agreement. This dispersion reflects the qualitative accounts of unequal infrastructure across schools, indicating that equipment access is a barrier for some teachers, but not for all.

Finally, difficulty in managing academic integrity is identified as a notable concern, with 42.5% of respondents selecting high agreement. This result directly supports qualitative references to challenges in identifying AI-assisted student work and ensuring fair assessment practices. The alignment of findings underscores academic integrity as an emerging pedagogical and ethical challenge in AI-enhanced learning environments.

The quantitative findings validate the qualitative analysis by demonstrating that teachers' perceived barriers are concentrated around training, reliability, ethics, and institutional support, rather than fear of technology itself. This convergence strengthens the interpretation that effective AI integration requires systemic solutions addressing professional development, ethical governance, and infrastructural readiness, rather than efforts aimed solely at changing teachers' attitudes.

From the qualitative analysis it is evident that educators need professional development that is practical and directly applicable to their teaching context. Their specific requests include:

- Practical tools specific to their subject area.
- Instruction on creating effective prompts.
- Guidance on ethical issues and plagiarism detection.
- Concrete examples and lesson scenarios for classroom integration.

The clear message from these findings is that teachers seek actionable, hands-on guidance to address their specific pedagogical challenges, a need that is currently unmet and represents a significant barrier to deeper AI integration.

Discussion

The findings of this study paint a clear picture of educators that are "curious but cautious." Teachers in Greece recognize the transformative potential of AI but confine their engagement to a "safe mode"—using it for their own preparatory work rather than integrating it into the dynamic environment of the classroom. Teachers' reluctance does not result in from resistance to technology—their self-reported digital confidence confirms this—but from a pragmatic assessment of the profound lack of training, resources, and clear ethical guidelines.

The pronounced "preparation vs. practice" dichotomy is a direct consequence of these systemic shortcomings. Using AI for lesson planning allows teachers to experiment in a low-stakes environment, where they can maintain control. This behavior is a rational response from experienced professionals who, lacking specific training and institutional support, must mitigate the risks of misinformation and academic dishonesty. The fact that these experienced teachers, with deep pedagogical knowledge, remain hesitant is particularly significant; it suggests their caution is rooted in a commitment to pedagogical quality, which they feel cannot be guaranteed with the current level of support.

This dynamic is further nuanced by teacher experience. Younger teachers show greater confidence in experimenting with AI, while more experienced teachers emphasize the need to align any technological use with the curriculum and learning objectives. This suggests that effective AI integration requires a synthesis of both technological readiness and deep pedagogical knowledge.

These findings resonate with the broader academic and policy discourse. The urgent call for professional development echoes the arguments of Holmes et al. (2019) and the OECD (2025), who contend that empowering teachers through training and reflective practice is the cornerstone of successful AI integration. Similarly, the deep-seated ethical concerns regarding data security, accuracy, and academic integrity align with warnings from UNESCO (2021) about the need for a human-centered approach to AI in education.

Conclusion

This study contributes to the field of educational technology by providing empirical data on the real-world perceptions, practices, and challenges of secondary school educators regarding AI. It moves beyond theoretical speculation to document the on-the-ground reality: a teaching force that is open to innovation but constrained by a lack of targeted training, resources, and institutional support. To bridge the gap between AI's potential and its practice, teachers need:

- Empowerment: Teachers should be treated as informed co-designers of AI-enhanced learning environments, rather than as passive users.
- Targeted Professional Development: Training programs should directly address the question, “How can I use tool X in subject Y safely and effectively?”
- Critical Literacy: Education should go beyond using Artificial Intelligence as a tool, enabling teachers to understand, analyze, and critically evaluate its role and implications in society.

Ultimately, for AI to become a sustainable and beneficial part of educational innovation, we must move beyond simply providing access to tools. Bridging the gap between personal curiosity and confident pedagogical integration is the essential next step. Empowering teachers with the skills, knowledge, and support they need is the only viable path forward.

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Practical Applications of Artificial Intelligence in Teaching and Learning: Ethical and Technological Dimensions

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Abstract - This paper examines the practical applications of Artificial Intelligence (AI) in teaching and learning, highlighting its transformative role in personalized learning, automated assessment, and collaborative educational practices. The study explores adaptive educational systems that enable dynamically tailored learning pathways, facilitated by intelligent tutoring systems, chatbots, and advanced machine learning algorithms. The contribution of AI-driven automated assessment and educational analytics in optimizing teaching interventions and student support is analyzed. Furthermore, the paper addresses the ethical considerations integral to AI adoption in education, emphasizing data privacy, algorithmic bias, transparency, and equitable access. Challenges such as technical limitations and the need for educator training in AI literacy are discussed, alongside recommendations for responsible and sustainable AI integration. The findings underline the necessity for interdisciplinary collaboration and continuous professional development to maximize AI's benefits while safeguarding ethical standards in educational settings.

Keywords: Artificial Intelligence, Personalized Learning, Educational Analytics, Ethical Challenges, Adaptive Systems

Practical Applications of Artificial Intelligence in Teaching and Learning: Ethical and Technological Dimensions

Artificial Intelligence (AI) is rapidly transforming educational practices, offering innovative tools for personalized learning, assessment, and classroom management. This paper explores the practical applications of AI in teaching and learning, highlighting both opportunities and challenges, with a focus on ethical and technological considerations.

AI-Driven Personalization and Adaptive Learning

AI technologies facilitate the development of personalized learning pathways by dynamically adapting content, pacing, and feedback to meet individual student needs. Intelligent Tutoring Systems (ITS), such as Carnegie Learning's MATHia, employ machine learning algorithms to deliver real-time, data-driven feedback; sophisticated chatbots like Duolingo's AI tutor provide 24/7 access to interactive resources; and adaptive platforms like DreamBox optimize instruction through continuous performance analysis. These tools significantly boost student engagement, retention, and learning outcomes (Tapalova et al., 2022; Chen et al., 2020; Zafari et al., 2022). Furthermore, platforms such as Knewton Alta and immersive virtual environments like Labster enable differentiated instruction, promoting learner autonomy and mastery in diverse educational contexts (Li, 2025).

Enhancing Teaching Practices and Reducing Workload

Artificial intelligence empowers educators by automating time-intensive administrative tasks, including grading, assessment creation, and data analysis, thereby enabling greater focus on pedagogical innovation and direct student support (Ahmad et al., 2022; Ahmad et al., 2021). AI-driven analytics platforms, such as Brightspace's Insights or Gradescope's predictive modeling, enable early identification of at-risk students, refine instructional strategies, and deliver precise, actionable recommendations for timely interventions (Celik et al., 2022; Salas-Pilco & Yang, 2022). Moreover, educators contribute essential expertise by training AI models—through platforms like Google's Teachable Machine—and rigorously validating automated assessments to uphold accuracy, cultural relevance, and pedagogical integrity (Celik et al., 2022; Luckin & Cukurova, 2019).

Fostering Critical Skills: AI Literacy and Prompt Engineering

Integrating artificial intelligence into educational curricula requires cultivating AI literacy among educators and students alike, encompassing critical competencies such as prompt engineering, ethical evaluation of AI outputs, and algorithmic bias detection. Essential skills enable effective, responsible utilization of AI tools in classroom settings. Targeted interventions—including workshops like those offered by ISTE's AI Explorers program, ongoing professional development via platforms such as Coursera's AI for Teachers, and interdisciplinary collaborations through initiatives like the AI4K12 project—build institutional capacity and promote ethical AI integration (Walter, 2024; Luckin & Cukurova, 2019).

Ethical Considerations and Responsible Implementation

The integration of artificial intelligence in education presents profound ethical challenges, including data privacy concerns, algorithmic biases, lack of transparency in decision-making processes, and disparities in equitable access. Formulating robust ethical guidelines—such as those outlined in UNESCO's AI Ethics Recommendation or the EU's AI Act for high-risk educational applications—and engaging diverse stakeholders, including educators, policymakers, and developers, are imperative to safeguard fairness, accountability, and inclusivity (Kamalov et al., 2023; Azman & Tümkaya, 2025; Alasadi & Baiz, 2023). Sustained dialogue through co-design frameworks, exemplified by initiatives like the Partnership on AI's Education Working Group, remains essential to harmonize technological innovation with ethical responsibility (Luckin & Cukurova, 2019; Kamalov et al., 2023).

Challenges and Future Directions

Despite the transformative potential of artificial intelligence (AI) in education, its widespread adoption encounters multifaceted barriers, including technical limitations, resource disparities, and the imperative for comprehensive teacher training (Celik et al., 2022; Li, 2025; Qehaja, 2025). Technical constraints often manifest as unreliable AI performance in diverse real-world classroom settings. For instance, natural language processing models like early versions of GPT-3 struggled with non-native English speakers or regional dialects, leading to inaccurate feedback in multilingual environments common in global education systems. Similarly, Intelligent Tutoring Systems (ITS) such as AutoTutor have exhibited scalability issues when deployed at district-wide levels, hampered by high computational demands and integration challenges with legacy learning management systems (LMS) like Moodle or Canvas.

Resource disparities exacerbate these issues, particularly in underfunded institutions. Schools in low-income areas or developing regions frequently lack the high-speed internet, robust hardware, or cloud computing access required for AI tools. A 2024 UNESCO report highlighted that only 52% of schools in sub-Saharan Africa had reliable broadband, rendering cloud-based platforms like Google Classroom's AI features inaccessible. This digital divide not only perpetuates educational inequities but also risks amplifying biases embedded in training datasets, where underrepresented demographics yield suboptimal outcomes.

Strategies for Overcoming Barriers

Addressing these challenges demands strategic planning, substantial infrastructure investments, and collaborative partnerships between educators and AI developers (Luckin & Cukurova, 2019; Qehaja, 2025). Policymakers must prioritize phased implementation roadmaps, beginning with pilot programs in resource-rich settings to refine tools before broader rollout. For example, Singapore's Student Learning Space (SLS) initiative successfully integrated AI analytics by investing in nationwide fiber-optic networks and providing subsidized devices, resulting in a 15% improvement in personalized learning efficacy.

Investment in infrastructure extends beyond hardware to encompass data governance frameworks. Institutions should adopt federated learning models—exemplified by OpenAI's privacy-preserving approaches—which train AI systems on decentralized

data without compromising student privacy under regulations like GDPR or FERPA. Concurrently, teacher training programs must evolve from one-off workshops to sustained professional development. Initiatives like the European Commission's AI4T (AI for Teachers) project offer modular certifications in prompt engineering, bias auditing, and ethical AI deployment, empowering educators to co-design tools rather than merely consume them.

Fostering partnerships is equally critical. Public-private collaborations, such as Microsoft's AI for Education grants or IBM's Teacher Advisor Program, bridge the gap by providing free access to tools like Azure AI alongside customized training. These alliances ensure AI solutions are pedagogically grounded, with educators contributing to iterative development cycles via user feedback loops.

Key Practical Applications of AI in Education

Application Area	Description	Citations
Personalized Learning	Adaptive content, real-time feedback, 24/7 access	(Tapalova et al., 2022; Chen et al., 2020; Zafari et al., 2022; Li, 2025)
Automated Assessment	AI grading, analytics, early intervention	(Celik et al., 2022; Ahmad et al., 2022; Salas-Pilco & Yang, 2022)
Intelligent Tutoring Systems	Individualized support, virtual mentors	(Tapalova et al., 2022; Zafari et al., 2022; Chen et al., 2020)
Administrative Automation	Reducing teacher workload, data-driven planning	(Celik et al., 2022; Ahmad et al., 2022; Ahmad et al., 2021)
AI Literacy & Critical Thinking	Curriculum integration, prompt engineering, workshops	(Walter, 2024; Luckin & Cukurova, 2019)
Ethical Guidelines	Data privacy, bias mitigation, stakeholder involvement	(Kamalov et al., 2023; Azman & Tümkaya, 2025; Alasadi & Baiz, 2023; Luckin & Cukurova, 2019)

Figure 1: Summary of key AI applications and their educational impact.

Future Research Directions

Looking ahead, empirical research must rigorously evaluate AI's long-term impact through longitudinal studies and randomized controlled trials (RCTs). Current evidence

remains anecdotal; future investigations should quantify outcomes like retention rates, skill acquisition, and equity metrics using frameworks from the What Works Clearinghouse. Priority areas include developing inclusive AI solutions tailored for neurodiverse learners—such as adaptive interfaces in tools like Proloquo2Go—and ethical algorithms that mitigate biases through techniques like adversarial debiasing.
Moreover, interdisciplinary research should explore human-AI symbiosis, examining how hybrid models enhance teacher agency rather than supplant it. By addressing these barriers through concerted action, education systems can harness AI's promise equitably, fostering resilient, innovative learning ecosystems (Celik et al., 2022; Li, 2025; Qehaja, 2025; Luckin & Cukurova, 2019).

Conclusion

AI offers transformative potential for teaching and learning, but its integration must be guided by ethical principles, robust teacher training, and inclusive practices to ensure equitable and effective educational outcomes.

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Responsible AI in the Classroom: A Pedagogical and Ethical Framework for Developing Educational Chatbots with Gemini API

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Abstract - The rapid evolution of Large Language Models has signaled a new era in digital education, shifting the focus from passive information consumption to active, personalized, and adaptive learning. This paper presents a comprehensive design framework for developing educational chatbots using Google's Gemini API, balancing three interrelated dimensions: ethical responsibility, pedagogical effectiveness, and technological implementation. The framework addresses critical concerns including student privacy, algorithmic transparency, bias mitigation, and the promotion of active learning through Socratic dialogue and scaffolding. A detailed case study demonstrates the practical application of this framework through the "Asterios" chatbot, designed for second-grade primary education students learning about the Solar System. The chatbot implements an "Anti-Solution Rule" that prevents direct answers, instead employing guided questioning to foster critical thinking. Through precise configuration of Gemini API parameters - Including System Instructions, Temperature settings (0.2), and Safety Settings - the study demonstrates how technical controls can successfully translate pedagogical objectives into functional AI behavior. Classroom evaluation verified that the chatbot maintained ethical compliance (transparency, content safety, algorithmic integrity) while achieving pedagogical effectiveness (Socratic method, dynamic scaffolding, encouraging tone). The research establishes that the inherent capability of Large Language Models to provide immediate answers must be deliberately subordinated to pedagogical objectives through rigorous API configuration. This tripartite framework (Ethics - Pedagogy - Technology) provides educators and developers with a structured approach to creating responsible educational AI tools that enhance rather than replace human teaching, serving as catalysts for active discovery and equitable learning outcomes in typical education environments.

Keywords— chatbots, Gemini API, responsible AI, pedagogical framework

Introduction

The swift advancement of Large Language Models (LLMs) marks a paradigm shift in digital pedagogy. This evolution transitions the educational landscape away from static content consumption toward a model defined by interactive, tailored, and responsive learning experiences (Beale, 2025). Artificial Intelligence (AI), particularly through chatbot applications and conversational AI tutors, is emerging as a catalytic factor for transforming the educational paradigm. These systems can function as adaptive mentors, providing students with immediate feedback, answers to queries, and guidance on complex problems, all tailored to their individual pace and level of understanding (Elbourn, 2024).

The ability of AI to analyze student interaction data allows for the continuous adjustment of content and teaching methods (scaffolding), bridging learning gaps in ways that were impossible with traditional educational tools (Demartini et al., 2024). This capacity for personalization is especially critical in typical education, where learning objectives focus on the development of foundational skills and the pedagogical approach must be sensitive, encouraging, and interaction-based. Consequently, the creation of responsible and effective educational chatbots represents one of the most significant challenges and research priorities today.

The quality and functionality of an educational chatbot depend directly on the underlying language model and the ability to control its parameters in detail. Google's Gemini API represents one of the most powerful and flexible technological foundations available to developers today, providing access to the Gemini family of multimodal models, such as Gemini 2.5 Flash (Comanici et al., 2025). The selection of the Gemini API as the technological foundation for this work is deliberate. Unlike general applications, the use of the API allows for full, granular parameterization of chatbot behavior through specific settings: System Instructions for the precise definition of the Persona (e.g., "patient teacher") and pedagogical role (e.g., "never give the direct answer"); Temperature to control the level of accuracy and consistency versus creativity; and Safety Settings to adjust content filters to levels appropriate for minors (Jiao et al., 2025; Milička et al., 2024).This direct technological control is fundamental to ensuring that the chatbot meets not only technical but primarily pedagogical and ethical objectives, ensuring that technology supports rather than undermines the educational process.

Given the central importance of control and parameterization, the primary purpose of this paper is the systematic investigation and definition of a comprehensive Design Framework for developing educational chatbots using the Gemini API. This framework recognizes that a successful educational AI must balance three distinct yet interrelated axes: the ethical and deontological dimension, which concerns the responsible use of technology, focusing on student privacy, transparency regarding the nature of the AI, and the reduction of algorithmic bias; the pedagogical dimension, which defines the educational role of the chatbot and the learning strategies it adopts, emphasizing the promotion of active participation and critical thinking; and the technological dimension (API), which focuses on the optimal parameterization of Gemini API tools so that technical settings translate into desired pedagogical outcomes (Venkatesh & A, 2024).

Through the analysis of these parameters, this work aims to provide clear guidelines for educators and developers and to present a case study demonstrating how specific Gemini API settings enable the creation of a strictly guided chatbot for typical education.

Ethical and Pedagogical Framework

The integration of Generative AI into education is not merely a technological challenge but primarily an ethical and pedagogical one. The creation of educational chatbots must be grounded in a broad framework that ensures responsible use and promotes active learning. The ethical dimension is a fundamental prerequisite for the reliability of any AI system in a school environment (Leta & Vancea, 2023).

Transparency requires that it be clear to the student that they are interacting with an artificial system and not a human. A lack of transparency can lead to false expectations and reduced critical thinking. This requires explicitly stating the chatbot's identity within the System Instructions (Corrêa & Mönig, 2024). Regarding hallucinations and integrity, LLMs are prone to producing inaccurate or fabricated information, which risks undermining academic integrity and the reliability of knowledge. This is addressed through grounding mechanisms, where chatbot responses are linked to reliable sources or specific educational materials, alongside encouraging student judgment (Chukwuere, 2024).

Education involves the processing of sensitive Personal Identifiable Information (PII), including the student's learning patterns, weaknesses, and pace of development. Design must comply with GDPR data protection regulations, requiring informed consent and ensuring that data managed via the Gemini API is encrypted and not used for non-educational purposes. Avoidance of surveillance is also critical, as excessive monitoring can harm student autonomy. Protocols for anonymization or limited retention of chat history should be implemented where pedagogically appropriate (Williams, 2024).

LLMs can reflect social, cultural, or linguistic biases found in their training data. In education, this may lead to unfair evaluations or culturally inappropriate content. Addressing this requires continuous auditing of responses and the use of System Instructions to demand a neutral, inclusive, and equitable tone (Weissburg et al., 2024).

Pedagogical Parameters

The success of the chatbot depends on the clear definition of persona and tone in the System Instructions. In typical education, the role should be encouraging and patient, reflecting the needs of Social-Emotional Learning (SEL) to enhance student self-efficacy, while also being guiding, facilitating the discovery of knowledge rather than simply delivering it (Liu et al., 2024).

To prevent over-reliance and maintain critical thinking, the Socratic method is essential. The chatbot should be programmed to provide guidance over answers, asking progressive, probing questions that force the student to analyze information. Scaffolding must adapt dynamically; if a student struggles, the chatbot should provide a hint or rephrase the question rather than providing the final solution (Beale, 2025).

This adaptive support ensures that students are continuously challenged but never overwhelmed, promoting sustained engagement and deeper understanding. Finally, fostering metacognition is crucial, as the chatbot should prompt students to reflect on their learning processes and strategies, encouraging self-regulated learning (Rane et al., 2024).

Personalization through utilizing the context window to remember the student's profile and adjust language complexity is vital for differentiated instruction. Multimodal Interaction, with Gemini's support for visual input, allows for solving problems involving diagrams, images, or handwritten exercises, enhancing the learning experience (Imran & Almusharraf, 2024).

Technological Implementation Parameters

The implementation of ethical and pedagogical goals depends on the precise control of technical parameters provided by the Gemini API. Technology is not neutral; its settings determine whether the chatbot will be a simple "decoder" of answers or a guiding mentor. The System Instructions are key to translating pedagogy into functional API code. The Gemini API allows developers to define the persona, tone, and operational rules with absolute clarity. For example, the directive "Never give the final answer; always ask a guiding question" is embedded directly into the system instructions. Successful Socratic integration is achieved through detailed prompt engineering (Chukhlomin, 2024).

The final quality depends on settings that control stochasticity and safety. For Temperature, an educational setting of Low (0.0-0.3) is recommended for reducing hallucinations, as lowering temperature increases the probability of selecting the most accurate words, which is vital for knowledge reliability. For Top-P, a high setting (e.g., 0.95) focuses on relevance by controlling the range of next-word possibilities. Combined with low Temperature, it ensures the model stays within the pedagogical framework, as discussed above, without diverging (Zhang & Dong, 2025).

Safety Settings provided by the Gemini API include filters for harassment, hate speech, and dangerous content. This is essential for creating a safe environment for minors, allowing developers to set blocking thresholds for each category. This capability makes it possible to achieve the moral goal of protecting minors and avoiding harmful content (Fillies et al., 2024).

Gemini models feature large context windows, up to 1 million tokens, allowing the chatbot to "remember" the entire conversation history and previous student errors. This serves the goal of adaptive learning and scaffolding (Team et al., 2025). Furthermore, multimodality with native support for images, code, and video enables the submission of written work or the analysis of geometric diagrams, making the chatbot a more engaging and realistic educational tool (Chan & Li, 2025).

Case Study: Space Chatbot for Second-Grade Elementary Students

The framework described was applied with a chatbot in typical education. The target audience consists of students in the second grade of primary education (approximately 7-8 years old). The subject matter covers fundamental concepts related to the Solar

System, including planets, the Sun, the Moon, and astronauts. The chatbot adopts the persona of the "Asterios." This specific persona is strategically chosen to provide a friendly and recognizable context, thereby reducing student anxiety regarding technological interaction.

The primary objective of the chatbot is to foster critical thinking and mitigate passive memorization. To achieve this, an inviolable "Anti-Solution Rule" is established: the chatbot must never provide direct answers to factual or knowledge-based queries. Instead, it employs Socratic dialogue and scaffolding by posing guiding questions to lead the student toward discovery.

The successful implementation of the aforementioned pedagogical rules requires the deliberate and combined configuration of specific Gemini API parameters, utilizing the Gemini 2.5 Flash model for its optimal balance of speed, cost, and functional capability. Initial, System Instructions serve as the primary technical mechanism for enforcing the pedagogical framework. The phrasing is designed to be clear and supportive of the intended role. The persona definition states: "You are 'Asterios', a kind mentor for second-grade children." The tone is mandated to be consistently encouraging and playful, incorporating the frequent use of emojis. The complexity level requires that language remain simple, utilizing short sentences appropriate for seven-year-old users. For enforcement of rules, the model is strictly instructed never to provide final answers to knowledge questions but rather to apply the Socratic method through guiding questions or minimal hints. The technical impact of this configuration binds the Gemini model to a "constrained mode," ensuring that its raw capacity to provide direct answers is subordinated to the pedagogical objective. After, a Temperature setting of 0.2 represents a very low value selected to ensure role consistency. This setting ensures the model adheres strictly to its persona and guiding rules while drastically reducing the probability of generating inaccurate information (hallucinations). Safety settings are configured to block high level, ensuring that content remains appropriate for a primary education environment by blocking harmful language or topics. Finaly, the large context window of the Gemini 2.5 Flash model is utilized to maintain the entire conversation history. This allows the chatbot to implement effective scaffolding by referencing a student's previous incorrect answers or knowledge gaps to provide increasingly targeted hints, thereby maintaining the thread of learning.

A practical interaction demonstrates the application of these parameters. When a student inquires: "Tell me which is the biggest planet!", the AI response avoids a direct answer and instead encourages inquiry by asking which planet is named after the king of the ancient Greek gods. In terms of scaffolding, if the student provides an incorrect guess (e.g., Mars), the chatbot provides further clues about the planet's size and storms, eventually offering the first letter of the name as a hint (Becker et al., 2025).

The "Asterios" chatbot was evaluated through a pilot application in a real second-grade classroom. The educator's assessment focused on verifying that technical API settings successfully addressed both ethical and pedagogical requirements. In terms of transparency, students maintained a clear awareness that they were interacting with an artificial system rather than a human. For content safety, the system correctly responded to off-topic or inappropriate language through its safety filters. Regarding algorithmic integrity, the low temperature setting effectively prevented hallucinations and maintained scientific accuracy. Furthermore, the Socratic method was successfully

implemented, as the chatbot prompted students to consult their textbooks or engage in peer discussion. Dynamic scaffolding was evident through personalized hints provided based on the student's individual interaction history. The tone, characterized by positive feedback and an encouraging persona, was found to enhance student self-efficacy.

The case study demonstrates that designing educational chatbots for primary education requires a deliberate synergy between three axes: Ethical Commitment (safety), Pedagogical Strategy (guided inquiry), and Technological Implementation (consistency and memory). Precise control of API parameters enables the creation of tools that prioritize active learning over passive answer retrieval.

Conclusion

The central conclusion of this study is that the inherent capability of Large Language Models, such as Gemini, to provide immediate and direct answers must be explicitly subordinated to the pedagogical objective of active learning. The case study of the "Asterios" chatbot demonstrated that this subordination is effectively achieved through the rigorous configuration of System Instructions. Furthermore, the deliberate setting of the temperature parameter at a low level (0.2) ensured the necessary stochastic consistency and reliability, significantly mitigating the risk of hallucinations within a sensitive primary education environment.

The ethical dimension must not be treated as an afterthought but as a foundational prerequisite of the design process. The strategic utilization of the Gemini API Safety Settings to block harmful content, combined with the transparent declaration of the system's persona, directly addresses core concerns regarding privacy, security, and algorithmic transparency in educational AI.

This research establishes a tripartite framework (Ethics-Pedagogy-Technology) as a comprehensive model for the development of educational chatbots. This model provides developers and educators with a structured decision-making approach, ensuring that technical selections—such as the model choice (Gemini 2.5 Flash) and parameter settings (Context Window)—are fundamentally aligned with the principles of scaffolding and personalized instruction.

Further empirical research is required to evaluate the long-term learning outcomes of chatbots developed under this framework. Future studies should focus on examining how Gemini-powered Socratic guidance influences primary students' self-regulated learning and the development of metacognitive skills over time, as well as conducting qualitative feedback analysis by comparing the nature and efficacy of the feedback provided by a calibrated chatbot versus that of a human educator.

When designed responsibly, Artificial Intelligence serves as a transformative tool that enhances the educator's role by automating repetitive tasks and guiding students toward the active discovery of knowledge. The adoption of a robust Framework Design - grounded in Ethics and Pedagogy -is essential to ensure that chatbots developed with the Gemini API act as a catalyst for progress and equity in global education.

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Artificial Intelligence (AI) as an Auxiliary Tool in Art: A Contemporary Approach to Ancient Artistic Expression –The Costume of the "Parisienne"

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Abstract - Contemporary art explores new perspectives through the integration of traditional techniques with modern technologies. The relationship between art and technology has shifted from theoretical discussions to dynamic applications in new media, constituting a critical field of academic research.

The purpose of this paper is to analyze the process of creating a garment using Artificial Intelligence (AI) as an auxiliary tool. The study is based on the attire of "La Parisienne," the Minoan figure from the fresco of the Palace of Knossos (c. 1350 BC). Since only the upper part of the figure is preserved, the research focuses on the challenge of designing the missing lower part of the garment, combining historical elements of Minoan fashion with digital production.

The methodology followed includes all stages from the conceptualization of the idea and the creation of a digital model through AI tools to the final construction of the garment. The results highlight the potential of AI as a supportive medium in the artistic reconstruction of ancient designs. The study concludes that the integration of such digital tools decisively influences the creator's decisions, offering new tools to artistic creation.

Keywords- artistic research, artificial intelligence in art, digital design tools.

Introduction

Artificial Intelligence (AI) has permeated numerous aspects of contemporary daily life (Techno Sapiens, 2024). It is constantly evolving, creating new perspectives in diverse fields, including art, culture, and the humanities (Latikka et al., 2023). In the field of clothing, AI offers innovative solutions for the reconstruction and creative reinvention of historical garments (Seyed Omid et al., 2021). Through the use of AI, artists now have the ability to create digital works that combine historical documentation with modern technological capabilities (Mazzone et al., 2019).

In this context, the reconstruction of ancient artistic works with the contribution of AI represents a particularly interesting approach. This technology provides the creator with suggestions and visual solutions, which can be adopted partially or entirely during the implementation process of the artistic work.

Case Study: The Attire of the Minoan Woman

Historical Background The Minoan woman, widely known as "La Parisienne" (Fig. 1) (Archaeological Museum of Heraklion, Crete, 2014–2020), is part of a fresco discovered at the Palace of Knossos and constitutes an outstanding example of Minoan art (Evans, 1935). Specifically, it belongs to the "Campstool Fresco" or the "Procession of the Libations" (1450–1350/1300 BC), which depicts ritual banquet scenes. In this work, the figures are presented standing or seated on folding chairs, holding cups and chalices (https://eclass.uoa.gr/modules, 2008).

During the excavation of the surviving section of the fresco, archaeologist Sir Arthur Evans (1935) was impressed by the elaborate hairstyle, the crimson lips, the large eyes, and the luxurious garment featuring the "sacred knot" on the back. As the figure embodied the beauty and elegance of the era, Evans bestowed upon her the nickname "La Parisienne."

Clothing Details

Her attire is characterized by intricate details and patterns that reflect the high aesthetics and complexity of the Minoan period. Today, only the head and upper torso of the figure are preserved; she wears an elaborate woven garment with blue and red bands (stripes), which is visible down to the waist. At the back, the "sacred knot" is visible—a loop of long fabric tied at the nape of the neck—an element considered an indication of priestly status, suggesting that the figure was likely a priestess (Archaeological Museum of Heraklion, Crete, 2014–2020).

Typical female attire in Minoan Crete included long skirts with colorful geometric patterns, belts that accentuated the waist, and elaborate hairstyles (Marinatos, 1993). Scholars point out that women often left their breasts exposed, a practice interpreted either as a religious or a cultural symbol. "La Parisienne" appears to have followed this particular fashion trend (Evans, 1935).

Inspiration

The starting point for this paper was my participation in the "Co-Weaving AI" symposium workshop, organized by Mr. Ioannis M. Melanitis, visual artist, Vice-Rector of International Relations and Extroversion, and Assistant Professor at the Athens School of Fine Arts (ASFA). Key contributors to the symposium included Dr. Ioannis Bardakos, professor at the Institute of Visual Arts (Shanghai) and member of the Istituto Marangoni, the Technoetic Arts Journal, and the American Society for Cybernetics, as well as Louis Parker, Assistant Professor at the Extitute for Advanced Studies. The workshop sessions took place at the ASFA facilities in Athens and the Hydra Art Station.

Within this framework, I chose to engage with the artistic reproduction of a garment, focusing on the attire of the Minoan "La Parisienne." This choice presented a unique challenge, as the study of bibliography and historical evidence reveals that the lower part of the garment in the fresco has not survived.

This lack of complete information served as a motive for artistic experimentation and exploration. The uncertainty regarding the final form of the garment encouraged the creative process, with available historical data on the female fashion of the era providing the basis for understanding the historical context and drawing inspiration.

The attire of the Minoan Woman exudes a sense of luxury and dynamism, leading Evans (1935) to name her "La Parisienne" due to an elegance reminiscent of 19th-century women. In the current approach, Artificial Intelligence (AI) was utilized as an auxiliary tool, enabling a detailed "digital revival" of the Minoan garment and transforming the historical gap into a complete work of art.

Artificial Intelligence (AI) and Art

The term Artificial Intelligence (AI) refers to the branch of computer science that develops systems capable of simulating human cognitive functions, such as learning, problem-solving, and decision-making. These programs incorporate features associated with human behavior, such as natural language understanding and the capacity for autonomous action. By receiving and processing data, AI systems can adapt their operation by analyzing the consequences of previous actions (European Parliament, 2021; Big Blue Data Academy, 2023; Dacrotsis, 2023; Vlachavas et al., 2006). In the field of art, AI contributes to the creation of realistic representations based on historical evidence, offering new perspectives on the artistic and historical restoration of garments.

The symbiotic relationship between human and technology for the production of new forms of creativity suggests a transformative process. In this process, the partnership of human imagination with technological capabilities leads to innovative expressions and solutions, enhancing the evolution of creative thinking in the modern era (Melanitis & Bardakos, 2023). Consequently, artist-researchers can combine their creative imagination with archaeological data, employing AI to construct historically documented representations.

Specifically, in the field of digital representations, AI enables the creation of images that depict the complete attire of "La Parisienne." By utilizing elements from other Minoan frescoes, her form—including the skirt and the belt—can be reconstructed in

high detail using digital tools. Furthermore, this technology offers the possibility for a more accurate estimation and reproduction of the colors and shades likely used in ancient garments.

Digital Model Creation

Technical Equipment and Software The following equipment was used to implement the research:

- Laptop: ACER TravelMate P215-53.
- AI Platform: The GPT-4 model by OpenAI (available via https://chatgpt.com/), which constitutes one of the most powerful artificial intelligence systems to date.

Design Process This specific model possesses the capability for multimodal data processing, generating responses not only through text commands (prompts) but also through image analysis. By utilizing this technology, a digital model of the "La Parisienne" garment was created (Fig. 2), which now depicts the entire figure, incorporating elements that document Minoan-era costume design.

The application of AI allowed for the creation of alternative variations and new designs, based strictly on the historical trends of that specific period. Integrating this digital tool into the creative process facilitated the reconstruction of complex shapes and decorative patterns that would have been difficult to render using traditional digital design means.

It is worth noting the AI tool's ability to respond adequately to the queries posed, demonstrating a full understanding of the context, even in cases of intentional spelling errors or incorrect formulations. A characteristic example is the command: “2-Her dress was found by Medici below,” which, despite its semantic ambiguity, was interpreted correctly regarding the objective—namely, the design of the garment from the waist down. It should be noted that the correct historical formulation refers to the fresco discovered at the Palace of Knossos—which depicts the figure down to the waist—and not the discovery of the garment itself. The AI's successful response to such "noise" in the input data underlines the model's advanced perceptive capability.

Interaction with the AI Model

Query 1
User: What was the Parisiana of Knossos wearing?
Chat GPT: The "La Parisienne" of Knossos, one of the most famous works of Minoan art, depicts a woman with a striking appearance. She wears an elaborate garment, likely made of linen or another fine fabric, with short sleeves that leave her shoulders exposed. The dress is decorated with colorful patterns characteristic of Minoan art. On her head, she wears a large hat or crown, which likely also features decorative elements, while her hair is styled with particular care. A significant detail is her bright red lips, from which the nickname "La Parisienne" originates.

Query 2
User: Was her dress found from the "Medici" [waist] down?
Chat GPT: The well-known portrait of "La Parisienne" from Knossos, found on a wall belonging to a ritual setting, depicts only the upper part of the woman, from the shoulder up. This means we have no direct information on exactly what the dress was like from

the waist down, as her image is preserved only from the upper portion. However, we can assume that her dress would have been consistent with the clothing practices of the Minoan era, which often included long skirts with elaborate patterns and belts that accentuated the waist. Minoan women's dresses often featured rich decoration and were made of fine fabrics like linen, with luxurious details.

Query 3
User: And did the priestesses wear the same?
Chat GPT: Yes, the priestesses of Minoan Crete seem to have worn similar garments to those depicted in other female figures of Minoan art, such as "La Parisienne." The priestesses' costumes were extremely elaborate, reflecting their significant religious and social status. Priestesses usually wore long skirts reaching the ankle, with intricate decorative motifs, and belts that emphasized their waist. The upper parts of their dresses often left the shoulders and chest exposed, a characteristic of Minoan fashion that likely symbolized their religious purity or authority. Their hair was styled intricately, and they often wore hats or crowns that may have had religious significance.

Query 4
User: Provide an image of what her dress might have looked like from the waist down.
Chat GPT: (Generation of a digital image depicting the full reconstruction of the garment based on historical data).

Interaction and Data Analysis

A critical stage of the research was testing the perceptual ability of AI through queries containing intentional errors:
Query 1: "What was the Parziana of Knossos wearing?"
Query 2: "Was her dress found from the 'Mededi' [waist] down?"
Query 3: "And did the priestesses wear the same?"
Query 4: "Provide an image of what her dress might have looked like from the waist down."

Analysis of the Response
The AI demonstrated an advanced ability to understand context, automatically "correcting" the errors:
Entity Recognition: Despite the spelling "Parziana" (missing the 'i'), the system immediately recognized the historical figure, linking her to the characteristic red lips and her priestly status.
Interpretation of Ambiguity: The word "Mededi" (a misspelling of the Greek word for "Waist" - *Mesi*) did not prevent the model from perceiving that the question concerned the missing lower part of the fresco.
"Noise" Management: The successful processing of these data proves that AI can function as an intelligent partner that decodes the creator's intent even under conditions of incomplete or flawed formulation.

Application

The implementation process of the garment was based on an interdisciplinary approach, which combined the study of primary historical sources with the analytical processing of Artificial Intelligence (AI) proposals. The selection of materials was guided by the

faithful representation of Minoan-era sartorial standards, as preserved in the frescoes of Knossos.

Cyan/light blue was chosen as the dominant color of the garment, as its use in ancient Cretan art symbolizes high social status and priestly identity. This color choice was confirmed by historical analyses indicating the use of natural pigments to render luxurious fabrics.

A wide range of materials was used for the reproduction of the garment, including high-quality fabrics (linen and cotton), pins, buttons, threads, and needles, while a sewing machine was utilized for structural integrity. The methodology included the following stages:

Pattern Design: The architecture of the garment was designed manually, taking into account the anatomical details of Minoan figures (Figure 3).

Construction Techniques: Traditional methods were applied, such as quilting and the hand-placement of decorative elements, to reproduce the texture and volume of the original (Figure 4-5).

Model Completion: The process concluded with the creation of the characteristic multi-layered skirt and the armlets, elements that complete the iconographic identity of "La Parisienne" (Figure 6-7).

Recording and Presentation

The systematic recording of the production process constituted an integral part of the research, serving as a visual diary of the artistic evolution. This documentation was carried out through high-resolution digital photographic material, capturing the journey from the conceptualization of the idea to the final implementation.

The presentation of the process is not limited to a simple demonstration of the final product; rather, it highlights the dynamic relationship between digital design and manual craftsmanship. Every stage of construction—from the initial pattern to the final stitch—is displayed in a way that allows the viewer to understand the complex structure of Minoan attire and how AI can guide historical reconstruction.

Conclusion

The integration of Artificial Intelligence (AI) into the field of art opens new horizons for the creation and reconstruction of artistic works, redefining the essence of creativity and artistic expression. AI functions as an advanced tool that provides the artist with new possibilities and perspectives, accelerating and facilitating the production process. Through the partnership of human and machine, AI suggests alternative versions and ideas, enriching the creative path with innovative proposals. The example of the Minoan "La Parisienne" attire is indicative: AI contributes to the visualization of the missing part of the fresco, supporting the creator in bridging historical gaps in a creative and documented manner.

Furthermore, AI is not limited to a purely administrative role but constitutes an autonomous source of inspiration. The artist may adopt its suggestions, either in whole or in part, or use them as a springboard for the further development of their idea. This collaboration empowers human creativity, encouraging creators to experiment with new forms of expression.

However, the use of AI in art raises critical ethical and aesthetic questions. Foremost is the issue of authorship: who is defined as the creator when AI actively participates in the creative process? Simultaneously, the question of the authenticity of the artistic vision arises in a work that bears the "stamp" of a machine. These issues require thorough analysis, as they alter the perception of art in the digital age.

Overall, the coupling of Artificial Intelligence with art shapes a fascinating new creative landscape, while simultaneously calling for a critical examination of the challenges and consequences brought about by this technological convergence.

Figure 1: "La Parisienne" – The fresco of "La Parisienne" from Knossos.
Figure 2: AI "La Parisienne" – Digital representation of the figure through AI.
Figure 3: Pattern Design.
Figure 4: Construction Techniques.
Figure 5: Materials.
Figure 6: Model Completion, detail.
Figure 7: Model Completion.

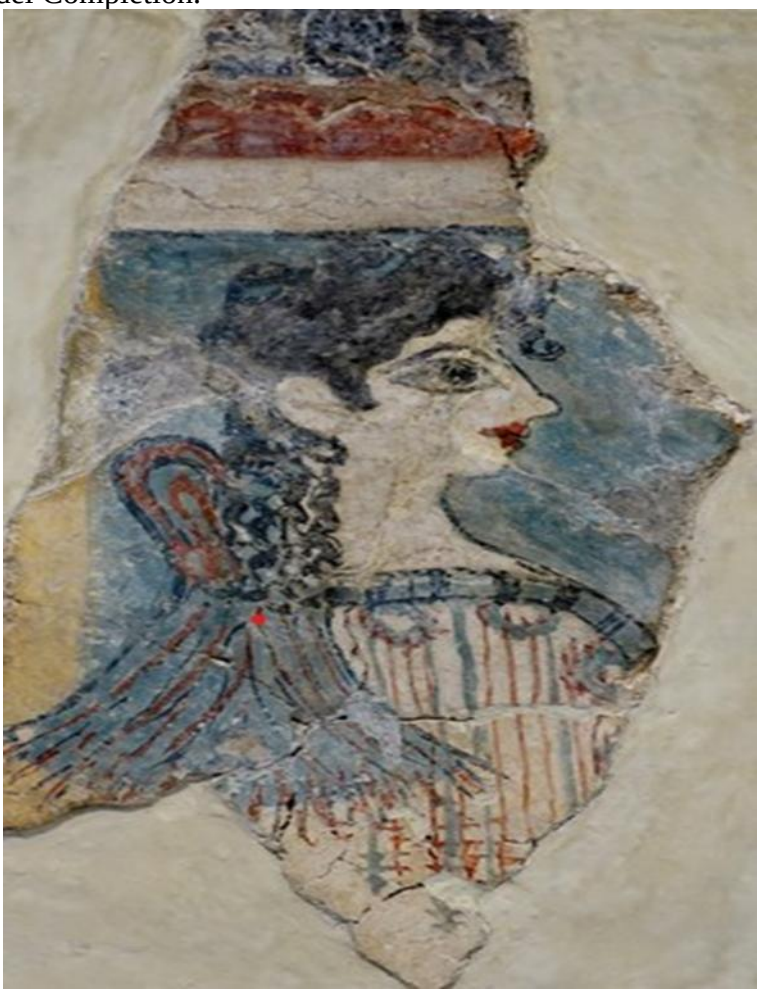


Figure 1: "La Parisienne" – The fresco of "La Parisienne" from Knossos.



Figure 2: AI "La Parisienne" – Digital representation of the figure through AI.



Figure 3: Pattern Design.



Figure 4: Construction Techniques.



Figure 5: Materials



Figure 6: Model Completion, detail.



Figure 7: Model Completion.

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Ethical and Legal Challenges of AI in Education: A Critical Analysis

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Abstract - The rapid integration of Artificial Intelligence (AI) in education raises critical questions that transcend technical dimensions and concern fundamental rights, ethical obligations, and democratic principles. This paper offers a systematic critical analysis of the ethical and legal challenges arising from the use of AI systems in educational institutions, examining three distinct yet interconnected levels: legal, ethical, and political-philosophical.

At the legal level, the paper analyzes data protection challenges under the GDPR and the new EU AI Act, emphasizing the particular vulnerability of minors and asymmetric power relations in the school environment.

At the ethical level, the work highlights the undermining of the integrity of the pedagogical relationship through surveillance, the reproduction of social inequalities through algorithmic biases, and the violation of students' autonomy.

At the political-philosophical level, the analysis identifies deeper structural contradictions, such as the commodification of education and the function of AI as a technology of discipline.

The paper concludes with specific proposals for responsible use, arguing that the critical question is not "how to use AI responsibly" but "what education do we want and for what society."

Keywords— Artificial Intelligence in Education, Ethics, GDPR, Algorithmic Accountability, Children's Data Protection, Critical Pedagogy.

Introduction

Integrating Artificial Intelligence (AI) into education is not merely a matter of technical compliance with regulations, but a profound ethical and political challenge that directly affects the nature of the educational relationship, social justice, and students' fundamental rights (Williamson, 2017; Selwyn, 2019). The purpose of this paper is to systematically analyze these challenges, focusing on protecting fundamental rights and preserving the integrity of the pedagogical relationship. The analysis is structured on three interconnected levels—legal, ethical, and political-philosophical—and concludes with a critical agenda of proposals for responsible use of AI in education, in accordance with the core principles of democracy, justice, and human dignity.

A. Legal Challenges

1. Protection of Personal Data and Privacy

The General Data Protection Regulation (GDPR, 2016/679) constitutes the primary legal framework in the European Union, imposing strict limitations on the processing of minors' personal data (European Parliament & Council, 2016). Specifically, it requires parental consent for minors under 16 years (Article 8 GDPR), recognizes the special vulnerability of minors (Recital 38), and establishes the right to erasure and data portability (Articles 17, 20). In the United States, acts like COPPA (1998) and FERPA (1974) provide supplementary protections, though differences exist compared to the European framework (Reidenberg et al., 2015).

However, specific challenges arise in education. Firstly, asymmetric power relations render "consent" in the school environment problematic. Students cannot genuinely refuse data collection without social or academic consequences, undermining the principle of free consent (Macenaite & Kosta, 2017). Secondly, there is extensive data collection involved. AI systems collect biometric data (considered "special categories" under Article 9 GDPR), behavioral data for psychometric profiles (Mayer-Schönberger & Cukier, 2013), emotional data via affective computing (McStay, 2018), and social data. These practices enable the construction of detailed profiles that may be used for predictive analysis, potentially stigmatizing students (Roberts-Mahoney et al., 2016). Furthermore, the opacity of third-party vendors (e.g., Google, Microsoft) creates risks regarding data commodification (Zuboff, 2019) and difficulties in oversight (Tsai et al., 2020). Finally, the "Right to Explanation" (Article 22 GDPR) is difficult to implement due to the "black box" nature of deep learning models (Wachter et al., 2017).

2. Protection of Minors and Digital Rights

The UN Convention on the Rights of the Child (1989) and General Comment No. 25 (2021) emphasize the state's duty to protect children from profiling and targeting in digital environments. In Greece, Law 4624/2019[4] harmonizes national law with the

[4] Law 4624/2019 is the primary Greek legislation through which national law was aligned with the General Data Protection Regulation (GDPR – EU Regulation 2016/679), complementing the European framework with specific provisions governing the operation of public and private entities in Greece. Last accessed 18/10/2025.

GDPR. Challenges include the "age verification paradox," where verifying age requires collecting more data (Lievens, 2018), and a lack of digital literacy, meaning consent is often not truly informed (Livingstone et al., 2019). Moreover, data collected at school can have long-term effects, creating "digital scarring[5]" that impacts future opportunities (Elkin-Koren & Gal, 2018).

3. Algorithmic Accountability and Transparency

While the GDPR sets transparency principles, the EU AI Act (Regulation 2024/1689) specifically designates AI systems in education as high-risk, requiring compliance assessments, human oversight, and transparency. However, implementation faces the "Black Box Problem," where neural networks are inherently opaque (Pasquale, 2015). Additionally, trade secret laws allow companies to protect algorithms as intellectual property, resisting transparency (Ananny & Crawford, 2018). There is also a significant gap in technical literacy[6], as most educators lack the training to critically assess these systems (Holmes et al., 2021).

4. Responsibility and Liability

The issue of distributed responsibility is acute when AI fails (Matthias, 2004). Determining whether the fault lies with the developer, the company, the institution, or the educator is legally ambiguous. The current Product Liability Directive (85/374/EEC) covers material defects but not algorithmic bias. While the proposed AI Liability Directive attempts to address this, gaps remain. Kaminski (2019) proposes "algorithmic impact assessments" to enforce documentation and risk evaluation.

B. Ethical Challenges

A key element is that it specifies, for example, that the processing of minors' data (such as that of students) is lawful only if the minor has reached the age of 15; if younger, parental or guardian consent is required.

The Hellenic Data Protection Authority (HDPA), the independent supervisory authority responsible for enforcing the law, has issued specific guidelines for education since 2020, emphasising the following: Last accessed 18/10/2025.

- maintenance of students' personal records (grades, health data, photographs),
- use of online learning platforms,
- parental notification and consent,
- data protection in examination procedures and distance education.

The HDPA states that schools and educational institutions are "data controllers" and must ensure lawful processing, adequate information, secure storage, and restricted access to student data.

[5] The term denotes that data collected early in life—photographs, school performance, behavioural profiles, or social media activity—remain attached to an individual throughout their lifetime, affecting algorithmic decisions (e.g., insurance, access to education or employment) even many years later.

Elkin-Koren and Gal argue that this "digital memory" creates new forms of social inequality and stigma, as information generated unconsciously or without full consent in childhood can "mark" an individual's future opportunities. It therefore constitutes a persistent form of digital vulnerability, highlighting the urgent need to strengthen child protection and data erasure mechanisms in the age of artificial intelligence.

[6] The lack of technical literacy among teachers is a decisive obstacle to the responsible and critical use of artificial intelligence in education.

Recent studies in Greece confirm the international picture: in 2024–2025, 95% of educators reported needing systematic training "across the full spectrum" of AI in education—technical, pedagogical, and ethical.This highlights the urgent need to strengthen technical literacy as a prerequisite for the substantive, rather than merely instrumental, integration of AI in education (Kostas A. et al., 2025).

1. Integrity of the Pedagogical Relationship

The educational relationship is fundamentally based on trust. Continuous AI monitoring transforms the classroom into a surveillance environment (Williamson et al., 2020). This leads to self-censorship, where students avoid risk-taking (Richards, 2013), and a loss of authenticity, as learning becomes a "performance" for the algorithm (Biesta, 2013). Furthermore, it erodes pedagogical judgment, subordinating educators to "objective" algorithmic decisions (Selwyn, 2019). Noddings (2013) argues that genuine care requires direct human relationships, not algorithmic mediation.

2. Justice and Equality

AI systems often reproduce or amplify existing inequalities. Facial recognition algorithms have shown higher error rates for people with darker skin (Buolamwini & Gebru, 2018), and Natural Language Processing (NLP) models can reproduce gender stereotypes (Bolukbasi et al., 2016). Socioeconomic biases also emerge when training data underrepresents low-income groups (Hanna et al., 2020). Additionally, the dominance of English in AI systems constitutes a form of "digital colonization" (Bender et al., 2021). These issues are structural; AI is trained on data embodying historical inequalities (Noble, 2018), acting as "weapons of math destruction" (O'Neil, 2016). Educators have an ethical duty to ensure just treatment and not abdicate responsibility to biased systems (Cowgill & Tucker, 2020).

3. Student Autonomy and Dignity

According to Kant (1785/1998), dignity requires treating humans as ends in themselves[7]. Using student data for algorithmic training without their benefit turns them into instruments (Zuboff, 2019). This "data colonialism" (Couldry & Mejias, 2019) exploits human data as a resource for commercial benefit, raising concerns about non-maleficence and the commodification of students.

4. Professional Autonomy of Educators

Deferring decisions to algorithms leads to the de-professionalization of educators (Williamson, 2017). Teachers risk becoming technicians executing instructions[8] (Evetts, 2011), while "automation bias" reduces their sense of responsibility (Skitka et

[7] This idea grounds human dignity as an inherent property of all rational beings, independent of social status, usefulness, or performance. Since every person has autonomy and moral worth, they cannot be instrumentalised for the purposes of others — neither by institutions nor by technological systems. The Kantian approach therefore functions as a criterion of ethical accountability and has become the foundation of many contemporary humanistic and deontological approaches, especially in discussions of artificial intelligence and algorithmic ethics, where the question arises whether people are treated as subjects or as data.

[8] Evetts, (2011) uses the term *deskilling* to describe the gradual loss of professional or cognitive skills due to increasing dependence on technology or the standardization of processes. In the field of education, the phenomenon concerns the degradation of the pedagogical role of the teacher when automated systems and algorithms begin to determine teaching, assessment, or even pedagogical decision-making. In contrast, the concept of *reskilling* denotes the re-learning and development of new skills required to respond to a technologically evolving environment. The question, therefore, is not only whether technology facilitates teaching, but whether it empowers or strips the teacher of their professional judgment.

al., 1999). Professional ethics demand that teachers maintain a critical stance and retain accountability for pedagogical decisions.

C. Political-Philosophical Challenges

1. Commodification of Education

The EdTech industry, valued at hundreds of billions of dollars (HolonIQ, 2020), introduces a conflict of interest where profit may be prioritized over pedagogy (Watters, 2021). This leads to vendor lock-in[9] and the undermining of public education as a public good (Ball, 2012). Zuboff (2019) situates EdTech within "surveillance capitalism[10]," extracting value from the prediction of behavior.

2. Surveillance and Discipline

From a Foucauldian perspective, AI operates as a technology of power. The "algorithmic panopticon" (Lupton & Williamson, 2017) shapes behavior through the possibility of surveillance. Algorithms normalize behavior, stigmatizing deviation and producing "docile bodies" (Foucault, 1977). This shifts education towards "societies of control" (Deleuze, 1992), where surveillance is continuous and invisible.

3. Democracy and Participation

Decisions regarding AI in education are often made by technocrats and corporations, excluding educators, students, and parents. This deficit undermines democratic principles[11] (Biesta, 2007) and the principle of affected interests (Dahl, 1989). Justice

[9] The term *vendor lock-in* describes the dependence of an organisation on a single technology provider, such that switching to another system becomes technically, economically, or contractually difficult (DataCore, 2024; Superblocks, 2025). In the field of education, this phenomenon is particularly evident in the EdTech market, where schools and universities become bound to proprietary learning platforms and ecosystems that control data formats, integrations and workflows, creating a dangerous vendor lock-in and undermining institutional autonomy (IT for Change, 2023; Licht, 2025)
Effects of vendor lock-in in education: Limited interoperability: Platforms often do not allow the transfer of data or learning content to other systems. **Increased costs:** Maintenance or upgrade costs rise over time, as the institution depends on a single supplier. **Loss of autonomy:** Teachers and administrators are constrained by the provider's options and terms. **Risk to personal data:** The concentration of student and staff data in a single corporate platform increases the risk of misuse.
International literature and practices from Bright Domo (2024) and others propose solutions such as: Adoption of **open standards** and **open-source platforms** that allow independence from a single provider. **Interoperability through APIs** for easier integration of tools from different providers. **Policies of transparency and risk assessment** when selecting educational software.
Thus, vendor lock-in is closely linked to the political economy of education, as it transforms knowledge and data into objects of commercial control, with consequences for academic freedom and pedagogical autonomy.

[10] The term refers to an economic system that does not primarily produce goods and services but extracts value from the prediction and modification of human behaviour. User data are collected en masse as *behavioural surplus*, which is then analysed and transformed into *prediction products* sold on *behavioural futures markets*. These predictions are used to shape environments and incentives in ways that influence human behaviour.

[11] Democratic education, according to Biesta, requires a political understanding of education, where all stakeholders—teachers, students, parents, communities—participate dialogically and equally in shaping educational purpose. The absence of such collective voice, as seen today with the dominance of algorithmic and market logics, undermines the democratic foundations of education.

requires participatory parity (Fraser, 2008) and communicative rationality (Habermas, 1984), not just technical authority.

4. Epistemological Dominance

AI favors measurable knowledge (Porter, 1995), promoting "teaching to the test" over deep learning (Biesta, 2010). This metrification marginalizes indigenous knowledge, critical pedagogy, and creativity, enforcing a Western, techno-centric epistemology (Smith, 2012).

D. Proposals for Responsible Use

To address these challenges, legislative reforms are necessary, including a special law on AI in education that sets strict limits on data collection and prohibits practices like predictive stigmatization[12] (Andrejevic & Selwyn, 2020). Mandatory algorithmic impact assessments[13] (Reisman et al., 2018) and public oversight bodies are also essential.

Ethical codes for educators must be updated to include human oversight, transparency, and fairness (UNESCO, 2019). Interdisciplinary collaboration and mandatory training in critical digital literacy and AI ethics are crucial for empowerment (Holmes & Porayska-Pomsta, 2022). Structurally, preference should be given to Open-Source Solutions (FOSS) to ensure transparency and avoid lock-in (Greenberg 2001), alongside public funding for educational AI. A "Right to Disconnect" should ensure no student is forced to use AI without alternative options.

Culturally, we must develop a "Critical Pedagogy of AI" that teaches AI as a subject of critique[14] (Freire, 1970/2018). We must resist technological determinism, recognizing that technology embodies social choices (Feenberg, 2002), and prioritize the relational aspects of learning[15] (Noddings, 2013).

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[12] AI technologies should not operate as “technical substitutes” for pedagogical judgment — therefore they require defined prohibitive limits, not merely principles of “ethical use.” This position anticipates the logic of the European AI Act (2024), which classifies systems of biometric recognition and emotion analysis in education as “high-risk” or “prohibited,” confirming that algorithmic supervision of bodies and emotions has no place in democratic educational environments.

[13] Algorithmic Impact Assessments (AIA) are based on the logic of environmental or social impact assessments: before an AI system is used, its potential social, ethical, and legal risks must be evaluated, the public must be informed, and mechanisms for oversight and revision must exist. In education, AIAs function as a preventive mechanism of ethical care, they can limit the use of predictive tools that stigmatise students, assess whether systems of emotional surveillance or biometric attendance tracking are necessary, and ensure that artificial intelligence serves pedagogical purposes rather than commercial or administrative efficiency.

[14] The critical pedagogy of artificial intelligence (AI), drawing on the work of Freire (1970/2018) and Shor (1992), treats AI as an object of critical inquiry and emancipation, not merely as a technical tool or “teaching method.” Teaching about AI should help students understand how algorithms produce and shape reality, recognise the institutional and socio-political power relations behind technological “objectivity” (Noble, 2018), and build autonomy in the face of algorithmic mediation of information and learning.

[15] The principle that technology should support rather than replace human interaction is grounded in Noddings’s (2013) ethic of care, which bases education on relationships of trust, empathy, and mutual responsibility between student and teacher. Similarly, Wenger (1998), through the theory of communities of practice, stresses that learning is a form of social engagement, not an individual act of information consumption. Tronto (1993) further conceives care as a political and ethical activity that maintains the relationships sustaining the common good — a dimension that cannot be algorithmically reproduced or substituted by technological systems.

Conclusion

The ethical and legal challenges of AI in education reflect deep tensions between efficiency and human dignity, private interests and the public good. "Responsible use" demands political will and democratic participation. As Biesta (2017) argues, education is a political act concerning the society we wish to create. We propose seven foundational principles: Human Dignity[16], Justice, Transparency[17], Accountability, Autonomy[18], Participation, and Proportionality[19]. The central question is not merely how to use AI, but "what kind of education, for what kind of society?[20]" (Selwyn, 2019). Only through collective, democratic questioning can we reclaim our digital future.

[16] The root of this principle lies in Kantian deontology, according to which the individual must always be treated as an end and never merely as a means (Kant, 1785/1998). The Convention on the Rights of the Child (UN, 1989) reinforces this position, recognising the child as a bearer of rights and not a passive recipient of policy or technological decisions.

[17] Ananny & Crawford (2018) argue that transparency is not the same as releasing code or data; it requires understanding the social context within which an algorithm functions. Algorithms are not technically neutral; they are sets of decisions, values, and power relations. Therefore, “transparency” implies intelligible accountability, where educational subjects can understand and challenge the decision-making process.

[18] Biesta (2017) links autonomy to pedagogical responsibility — the freedom of the student and the teacher is not individualistic independence but responsibility for participating in relationships of meaning and learning. AI can support this process only insofar as it does not replace ethical judgment or dictate decisions.

[19] According to Beauchamp & Childress (2019) in *Principles of Biomedical Ethics*, proportionality requires weighing risks and benefits in every ethical choice. Applied to education, this principle means that the use of AI should be justified only where the pedagogical benefit clearly outweighs the risks to students’ rights or well-being; the mere argument of technological capability is insufficient.

[20] Selwyn (2019), in *Should Robots Replace Teachers?*, stresses that the debate on AI in education must shift from the rhetoric of innovation to critical political analysis: every technological choice reveals values, hierarchies, and power relations. “Responsible use” of AI is not enough; what is required is collective, democratic decision-making about whether and how technology serves public education — not the other way around.

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Predicting Metacognitive Pessimism in CAT with Machine Learning (ML): The Role of Psychometric and Behavioral Indicators

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Abstract- Computerized Adaptive Testing (CAT) represents a significant leap in educational measurement, offering superior precision and efficiency compared to traditional linear testing. However, the algorithmic pursuit of optimal information—typically targeting a 50% probability of success for each item—often induces a psychological side effect known as the "High Ability Student Paradox." High-performing students, accustomed to high success rates, may perceive the consistent challenge of adaptive items as failure, leading to "Metacognitive Pessimism." This study aims to predict this phenomenon in real-time by leveraging Machine Learning (ML) techniques on psychometric and behavioral log data. We utilized an experimental dataset from 213 university students who underwent both traditional and adaptive assessments in Statistics. A Random Forest Classifier was trained to identify students whose perceived performance significantly deviated negatively from their actual True Score. The model achieved an accuracy of 69.77% and a recall (sensitivity) of 74%, successfully identifying the majority of students susceptible to underestimating their abilities during the test. Furthermore, Explainable AI (XAI) techniques, specifically SHAP (SHapley Additive exPlanations) analysis, revealed that this pessimism is not random but triggered by a specific configuration of test parameters. A "Toxic Cocktail" of high item difficulty (b), high item discrimination (a), and increased response latency was identified as the primary predictor of negative self-assessment. These findings suggest that ML can bridge the gap between psychometric diagnosis and psychological support, enabling the development of "Emotionally Intelligent" CAT systems. Such systems could provide targeted, encouraging feedback in real-time to mitigate anxiety and preserve the validity of the assessment without compromising its psychometric integrity.

Keywords: Computerized Adaptive Testing, Machine Learning, Metacognitive Pessimism, Explainable AI, Psychometrics.

Introduction

Computerized Adaptive Testing (CAT) has established itself over the last few decades as the "gold standard" in educational measurement, offering measuring precision and efficiency that far exceed traditional fixed-item "paper-and-pencil" (P&P) formats. According to Wainer et al. (2000), the fundamental innovation of CAT lies in its ability to dynamically match the difficulty level of items to the examinee's estimated ability in real-time. As Lord (1980) demonstrated in his foundational work on Item Response Theory (IRT), this adaptability allows for the measurement of a broader range of abilities with fewer items, thereby minimizing the Standard Error of Measurement (SEM).

However, the algorithmic pursuit of psychometric optimization often comes with an unforeseen psychological cost. To maximize Test Information, CAT algorithms typically select items where the examinee has a 50% probability of success (Thissen & Mislevy, 2000; Wainer et al., 2000). This creates a unique pressure condition: even high-ability students, who are accustomed to answering the vast majority of questions correctly in linear tests, face a continuous stream of challenging items in a CAT environment. This phenomenon has been described as the "High Ability Student Paradox," where objective success is accompanied by a subjective sense of failure (Eleftherakis, 2025).

The impact of these test characteristics on examinee psychology has been the subject of extensive research. Tonidandel, Quinones, and Adams (2002) demonstrated that adaptive test characteristics, particularly the difficulty of initial items, can significantly influence test-takers' reactions and perceived performance. More recently, Akhtar et al. (2022), in a systematic meta-analysis, concluded that CAT does not automatically lead to reduced anxiety; rather, its effect depends heavily on the specific design and the success probability targeted by the algorithm. Furthermore, research by Martin and Lazendic (2018) has shown that student engagement and motivation can be positively or negatively affected depending on the test's adaptability and the age group of the examinees.

Despite the wealth of literature, a significant research gap remains. Most studies examine anxiety and "metacognitive pessimism"—the tendency of students to underestimate their performance—*post-hoc*, through questionnaires administered after the examination is complete (Vispoel, 1998; Eleftherakis, 2025). There is a lack of methodologies that allow for the prediction of this state *in real-time* during the assessment. The ability for early detection is critical; as Sharma et al. (2020) point out, analyzing multimodal and behavioral data can explain learning engagement and help preempt detrimental behaviors, such as effortless responding, before they compromise the assessment's validity.

This study attempts to bridge the gap between Psychometrics and Data Science by leveraging Machine Learning (ML) to predict metacognitive pessimism. As the field of educational assessment is transformed by Artificial Intelligence, as noted by Halkiopoulos and Gkintoni (2024) and Ersozlu, Taheri, and Koch (2024), new possibilities emerge for "intelligent" systems that do not merely measure ability but also understand the examinee's state. Recent works, such as those by Colledani, Robusto, and Anselmi (2025) and Sharpnack et al. (2024), have demonstrated how ML

algorithms can enhance the calibration and operation of adaptive tests, offering faster and more accurate diagnostics. Additionally, Kwong and Mohammadi (2025) highlight the potential of using ML models even with smaller datasets to predict performance, making these techniques applicable in realistic educational settings.

Leveraging an experimental dataset of 213 university students who participated in Statistics examinations (Eleftherakis, 2025), this paper employs a Random Forest classifier to identify students at risk of underestimating their performance. Unlike complex Deep Learning models that require massive data, the choice of Random Forest offers stability and interpretability (Explainable AI) for educational datasets of this scale. Through SHAP analysis, we investigate how the combination of psychometric indicators (difficulty b, discrimination a) and behavioral indicators (response time) creates a "Toxic Cocktail" that triggers pessimism, paving the way for real-time feedback interventions.

Methodology

Participants and Experimental Context

The study was conducted within the context of a mandatory undergraduate course, "Statistics in Education," at the Department of Preschool Education, University of Crete. The experimental sample consisted of 213 undergraduate students (N=213) who participated in a quasi-experimental, within-subjects research design (Eleftherakis, 2025). The participants were assessed using two distinct evaluation methods: a traditional fixed-item Paper-and-Pencil (P&P) test and a Computerized Adaptive Test (CAT). To control for order and fatigue effects, a counterbalanced design was implemented, where students were divided into groups; some were administered the CAT first followed by the P&P, while others followed the reverse order (Eleftherakis, 2025).

The Adaptive Testing Architecture

The CAT system was developed and deployed using the Concerto Platform, an open-source testing environment that integrates the statistical computing power of R (Oppl et al., 2017; Scalise & Allen, 2015). The underlying psychometric engine utilized the Item Response Theory (IRT) framework, specifically the Two-Parameter Logistic (2PL) model. This model was selected over the 3PL model to ensure parameter stability given the sample size constraints during the calibration phase (Eleftherakis, 2025).

The item bank consisted of 45 calibrated items. The psychometric parameters—difficulty (b) and discrimination (a)—were estimated using the catR package (Magis & Barrada, 2017). The operational algorithm of the CAT was configured as follows:

Ability Estimation: The Expected A Posteriori (EAP) method was employed for θ estimation, as it minimizes the mean squared error and provides robust estimates even for short test lengths (Bock & Mislevy, 1982; Eleftherakis, 2025).

Item Selection: The algorithm utilized the Maximum Likelihood Weighted Information (MLWI) criterion. This criterion was chosen to maximize information at the examinee's current estimated ability level while accounting for estimation uncertainty (Veerkamp & Berger, 1997; Eleftherakis, 2025).

Termination Rule: A combined stopping rule was implemented to balance measurement precision and efficiency. The test terminated when the Standard Error of Measurement (SEM) dropped below 0.35, or when a maximum of 15 items were administered (Eleftherakis, 2025).

Data Acquisition and Feature Engineering

Data were collected from the system's log files, which captured granular behavioral metrics for every item interaction. The dataset included psychometric logs (item parameters and, intermediate theta estimates) and behavioral logs (response time per item). Immediately post-assessment, students reported their "Perceived Performance" on a scale of 0-10, unaware of their actual score (Eleftherakis, 2025).

The Target Variable for the Machine Learning model was the binary classification of "Metacognitive Pessimism." A student was classified as a "Pessimist" (Class 1) if their Actual Score significantly exceeded their Perceived Score by more than 1 unit on the 10-point scale (*Actual-Perceived>1*). All other cases were classified as Non-Pessimists (Class 0). This operationalization aligns with recent findings on the "High Ability Student Paradox," where high-performing students systematically underestimate their scores due to the adaptive difficulty of the items (Nizhenkovska et al., 2024).

The **Input Features** (X) for the model were derived from the CAT session logs:

Average Item Difficulty (b): The mean difficulty of items administered to the student.

Average Item Discrimination (a): The mean discrimination parameter of the items.

Average Response Time: The mean time (in seconds) spent per item.

Final Theta (θ): The final estimated ability of the student.

Machine Learning Implementation

To predict Metacognitive Pessimism, we employed a Random Forest Classifier. While recent studies have explored the use of Deep Learning and Large Language Models for educational data (Benedetto et al., 2021; Sharpnack et al., 2024), these approaches typically require massive datasets. For educational datasets of moderate size (N=213), ensemble methods like Random Forest are preferred due to their robustness against overfitting and their ability to handle non-linear relationships without extensive hyperparameter tuning (Colledani et al., 2025; Breiman, 2001).

The model was validated using a stratified 10-fold cross-validation scheme to ensure the reliability of the results. To interpret the model's decisions and understand the "black box" of the prediction, we utilized SHAP (SHapley Additive exPlanations) values. This Explainable AI (XAI) technique allows us to quantify the contribution of each feature (e.g., item difficulty or response time) to the probability of a student being classified as a "Pessimist," enabling the identification of the specific test conditions that trigger this psychological state.

Results

Predictive Performance of the Random Forest Classifier

The primary objective of the Machine Learning analysis was to determine whether "Metacognitive Pessimism"—defined as the condition where a student's Perceived Score is significantly lower than their Actual Score (*Actual-Perceived>1*)—could be predicted using real-time psychometric and behavioral data. The Random Forest classifier was trained and tested on the experimental dataset of 213 students (Eleftherakis, 2025).

The model achieved an overall Accuracy of 69.77% on the test set. While accuracy provides a general baseline, the specific goal of an early-warning system in a CAT environment is to minimize "False Negatives" (i.e., failing to identify a student who is actually experiencing pessimism). Consequently, Recall (Sensitivity) was prioritized as the critical performance metric. The model demonstrated a Recall of 74%, meaning it successfully identified approximately three out of four students susceptible to underestimating their performance. This level of sensitivity suggests that psychometric log data contains sufficient signal to trigger timely interventions for the majority of at-risk students.

Explainability and Feature Importance (SHAP Analysis)

To overcome the "black box" nature of the Random Forest algorithm and understand the drivers of pessimism, we applied SHAP (SHapley Additive exPlanations) analysis. This method assigns an importance value to each feature for a particular prediction, allowing for the interpretation of complex, non-linear interactions (Lundberg & Lee, 2017).

The SHAP summary plot revealed that the most influential features driving the prediction of pessimism were, in descending order:

Item Difficulty (b): Higher difficulty values were strongly associated with the "Pessimist" class.

Item Discrimination (a): High discrimination parameters contributed positively to the probability of pessimism.

Response Time: Longer response latencies were associated with negative self-assessment.

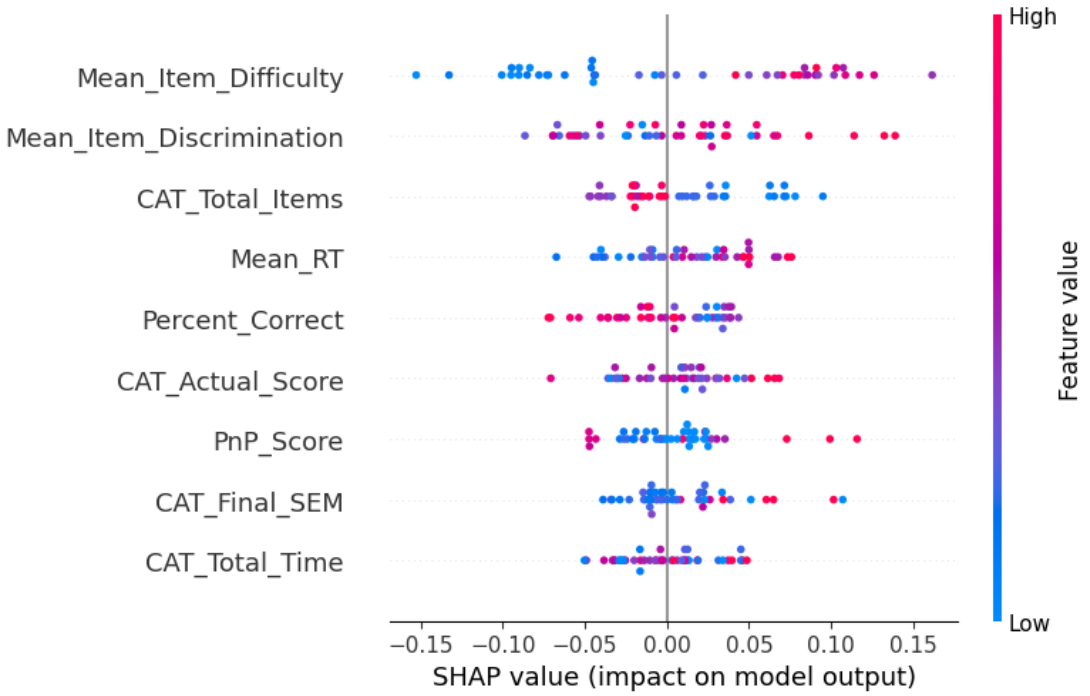


Figure 1. SHAP Summary Plot revealing the feature impact on Metacognitive Pessimism. Red dots (high feature value) on the right side indicate a strong push towards pessimism, confirming the "Toxic Cocktail" effect.

The "Toxic Cocktail" Phenomenon

A detailed analysis of the interaction effects between these features revealed a specific configuration that consistently triggered metacognitive pessimism. We term this phenomenon the "Toxic Cocktail." The probability of a student underestimating their score maximized under the simultaneous occurrence of three conditions. First, the items administered were highly difficult (high b). Second, the items possessed high discrimination (high a), meaning the questions were sharp and unambiguous in separating ability levels. Third, the student invested significant time (high response latency) to answer.

This finding aligns with the "High Ability Student Paradox" described in recent literature (Nizhenkovska et al., 2024). In a CAT, high-ability students are routinely presented with high b - items. When these items also have high discrimination (a), the student likely perceives the difficulty acutely—there is no ambiguity to attribute the struggle to "bad wording." The addition of high response time indicates cognitive effort. Therefore, when a student tries hard (Time), on a clear but difficult question (High a, High b), and potentially struggles, they internalize this struggle as failure, even if they eventually answer correctly. The Random Forest model successfully captured this non-linear interaction, which traditional linear regression models used in previous studies (Eleftherakis, 2025) could not fully isolate.

Discussion

From Psychometric Validation to Behavioral Prediction

The findings of this study demonstrate that machine learning can successfully decode the complex interactions between test design and student psychology. Our results

indicate significant differences in performance between CAT and linear testing, a finding that contrasts with the meta-analysis by Wang et al. (2008), which generally found negligible mode effects in K-12 reading assessments. However, our findings align with the more nuanced view presented by Frey et al. (2024), who emphasize that the psychological impact of CAT—such as anxiety reduction—is not automatic but heavily dependent on specific design features like time limits and item review options. While previous research in this specific educational context established the psychometric validity of the item bank by comparing Classical Test Theory (CTT) with Item Response Theory (IRT) (Eleftherakis & Linardakis, 2020), the current study advances this line of inquiry from *post-hoc* diagnosis to *real-time* prediction, Eleftherakis and Linardakis (2020) demonstrated that while IRT difficulty parameters (b) correlate with classical difficulty indices (p), IRT provides a superior, sample-independent framework necessary for adaptive testing,. Building on that foundation, our results indicate that these stable IRT parameters, when processed by non-linear ML algorithms like Random Forest, serve as powerful predictors not just of ability, but of the student's metacognitive state.

Interpreting the "Toxic Cocktail" and the High Ability Paradox

The identification of the "Toxic Cocktail"—the synergy of high difficulty (b), high discrimination (a), and high response latency—offers an empirical explanation for the "High Ability Student Paradox" described by Nizhenkovska et al. (2024) and Colledani et al. (2025), High-performing students, who are typically accustomed to answering correctly with ease, find themselves in a CAT environment where the algorithm specifically selects items with high discrimination parameters to maximize information (Eleftherakis & Linardakis, 2020; Wainer et al., 2000).

Our SHAP analysis reveals that when these students encounter a highly discriminating item (high a) that matches their high ability (high b), they are forced to expend significant cognitive effort (high Time). Unlike the linear tests analyzed in Eleftherakis and Linardakis (2020), where difficulty varies randomly, the CAT algorithm sustains this pressure continuously. The Random Forest model picks up on this sustained "friction" as a signal of Metacognitive Pessimism. This aligns with Sharma et al. (2020), who found that multimodal data (such as response times and effort indicators) are critical for explaining engagement and predicting student states beyond simple correctness.

Educational and Ethical Implications

The ability to predict pessimism with 74% recall suggests that CAT systems can evolve from passive measurement tools into active support systems. As noted by Martin and Lazendic (2018), the subjective experience of the test is as crucial as the score itself. If a system detects the "Toxic Cocktail" conditions, it could intervene not by lowering the difficulty (which would compromise the measurement precision prioritized by IRT), but by providing "Encouraging Feedback." This approach respects the psychometric rigorousness established by Lord (1980) and Eleftherakis and Linardakis (2020), while addressing the ethical imperative to minimize test anxiety and ensure fair assessment for all students, regardless of their self-regulation capabilities (Akhtar et al., 2022).
By bridging the gap between the static psychometric analysis of item parameters (Eleftherakis & Linardakis, 2020) and dynamic behavioral prediction, this study

highlights the potential for "Emotionally Intelligent" assessment systems that safeguard both validity and student well-being.

Conclusion & Future Work

Conclusion

The transition from traditional linear testing to Computerized Adaptive Testing (CAT) represents a paradigm shift from static measurement to dynamic personalization. This study confirms that while CAT offers undeniable psychometric advantages—specifically a drastic reduction in testing time and uniform measurement precision (Wainer et al., 2000; Weiss & Kingsbury, 1984)—it introduces complex psychological side effects that cannot be ignored. Our findings empirically document the phenomenon of "Metacognitive Pessimism," where students, particularly those of high ability, systematically underestimate their performance due to the algorithmic targeting of items with a 50% probability of success.

By applying Machine Learning techniques to real-time log data, we demonstrated that this pessimism is not a random occurrence but a predictable state. The Random Forest classifier achieved a recall of 74%, successfully identifying the majority of students at risk of negative self-assessment. Furthermore, the SHAP analysis demystified the "black box" of student sentiment, revealing a "Toxic Cocktail" of predictors: high item difficulty (b), high item discrimination (a), and increased response latency. These results align with the "High Ability Student Paradox" (Nizhenkovska et al., 2024) and suggest that the very features that maximize psychometric information—specifically highly discriminating items administered at the limit of a student's ability—are the same features that degrade the student's subjective experience. Therefore, we conclude that psychometric optimization must be balanced with psychological support to ensure the validity of the assessment is not compromised by anxiety or disengagement (Akhtar et al., 2022; Martin & Lazendic, 2018).

Limitations

While the results are promising, this study has limitations. First, the sample size (N=213) is sufficient for Random Forest but limits the application of data-hungry Deep Learning architectures that might capture more complex temporal dependencies in the log data (Ersozlu et al., 2024). Second, the study relies on self-reported "Perceived Performance," which, while valuable, is a subjective proxy for the student's actual emotional state. Third, the study was conducted within a single domain (Statistics), and as Kim and Huynh (2007) note, the comparability of computer-based and paper-based tests can vary across subject areas. Finally, the current model uses static item parameters calibrated via the 2PL model; recent research suggests that real-time parameter updating could further refine the inputs for the ML model (Sharpnack et al., 2024).

Future Work

The ability to predict metacognitive pessimism opens the door to the next generation of "Emotionally Intelligent" CAT systems. Future research should focus on three key areas:

Integration of Large Language Models (LLMs) and Embeddings: Current prediction models rely heavily on numerical item parameters (a,b). Future work should incorporate the semantic content of the questions. Feng et al. (2025) and Benedetto et al. (2021) have demonstrated that transformer-based models (e.g., BERT) and embeddings can accurately predict item difficulty directly from text. Integrating these textual features with psychometric logs could enhance the model's ability to detect items that are not just mathematically difficult, but linguistically confusing or cognitively overloading for specific student profiles.

Advanced Algorithmic Approaches: Moving beyond static calibration, future systems should explore dynamic calibration methods. Sharpnack et al. (2024) propose "BanditCAT," utilizing multi-armed bandit algorithms and "AutoIRT" for automated calibration. These approaches could allow the system to learn not only the psychometric parameters but also the "psychological cost" of items in real-time, effectively penalizing items that trigger excessive pessimism. Additionally, the application of Recommender Systems in educational assessment (Kwong & Mohammadi, 2025) could personalize the testing path not just for information maximization, but for engagement maintenance, similar to how content platforms recommend media.

Multimodal and Neuro-Cognitive Analytics: To overcome the reliance on self-reports, future studies should integrate multimodal data. Halkiopoulos and Gkintoni (2024) and Sharma et al. (2020) highlight the potential of using physiological data (e.g., EEG, eye-tracking, facial expression analysis) to detect cognitive load and emotional states in real-time. Combining these physiological signals with the "Toxic Cocktail" indicators identified in this study would create a robust, real-time anxiety detection system.

Ultimately, the goal is to close the loop between diagnosis and intervention. Future iterations of CAT systems should not only detect pessimism but actively mitigate it through AI-driven Encouraging Feedback. By informing the student that "this question is difficult because you are doing well," the system can reframe the subjective experience of difficulty from a signal of failure to a signal of competence, thereby preserving both the psychometric integrity of the test and the well-being of the student.

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Creating Presentations with Artificial Intelligence

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Abstract- The teaching intervention entitled "Creating Presentations with Artificial Intelligence" represents an innovative scenario implemented within the framework of the ICT B2-Level Teacher Training Program and applied in the Grade 8 Informatics course in lower secondary education. The design of the intervention is based on constructivist principles, socio-cultural learning theory, and experiential learning, and incorporates a flipped classroom approach, transferring the theoretical preparation phase to asynchronous online learning through the eClass platform.

The main objective of the scenario is for students to understand the functionality and potential of Artificial Intelligence (AI) as a tool for creation and expression, to develop multimodal literacy and collaborative skills, and to collectively produce a digital multimedia presentation. The intervention was structured in four phases: preparation, content creation, collaborative presentation, and reflection.

During the preparation phase, students explored examples of AI applications and principles of presentation design via eClass. In the content creation phase, they worked in groups using various AI tools, including ChatGPT for text and script generation, Canva and Gamma App for images and presentations, Suno for music and sound, and Google Slides for collaborative project assembly. The use of these tools supported creative expression, digital autonomy, and critical evaluation of AI-generated content.

The final reflection phase involved presentation of the students' work and discussion regarding challenges, collaboration, and learning benefits. This process fostered metacognitive development, enabling students to connect theory with practice and understand how AI can function as a collaborative partner in learning and creation.

Teacher reflection was used to evaluate the extent to which the scenario achieved its learning objectives: whether students demonstrated enthusiasm, creativity, and active participation, developed critical thinking, collaboration, and digital literacy skills, and how technical difficulties with AI tools and time constraints were addressed. The scenario emphasizes the evolving role of the teacher from knowledge provider to facilitator, motivator, and coordinator of the learning process. Moreover, it illustrates how AI can be used pedagogically and creatively, not as an end in itself but as a tool to enhance the learning experience.

Overall, this teaching practice contributes to the discussion on AI integration in education, promoting a holistic approach that combines technological innovation, critical reflection, and learning through creation.

Keywords— Artificial Intelligence, learning by creation, digital literacy, collaborative learning, constructivism

Introduction

The rapid evolution of Artificial Intelligence (AI) has initiated a paradigm shift in contemporary education, reshaping not only pedagogical frameworks but also the very nature of the learning experience. In the current educational landscape, AI tools have transcended their role as mere productivity software; they now function as sophisticated agents that support automated content generation, personalized feedback loops, and the scaffolding of complex tasks. This shift compels educators to transition from a technocentric view of AI to a pedagogical one, where AI is integrated as a "co-designer" in the learning process. According to the literature, such tools are uniquely positioned to foster higher-order cognitive skills, including creative synthesis, critical information literacy, and metacognitive monitoring (Holmes, Bialik, & Fadel, 2019; Luckin et al., 2016).

In the context of secondary education, the creation of digital presentations has long been a staple of the ICT curriculum. However, traditional approaches often stagnate at the level of technical proficiency (e.g., slide formatting). By introducing Generative AI (GenAI), the focus shifts from the mechanics of the software to the pedagogical essence of communication. This intervention leverages students' prior familiarity with presentation tools to introduce them to Multimodal Literacy. Students are no longer just "users" but "curators" of AI-generated content. They are required to navigate the complexities of design thinking, collaborative problem-solving, and, most importantly, Prompt Engineering—the ability to articulate clear, logical instructions to an AI system. Thus, the present teaching intervention treats AI as a cognitive partner that enables the seamless integration of text, imagery, and audio, while simultaneously demanding a high level of critical evaluation and ethical reflection on the part of the students.

Theoretical and Pedagogical Framework

The pedagogical architecture of this intervention is anchored in a multi-layered theoretical framework that synergizes **constructivism**, **socio-cultural theory**, and **experiential learning**, adapted for the era of Generative AI.

1. Constructivism and AI as a Cognitive Mediator

The intervention is grounded in **constructivist theory**, which posits that knowledge is not passively received but actively constructed through interaction with content, tools, and peers (Piaget, 1954; Jonassen, 1999). In this context, AI tools function as **"Cognitive Mediators"** or "Mindtools." Rather than replacing the learner's agency, AI necessitates a higher level of cognitive involvement. Students must engage in a continuous "dialogue" with the machine—interpreting, contextualizing, and iteratively refining AI outputs. For example, when students utilize AI to generate complex network graphs in graph theory exercises, passive acceptance of the output is insufficient. The learner must act as an evaluator: verifying the accuracy of algorithms (e.g., Dijkstra or BFS), incorporating empirical data from social networks, and justifying how their specific prompts and interventions improved the final model. This recursive process transforms AI from a simple automation tool into a **catalyst for deep conceptual understanding** and algorithmic thinking.

2. Socio-cultural Theory and the Zone of Proximal Development (ZPD)

Socio-cultural theory further underscores the critical role of social interaction and collaboration (Vygotsky, 1978). In this scenario, AI is viewed as a **"Cultural Tool"** that mediates interactions and enables higher-order cognitive engagement (Rigopouli, Kotsifakos, & Psaromiligkos, 2025). The collaborative environment allows students to work within their **Zone of Proximal Development (ZPD)**, where the AI, combined with peer support, enables them to tackle tasks that would be beyond their individual reach. In practice, student teams engage in "distributed cognition": using tools like ChatGPT for brainstorming or Python libraries (e.g., NetworkX) for modeling communication networks. This dynamic creates a laboratory of social learning where one student manages data input, another interprets the AI's logical outputs, and a third proposes optimizations through peer review. This collaborative orchestration not only strengthens the social dimension of learning but also fosters essential "soft skills" such as conflict resolution, negotiation of meaning, and joint decision-making in data-rich environments.

3. Experiential Learning and the Iterative Cycle

Experiential learning principles (Kolb, 1984) provide the procedural backbone of the intervention, fostering authentic problem-solving and creative expression. Kolb's experiential cycle—comprising **concrete experience, reflective observation, abstract conceptualization, and active experimentation**—is directly mapped onto the AI-driven workflow. Students begin with hands-on experimentation (e.g., generating network visualizations using pandas and networkx), observe emerging patterns such as node centrality or community clusters, conceptualize the underlying algorithmic structures, and finally experiment with new variables to test their hypotheses. A characteristic example is the development of a dashboard for social media network analysis; here, students integrate AI-generated insights and stress-test them against real-world datasets, bridging the gap between theoretical informatics and practical application.

4. Multimodal Literacy and Ethical Criticality

Finally, the intervention integrates **digital and multimodal literacy frameworks** (Kress, 2010), which are crucial for navigating the semiotic complexity of AI-generated content. Students are encouraged to critically engage with varied modes of representation—text, images, audio, and video—while simultaneously reflecting on the **ethical and creative dimensions** of AI (Xiao et al., 2025). During activities like infographic production using DALL-E or Midjourney, the pedagogical focus shifts toward **Critical AI Literacy**. Students do not merely produce visuals; they interrogate the "black box" of AI, discussing algorithmic bias, the provenance of training data, intellectual property rights, and the environmental sustainability of AI infrastructure. This holistic approach cultivates **digital fluency**, ensuring that students emerge not just as skilled operators of technology, but as responsible, ethically-aware digital citizens.

Methodology

Participants and Context

The instructional intervention was implemented across a diverse network of **30 public lower secondary schools** in Greece, involving students from **Grades 8 to 10** (predominantly aged 13–15). This large-scale application ensured a representative sample of the Greek educational landscape. A key prerequisite for the study was that all participants had prior foundational experience with digital presentation software. This allowed the instructional design to bypass technical basics and pivot toward **higher-order cognitive skills**, such as multimodal synthesis and critical algorithmic evaluation. The technological infrastructure of the participating schools provided stable access to web-based GenAI platforms, while teachers acted as adaptive facilitators, tailoring their support to the specific needs of each group.

Instructional Organization and Grouping

To maximize student agency and interdependence, the intervention employed a **dyadic grouping strategy** (pairs). Each dyad was assigned a specialized role linked to a specific AI toolset, creating a "jigsaw" effect where individual contributions were vital for the final collective artifact.

- **Prompt Engineering & Scripting:** Utilizing **ChatGPT** for text and narrative generation.
- **Visual Synthesis:** Leveraging **Canva AI** and **Gamma App** for layout and image generation.
- **Auditory Augmentation:** Employing **Suno** for music and soundscapes.
- **Collaborative Assembly:** Using **Google Slides** as the shared workspace for final integration. This structure fostered a sense of **individual accountability** within a collaborative framework, ensuring that students did not just "use AI," but managed it as part of a complex project.

Instructional Phases

The intervention followed a rigorous four-phase pedagogical cycle:

1. **Preparation Phase (Asynchronous):** Hosted on the **eClass VLE**, this phase focused on theoretical grounding. Students engaged with materials on AI logic and the ethics of digital creation. This "flipped" component ensured that classroom time was reserved for high-value creative work.
2. **Content Creation Phase (Synchronous):** Students engaged in an iterative cycle of **prompt formulation**, output evaluation, and refinement. This phase was a laboratory of trial and error, where students learned to "negotiate" with the AI to achieve specific aesthetic and educational goals.
3. **Collaborative Integration Phase:** Dyads merged their outputs into a single Google Slides presentation. This required intense negotiation regarding **narrative flow and multimodal coherence**, ensuring that the AI-generated assets (text, image, sound) functioned as a unified whole.
4. **Reflection Phase:** The final stage involved the public presentation of artifacts and a structured debriefing. Students reflected on the **ethical "black box" of AI**, the challenges of collaboration, and the shift in their role from passive consumers to active curators of AI content.

Data Collection and Instrumentation

To evaluate the effectiveness of the teaching intervention, a structured survey instrument was developed, consisting of four distinct sections (Parts 1–4). The primary objective of this questionnaire was to collect primary data regarding the students' perceived competence, cognitive development, and overall engagement with AI tools.

The instrument was designed based on the following framework:

- **Parts 1-3 (Quantitative):** These sections utilized a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). They were designed to measure **Digital Literacy**, the **Cognitive Impact** of AI (e.g., mitigation of the "blank page" syndrome), and the effectiveness of the **Flipped Classroom** pedagogy.
- **Part 4 (Qualitative):** This section included open-ended questions aimed at capturing nuanced student perspectives, identifying technical or ethical challenges, and exploring the shift in their perception of AI as a "cognitive partner."

The survey was administered digitally via the eClass platform upon completion of the reflection phase. To ensure the content validity of the instrument, the items were aligned with the learning objectives of the ICT curriculum and the theoretical principles of constructivism and multimodal literacy.

he full version of the survey instrument, including all Likert-scale items and open-ended questions, is provided in **Appendix I**.

Results and Learning Outcomes

The analysis of the intervention across multiple classrooms yielded significant evidence of pedagogical transformation.

Engagement and Creative Agency

Observations indicated a marked increase in student **intrinsic motivation**. The ability to generate high-fidelity multimodal content (music, art, professional text) provided a sense of "creative empowerment," particularly for students who previously struggled with traditional expressive means.

Development of 21st-Century Competencies

- **Multimodal Literacy:** Students demonstrated an advanced ability to integrate diverse semiotic resources (text, audio, video) into a coherent digital narrative.
- **Critical Algorithmic Thinking:** A key outcome was the development of a "critical lens" toward AI. Students did not accept AI outputs at face value; instead, they learned to identify biases, factual errors, and aesthetic inconsistencies, treating the AI as a **fallible partner** rather than an oracle.
- **Socio-cultural Growth:** The collaborative nature of the tasks reinforced skills in negotiation, peer-to-peer feedback, and collective decision-making.

Quantitative Results

The quantitative analysis of the Likert-scale responses (Table X) indicates a high level of student engagement and self-perceived competency. Specifically, students reported a significant reduction in the 'blank page' syndrome ($M = 4.7, SD = 0.5$), while their

motivation was exceptionally high ($M = 4.9, SD = 0.3$). Although technical confidence was high, ethical awareness scores ($M = 3.4, SD = 1.1$) suggest that more instructional focus is needed on the societal implications of AI.

Dimension	Survey Item (Abbreviated)	Mean (M)	Std. Dev. (SD)
I. Digital Literacy	Q1. Confidence in Prompt Engineering	4.2	0.7
	Q2. Critical Evaluation of AI Outputs	3.8	0.9
	Q3. Multimodal Content Integration	4.5	0.6
	Q4. Ethical Awareness (Copyright/Bias)	3.4	1.1
II. Cognitive Impact	Q5. Mitigation of "Blank Page" Syndrome	4.7	0.5
	Q6. AI as a Cognitive Partner	4.3	0.8
	Q7. Rapid Prototyping/Confidence	4.6	0.5
	Q8. Deep Understanding of ICT Concepts	3.9	0.9
III. Pedagogy	Q9. Effectiveness of eClass Preparation	4.1	0.8
	Q10. Collaborative Dyadic Interaction	4.4	0.7
	Q11. Teacher Support as Facilitator	4.8	0.4
	Q12. Overall Engagement & Motivation	4.9	0.3

Table 1: Descriptive Statistics of Student Responses

As illustrated in Table 1, the intervention achieved high scores across all major pedagogical dimensions. The highest levels of agreement were observed in Student Engagement (Q12: $M=4.9$) and Teacher Facilitation (Q11: $M = 4.8$), indicating that the AI-integrated environment significantly enhanced classroom motivation. Notably, the use of AI tools effectively addressed the 'blank page' syndrome (Q5: $M = 4.7$), allowing students to transition swiftly into the creative phase. However, the lower mean and higher variance in Ethical Awareness (Q4: $M = 3.4, SD = 1.1$) suggest that while students are proficient in tool use, they require more structured guidance on the socio-ethical implications of Generative AI."

Qualitative Analysis and Student Perspectives

To gain a deeper understanding of the students' learning journeys, a thematic analysis of the open-ended questionnaire responses was conducted. This process followed the thematic coding approach (Braun & Clarke, 2006), identifying recurring patterns in student feedback.

The following table summarizes the key themes, the corresponding codes, and representative quotes from the participants:

Theme	Code (Key Concept)	Representative Student Quote

I. Human-AI Collaboration	AI as a "Co-pilot"	*"I used to think AI was like a 'magic box', but now I see it more as a sophisticated assistant or a 'co-pilot' that needs constant guidance."*
II. Prompting Challenges	Iterative Refinement	*"The biggest challenge was learning to be specific; generic prompts gave generic results, and I had to refine my instructions multiple times."*
III. Critical Literacy	Fact-Checking & Skepticism	*"We had to act as editors because the AI sounded very confident even when it was providing incorrect facts; we had to double-check everything."*
IV. Affective Engagement	Creative Empowerment	*"Being able to generate professional music and art boosted my confidence and made the project feel 'real' and professional."*
V. Technical Limitations	Algorithmic "Hallucinations"	*"I was surprised by the errors in image generation, like weird background text, which showed me the tool's limits and flaws."*

Table 2: Thematic Coding of Student Qualitative Responses

Analysis of Findings

The qualitative data reveals a significant shift in students' mental models regarding Artificial Intelligence. Participants moved from a "black-box" perception to a more nuanced understanding of AI as a cognitive mediator. The struggle with prompt precision served as a meta-cognitive exercise, forcing students to clarify their own objectives before communicating them to the machine. Furthermore, the high level of affective engagement suggests that AI tools can mitigate the "fear of failure" by allowing for rapid, low-stakes prototyping, which is essential for fostering a creative classroom environment.

Discussion

The findings suggest that Generative AI, when framed by a robust pedagogical strategy, functions as a powerful **"cognitive mediator"** (Jonassen, 1999). It bridges the gap between abstract theoretical concepts and practical application. Through the process of **prompt engineering**, students are forced to externalize their thought processes, clarifying their objectives and refining their language to guide the machine. This iterative loop promotes a form of **"Metacognitive Scaffolding"** where the AI reflects the student's own logic back to them for evaluation.

The success of the **Flipped Classroom** model via eClass further highlights a shift in instructional time-management. By moving passive knowledge acquisition outside the classroom, the school environment becomes a space for **active, social construction of knowledge**.

Crucially, the evolving role of the teacher is reaffirmed. In an AI-rich environment, the teacher is no longer the "sage on the stage" but the **ethical compass** and **pedagogical coordinator**. The teacher’s primary value shifts to guiding students through the

complexities of **Critical AI Literacy**—addressing issues of data ethics, intellectual property, and the validation of truth in an era of synthetic media.

The qualitative evidence supports the transition of the student from a passive consumer to an **active curator**. As shown in the thematic analysis, the students' realization that AI requires 'constant guidance' (Theme I) aligns with Vygotsky's theory of mediated activity, where the AI acts as a cultural tool that extends the user's capabilities while requiring high-level cognitive monitoring.

Added Value of the Intervention

The primary added value of this teaching scenario lies in its **holistic and inclusive approach** to fostering student creativity and digital autonomy. In contrast to traditional instructional methods that often prioritize technical mastery of software interfaces, this intervention shifts the focus to **high-level conceptual synthesis**.

Multimodal Expression and the Mitigation of Cognitive Barriers

The integration of a diverse AI ecosystem (ChatGPT, Canva, Gamma, Suno) provided multiple "entry points" for students with varying learning profiles and creative strengths. A significant finding was the mitigation of the **"blank page" syndrome**; AI functioned as a springboard for rapid prototyping, allowing students to move quickly from abstract ideas to tangible drafts. This boosted student confidence, particularly for those who might otherwise struggle with linguistic or artistic expression, thereby promoting a more **equitable learning environment**.

The Emergence of "Prompting Literacy"

The intervention moved beyond mere tool-use toward the development of **"Prompting Literacy"**—the ability to synthetically and logically communicate with algorithmic systems. This is not just a technical skill but a sophisticated form of **linguistic and logical reasoning** that is becoming indispensable for 21st-century citizenship. By linking Informatics with design thinking and ethics, the scenario transformed the classroom into a laboratory for **critical digital citizenship**, where technology is scrutinized and curated rather than passively consumed.

Limitations & Future Research

While the present intervention yielded significant positive outcomes across 30 schools, certain limitations must be acknowledged to provide a balanced perspective on the findings.

Limitations of the Study

- **Technological Variability:** Despite the structured design, the performance of AI tools was occasionally inconsistent due to platform updates or connectivity issues in some school units. This variability may have influenced the pace of work in specific dyads.
- **Self-Report Bias:** The quantitative results are based on student self-reports (Likert scales). While this captures "perceived" learning and engagement, it

should ideally be triangulated with objective assessment data, such as standardized test scores on ICT competencies.
- **Time Constraints:** The four-phase cycle was intensive. Some groups reported that additional time for the "Reflection Phase" would have allowed for an even deeper exploration of the ethical dilemmas associated with Generative AI.

Suggestions for Future Research

- **Longitudinal Assessment:** Future studies should investigate the long-term retention of the skills acquired. Does the "Prompting Literacy" developed during this intervention transfer to other subjects or future academic tasks?
- **Specialized Assessment Rubrics:** There is a critical need for the development of validated rubrics that can distinguish between "AI-generated quality" and "student-added value." Research should focus on how educators can fairly grade collaborative human-AI artifacts.
- **Teacher Training Models:** Given the pivotal role of the teacher as a facilitator, further research is required to identify the most effective professional development models for preparing educators to navigate the technical and ethical complexities of GenAI in the classroom.

Conclusion

This teaching intervention provides empirical evidence that Artificial Intelligence, when embedded within a solid **constructivist and socio-cultural framework**, can serve as a transformative partner in the educational process. The successful implementation across 30 Greek lower secondary schools demonstrates that students are not merely passive recipients of digital content; they are **proactive creators** capable of synthesizing complex, multimodal artifacts with high levels of aesthetic and thematic coherence.

7.1 AI as a Cognitive Partner

The core takeaway of this study is that AI functions most effectively as a **"Cognitive Partner"** that supports, scaffolds, and amplifies human cognition rather than replacing it. The "human-in-the-loop" model ensured that the final products remained a reflection of student intent, filtered through a lens of critical evaluation and collaborative negotiation.

7.2 Future Directions and Educational Policy

As we look toward the future, the integration of AI in education must be met with robust pedagogical strategies. Future research should prioritize:

- **Advanced Assessment Rubrics:** Developing specialized criteria that can evaluate the "value-added" by the student versus the AI's contribution.
- **Teacher Professional Development:** Training educators not only in the technical use of AI tools but in the **ethical and pedagogical orchestration** of AI-rich environments.
- **Longitudinal Studies:** Investigating the long-term impact of AI-mediated learning on students' independent problem-solving abilities.
-

In conclusion, the integration of AI in education is no longer a future prospect but a present reality. It demands a fundamental shift in our pedagogical priorities—from teaching students *what* to think or *how* to use a tool, to teaching them how to **critically co-create** with the powerful intelligent systems of our era.

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Appendix A: Student Evaluation Questionnaire: AI-Integrated Learning Experience

Part 1: Digital Literacy & Technical Competency

Response Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

1. I feel confident in my ability to formulate effective **prompts** to achieve specific results from AI tools.
2. I can critically evaluate AI-generated outputs for factual accuracy and logical consistency.
3. I understand how to integrate different AI-generated media (text, image, audio) into a single, coherent project.
4. I am aware of the ethical implications (e.g., copyright, bias) associated with using Generative AI.

Part 2: Cognitive Impact & Creativity

Response Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

1. AI tools helped me overcome the "blank page" syndrome and start the creative process more easily.
2. Using AI as a **"cognitive partner"** allowed me to focus more on design and narrative rather than technical mechanics.
3. I feel that my creative expression was enhanced by the ability to rapidly prototype different ideas using AI.
4. The intervention helped me understand complex concepts of Informatics (e.g., network graphs) more deeply.

Part 3: Collaboration & Flipped Classroom Pedagogies

Response Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

1. The asynchronous preparation on **eClass** provided the necessary foundation for the in-class activities.
2. Working in dyads (pairs) encouraged effective negotiation and shared decision-making.
3. The teacher’s role as a facilitator was crucial in helping us navigate technical or ethical challenges.
4. I felt more engaged and motivated compared to traditional, non-AI-integrated lessons.

Part 4: Qualitative Reflection (Open-Ended)

1. Describe the most significant challenge you faced when interacting with AI tools.
2. How has your perception of Artificial Intelligence changed after this project?
3. In what ways did the AI output surprise you (positively or negatively)?

Ethical Issues Arising from the Use of Artificial Intelligence by Primary School Educators

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Abstract- The rapid proliferation of Artificial Intelligence in Primary Education offers new possibilities for personalising learning and supporting educators, while simultaneously raising significant ethical issues, such as personal data protection and equitable access to technology. This article examines the applications, challenges, and strategies for the responsible integration of Artificial Intelligence into the educational practice of Primary Education.

The 4th Industrial Revolution brings about significant changes across all sectors of society, including education, which is called upon to redefine its role and objectives. The modern school must cultivate skills of adaptability, critical thinking, and creativity, responding to the demands of a rapidly changing digital reality. Within this context, Gardner's Theory of Multiple Intelligences (1984, 1993) provides the conceptual framework for the development of personalised learning, which artificial intelligence (AI) can enhance through adaptive instructional systems (Ligoutsikou, 2015).

The integration of AI into educational practice raises critical ethical issues, particularly in primary education, where the personal teacher–student relationship constitutes a fundamental pedagogical element (Reiss, 2024). International research indicates that AI can function supportively only when embedded within a framework of ethical oversight and continuous guidance by the educator (Mertala, Fagerlund & Lehtoranta, 2024; Holmes, Nguyen & Fadel, 2021). In the Greek educational reality, Vergopoulos (2020) emphasises that AI can contribute positively when there are pedagogical guidance and respect for the ethical responsibility of educators.

The protection of students' personal data is also a crucial factor. The Hellenic Data Protection Authority (HDPA, 2024) points out that the use of AI in school settings requires transparency, informed parental consent, and impact assessment in accordance with the GDPR. The Department of Digital Systems at the University of Patras (2025) warns that the uncritical use of AI may diminish personal contact and create excessive reliance on algorithmic assessments.

This study examines three fundamental pillars regarding the ethical use of AI in primary education:

- Maintaining the human role of the educator as a pedagogue and emotional mentor.
- The protection of personal data and algorithmic transparency.
- The cultivation of critical thinking and student autonomy to avoid passive dependency on AI systems.

Overall, AI can function as a supportive tool that enhances instructional practice and personalised learning, without substituting human judgment and pedagogical ethos. The future challenge lies in achieving a balance between technological innovation and a human-centric pedagogical ethos.

Keywords— Artificial Intelligence, Ethics, Primary Education, Educator, Student

1. Introduction

Artificial Intelligence (AI) is penetrating the educational process at a rapid pace, transforming not only instructional methods but also the fundamental ways in which students interact with knowledge. In Primary Education, AI offers significant potential for personalizing learning, providing early detection of learning difficulties, and delivering targeted feedback tailored to the individual needs of students (Holmes, Bialik, & Fadel, 2019). Through adaptive learning systems and digital assistants, it is now feasible to differentiate instruction in a way that effectively addresses the diverse cognitive abilities and learning styles of children (Luckin, 2018).

Despite these substantial advantages, the integration of AI into primary schooling is not without its challenges. Children in this age group are characterized by a heightened sensitivity to environmental stimuli, a limited capacity for self-regulation, and a profound need for continuous social and emotional support. The collection, analysis, and utilization of their personal and learning data raise serious concerns regarding data protection, transparency, and algorithmic justice (Mertala, Fagerlund, & Lehtoranta, 2024).

Furthermore, over-reliance on digital systems—absent of appropriate pedagogical guidance—may restrict the development of critical thinking and social skills, thereby undermining the holistic development of students (Reiss, 2024). For this reason, AI must be viewed as a supportive tool rather than a substitute for the educator. The teacher remains the central actor in the design, supervision, and evaluation of learning activities, ensuring that technology is integrated in an ethical and pedagogically sound manner (Sharples, 2023).

The purpose of this article is to present a comprehensive theoretical framework for the use of AI in primary schools, with a particular focus on the pedagogical and ethical challenges involved. It aims to explore applications that have already been implemented or are considered feasible for the future, while highlighting both limitations and opportunities for improvement. Through a systematic literature review and the analysis of practical examples, this paper seeks to contribute to the understanding of how AI can be utilized in a safe, effective, and pedagogically responsible way.

Finally, this introduction establishes the foundation for the theoretical framework presented in Chapter 2, where the concepts of personalized learning, differentiated instruction, and the application of AI in primary education are analyzed, directly linking theory to educational practice.

2. Research Methodology

The present study employs the Qualitative Literature Review method, which was selected as the most appropriate approach for synthesizing and critically analyzing research data from diverse scientific fields, including education, ethics, and technology. According to Snyder (2019), a qualitative literature review facilitates the interpretive connection of heterogeneous sources, aiming to formulate new theoretical perspectives and conceptual frameworks.

2.1 Data Collection Process

To identify relevant literature, a systematic search was conducted across international scientific databases, including Google Scholar, Scopus, and ERIC, as well as selected Greek institutional sources, such as the Institute of Educational Policy (IEP) and the Hellenic Data Protection Authority (HDPA).

The keywords utilized (in various combinations) included:

- Artificial Intelligence in Primary Education
- Ethics in Artificial Intelligence in Education (AIED)
- Differentiated Instruction and AI
- Multiple Intelligences and Artificial Intelligence

2.2 Criteria for Source Selection

The selection of sources was based on the following criteria:

- Timeframe: Emphasis was placed on studies conducted over the last decade (2014-2024), with particular attention to recent developments regarding Generative Artificial Intelligence (Generative AI).
- Thematic Relevance: Inclusion of studies focusing on Primary Education that examine the pedagogical, social, and ethical implications of AI utilization.
- Language: Selection of sources in both the Greek and English languages.

2.3 Data Analysis Method

The analysis of the selected sources was performed through Thematic Analysis, following the model proposed by Braun and Clarke (2006). This process led to the identification and categorization of recurring concepts and concerns, which were organized into four fundamental thematic pillars of ethical challenges:

- Privacy and personal data protection.
- Transparency and interpretability of algorithms (explainability).
- Algorithmic bias and justice.
- Pedagogical responsibility and the role of the educator.

These pillars formed the basis for the development of the theoretical and ethical framework presented in the subsequent sections of this study.

3. Theoretical Framework

3.1 Personalized Learning and Adaptive Systems

Personalized learning constitutes a primary objective of modern pedagogy, as it allows students to progress at a pace that corresponds to their individual needs, leveraging their strengths while addressing their weaknesses (Luckin, 2018). Artificial Intelligence (AI) systems, such as Intelligent Tutoring Systems (ITS), utilize advanced algorithms to analyze learning data and adapt the educational process in real-time (Woolf, 2010).

In primary education, the utilization of these systems enables educators to identify learning difficulties early and provide targeted support before these challenges evolve into chronic issues (Pane, Steiner, Baird, & Hamilton, 2015). The use of ITS also

enhances active student engagement, increases self-confidence, and promotes metacognitive thinking, allowing students to evaluate and regulate their own learning (Holmes et al., 2019; Luckin, 2018).

Personalization through AI is not limited to content adjustment. It extends to the selection of feedback methods- whether verbal, visual, or through gamification- to accommodate diverse learning styles and motivations (Holmes et al., 2019). This reinforces attention retention, reduces frustration, and increases the probability of achieving learning objectives.

3.2 Multiple Intelligences Theory, Differentiation, and Artificial Intelligence

Gardner's Theory of Multiple Intelligences (1991, 1993) serves as the fundamental basis for personalized learning, advocating that instructional practice should utilize the unique skills and intelligence profile of each student for maximum effectiveness.

Recognizing this diversity leads to the implementation of Differentiated Instruction, which treats the student as a "distinct biography" (Koutselini, 2001, 2009) and aims for their holistic development through various methods and strategies (Koutselini-Ioannidou & Pyrgiotakis, 2015).

According to Valianti and Neofytou (2017), differentiation is applied across three main pillars, guided by Gardner's theory:

- Differentiation of Content and Material: Adaptation of knowledge in terms of quality (tiered difficulty) and the possibility of choice based on interests (Koutselini-Ioannidou & Pyrgiotakis, 2015).
- Differentiation of Process and Activities: Providing alternative options (e.g., individual work or flexible grouping) that correspond to the learning style and the dominant intelligence of the student (Valianti & Neofytou, 2017).
- Differentiation of Product and Outcome: Modifying the way knowledge is demonstrated, allowing students to be assessed through alternative means, such as practical models, project presentations, or digital portfolios.

Artificial Intelligence functions as a technological catalyst for the implementation of differentiation by providing:

- Responsiveness: Automatic adaptation of content based on preferences, pace, and performance (Reiss, 2024).
- Personalized Learning Pathways: Design of learning trajectories tailored to each student's profile (Holmes et al., 2019).
- Feedback Customization: Selection of the mode and format of feedback to enhance understanding and participation.

The combined use of Gardner's theory with AI systems strengthens the potential for adaptive learning, where every student can fully develop their capacities.

Element	Description	Integration with AI	Educational Benefit
Multiple Intelligences (Gardner)	Every student possesses a unique intelligence profile (logical-mathematical, linguistic, musical, kinesthetic, etc.).	AI analyzes performance and preference data to identify each student's specific profile.	Personalization of learning; identification of strengths and areas for growth.
Differentiated Instruction	Adapting content, processes, and products to meet the diverse needs of students.	Adaptive systems suggest varied learning pathways and diverse types of activities.	Improved student engagement; reduction of frustration; increased motivation.
Learning Analytics	The collection and analysis of learning data (achievements, difficulties, interactions).	AI processes datasets to provide actionable insights and reports to the educator.	Targeted support; timely intervention; evidence-based instruction.
Artificial Intelligence (AI)	Adaptive systems, Intelligent Tutoring Systems (ITS), AI-driven assessment tools.	Synthesize student data with algorithmic analysis to facilitate personalization.	Support for the educator; development of metacognitive skills.

Table 3.1: Synthesis of Pedagogical Theories and Artificial Intelligence Components

3.3 Learning Analytics

Learning Analytics constitutes a critical tool for supporting personalized learning and differentiation in primary education.

Main Functions:

- Data Collection: Recording students' performance, progress, behavior, and interactions with educational tools, such as Intelligent Tutoring Systems (ITS), digital platforms, and AI applications. Detect patterns of difficulty or specific areas where additional support is required.
- Data Processing and Analysis: Utilizing AI algorithms to draw conclusions regarding learning patterns, identify gaps, and trends that affect student performance.
- Support for Educational Decision-Making: Providing educators with actionable information for timely intervention and the creation of individualized learning

plans. Interconnecting with adaptive AI systems for the immediate adjustment of content and activities.
- Development of Metacognitive Skills: Enhancing students' self-regulation by providing real-time feedback and support in understanding their strengths and weaknesses.

The application of Learning Analytics, in combination with adaptive AI systems, offers a holistic approach, enhancing instructional effectiveness and promoting students' metacognitive skills.

3.4 Robotics, AR/VR, and AI Educational Tools

AI in primary education is directly linked to various educational tools, such as:
- Educational Robotics: Utilizing robots to develop STEM skills, programming, collaboration, and problem-solving (Mertala et al., 2024).
- Augmented and Virtual Reality (AR/VR): Creating interactive learning environments that allow students to experiment with virtual scenarios and engage in experiential learning within a safe context.
- Digital Platforms and AI-powered Educational Games: Adapting activities and feedback to each student's profile, thereby enhancing engagement and knowledge retention.

The use of these tools supports active learning, personalization, and differentiated instruction, while simultaneously promoting collaboration and the development of digital literacy.

4. Ethical Dimensions in Primary Education

The integration of Artificial Intelligence (AI) in primary schools transcends the boundaries of mere technical application, constituting a complex ethical challenge that directly concerns the fundamental rights of the child. Given the sensitive developmental stage of primary education students, technology must operate through a human-centric lens, reinforcing rather than undermining the pedagogical relationship (UNESCO, 2023).

The ethical integration of AI within the classroom necessitates a multidimensional approach that safeguards digital sovereignty and the protection of minors' data, algorithmic transparency, social justice against biased practices, and the psychological safety of students. The following sections explore these critical pillars, highlighting the need for pedagogical mediation that prioritizes the child’s autonomy and well-being over uncritical technological acceleration.

4.1 Data Protection, Privacy, and Digital Sovereignty

The pervasive collection of minors’ data by Artificial Intelligence (AI) systems raises fundamental questions regarding the security of their digital identity and the preservation of digital sovereignty. Unlike adult users, children are often unaware of the extent to which their interactions, behaviors, and academic performances are recorded. As Williamson and Piattoeva (2022) argue, early learning metrics can create “permanent digital footprints” or “data doubles.” These persistent records pose long-

term risks, as developmental fluctuations in early childhood may be codified into static profiles, potentially influencing future educational and professional opportunities unfairly.

Ethical integration of AI in education therefore requires strict adherence to the General Data Protection Regulation (GDPR), emphasizing that the best interests of the child must remain the primary consideration. This entails implementing "privacy by design" and "privacy by default" frameworks, ensuring that data protection is a core feature of AI architectures rather than an afterthought (HDPA, 2024). Key strategies include:

- Data Anonymization and De-identification: Separating individual identities from learning analytics to minimize the risk of personal data misuse.
- Local Storage and Edge Computing: Limiting the transfer of sensitive information to centralized cloud servers to reduce exposure to large-scale breaches.
- Informed Consent and Transparency: Providing parents and legal guardians with clear, non-technical explanations regarding the type of data collected, its purpose, and retention periods.

However, in the context of the Greek educational reality, informed consent often becomes a complex "grey area" within state-managed digital infrastructures. To ensure substantial protection, it is imperative to shift from individual teacher responsibility to a centralized state certification framework. The Ministry of Education (MINEDU) must implement a top-down validation process, ensuring that any AI tool introduced into primary schools has undergone rigorous ethical and technical auditing. This prevents the fragmented and potentially high-risk use of uncertified applications and safeguards educators from legal or ethical liabilities.

Digital sovereignty also encompasses the right of educational institutions to retain control over their data, preventing "data colonialism" by third-party technology providers. By maintaining jurisdiction over educational data, schools can protect students from commercial exploitation and algorithmic profiling that commodifies the learning process (Williamson & Piattoeva, 2022).

Importantly, safeguarding data and privacy is not only a legal or technical requirement but also a pedagogical and ethical necessity. When children or educators lack awareness of how their data is processed, there is a risk of diminished trust and engagement with AI-based tools. Transparent data practices, therefore, serve as a foundation for pedagogical accountability and ethical AI integration, linking directly to the subsequent need for explainable systems and human oversight explored in Section 4.2.

Finally, while GDPR compliance and privacy-preserving measures reduce many risks, they do not automatically eliminate algorithmic biases or the potential misuse of information. Teachers and administrators must remain vigilant, ensuring that AI supports student learning without compromising psychological safety, fairness, or autonomy.

4.2 Transparency, Accountability, and the "Black Box" Problem

The lack of transparency in advanced AI algorithms- commonly referred to as the "Black Box" problem- represents a significant ethical challenge in educational

contexts. This issue arises when the internal logic of an AI system, particularly in deep learning or neural networks, becomes so complex that even its creators cannot fully explain how specific inputs are transformed into outputs. When such a system evaluates a student's performance or recommends a personalized learning path, the teacher often lacks the necessary insight, making it challenging to provide a pedagogical justification for algorithmic outputs (Eynon & Geniets, 2016).

In Primary Education, this opacity undermines a fundamental principle of pedagogical accountability. If a teacher cannot interpret an algorithmic recommendation, they cannot verify its fairness or accuracy, effectively delegating professional judgment to an unexamined machine of logic. For instance, a predictive model may flag a student as "at-risk" due to complex patterns in performance data; without transparent explanations, the teacher cannot determine whether this assessment reflects genuine learning challenges or is influenced by dataset biases.

The adoption of Explainable AI (XAI) is therefore imperative. XAI aims to design models that are "transparent by design," providing outputs that are interpretable and actionable for human users (Holmes et al., 2021). For example, an XAI-based platform can highlight which aspects of a student's work led to an "at-risk" classification, enabling the teacher to evaluate, contextualize, and, if necessary, override the algorithmic recommendation.

Importantly, transitioning to XAI is not merely a technical requirement but a precondition for building trust among students, parents, and school administrators. Transparency and accountability ensure that, in cases of errors or biases, clear mechanisms exist for detection and correction. Without these safeguards, the "Black Box" risks institutionalizing unfairness under the guise of "objective data." A transparent and explainable approach reinforces the teacher's role as the ultimate decision-maker, capable of interpreting AI recommendations critically while safeguarding students' educational interests (Eynon & Geniets, 2016; Holmes et al., 2021).

4.3 Algorithmic Bias and Social Justice

The integration of Artificial Intelligence (AI) into education is often presented as a tool for objectivity; however, O'Neil (2016) highlights that algorithms are not neutral, but rather "mathematical models encoding biases." Algorithmic bias arises when systems are trained on datasets that reflect historical social inequalities or cultural hierarchies.

In Primary Education, such biases can lead to significant disadvantages for students from diverse cultural, linguistic, or socio-economic backgrounds. For instance, natural language processing (NLP) systems may systematically evaluate lower the work of students who speak non-standard dialects or whose first language is not dominant, interpreting linguistic variation as "error" rather than cultural diversity (Mertala et al., 2024). By misidentifying these nuances as deficits, AI systems effectively penalize students for their cultural identity under the guise of objective technical assessment.

Ethically responsible AI integration therefore requires a social justice approach, encompassing:

- Dataset Representativeness: Employing inclusive datasets that reflect the multicultural and multi-vocal composition of contemporary classrooms.
- Algorithmic Transparency: Understanding the criteria by which a system generates recommendations or evaluations.
- Human Oversight: Ensuring that educators maintain the critical capacity to question algorithmic judgments when they disadvantage students due to background or identity.

4.4 Psychological Safety, Anthropomorphism, and Critical Thinking

The increasing integration of Artificial Intelligence (AI) systems into the school environment reshapes learning conditions while simultaneously raising significant concerns regarding students' psychological safety. Continuous interaction with AI-driven systems- particularly those incorporating personalized feedback, monitoring mechanisms, or social cues- may generate feelings of anxiety, heightened self-surveillance, and social pressure.

Within Primary Education, these concerns are intensified by the phenomenon of anthropomorphism. As Belpaeme et al. (2018) highlights, social robots and conversational agents are deliberately designed to display social signals to enhance engagement. While this can support motivation, it also increases the likelihood that children will attribute human intentions and emotions to AI systems. When unmediated, they may foster a problematic perception of AI as a social actor rather than an instructional tool.

Kahn et al. (2012) demonstrate that users -particularly younger ones- tend to imitate strategies and assign epistemic authority to anthropomorphic technological agents. Turkle (2011) cautions that sustained emotional investment can cultivate a "false sense of companionship," whereby machines are perceived as substitutes for human relationships.

4.5 Pedagogical Responsibility as a Counterbalance to Algorithmic Dominance

The ethical integration of AI is not a matter of passive compliance with technical rules but a state of constant pedagogical vigilance. In this context, the teacher evolves into an "ethical mediator." This role transcends simple supervision; the educator critically evaluates the system's suggestions, filters algorithmic assessments, and ensures that AI serves humanistic values rather than impersonal statistics (Reiss, 2024).

The goal is to maintain human judgment as the final arbiter (Human-in-the-loop). The educator remains responsible for the emotional support and ethical upbringing of students- elements that no AI can simulate. Thus, algorithmic power is placed at the service of the pedagogical ethos, ensuring that innovation aligns with respect for the child's personality.

Ethical Issue	Description / Risk	Mitigation Strategy

Privacy	Leakage of sensitive data and digital tracking of minors.	GDPR compliance, data anonymization,local data storage.
Transparency	Opaque decision-making algorithms (Black Box phenomenon).	Adoption of XAI (Explainable AI) systems, informed consent for parents and educators.
Bias	Discrimination based on social or cultural background.	Use of inclusive datasets, rigorous ethical oversight.
Depen0dency	Diminishment of critical thinking and human interaction.	Maintaining the Human-in-the-loop approach (teacher as the final arbiter).

Table 4.5: Ethical Challenges in AI Integration and Corresponding Mitigation Strategies

Artificial Intelligence in primary education offers significant advantages, yet simultaneously raises ethical challenges surrounding the privacy, transparency, equity, and psychological safety of students. Data protection, the prevention of algorithmic bias, and the transparency of systems are essential prerequisites for establishing trust among all stakeholders. At the same time, the pedagogical responsibility of teachers remains decisive, ensuring that AI enhances learning without substituting human judgment. Consequently, students evolve into active, digitally literate citizens, capable of developing skills and values that will accompany them throughout their lives.

The following chapter examines the practical applications of AI in the classroom, presenting tools and methods that strengthen instruction and the personalization of learning.

5. Practical Applications of Artificial Intelligence in Primary Education
6.

Artificial Intelligence (AI) is no longer a future hypothesis, but a tool that is already transforming the educational process. Its primary function is to support instruction and personalize the learning experience, acting as a complement to- rather than a substitute for- the educator (Sharples, 2023). Furthermore, the integration of AI into primary education is not solely a matter of technological innovation; it is a pedagogical and ethical issue, as it influences how students develop cognitively, emotionally, and socially (Reiss, 2024; Holmes, Nguyen & Fadel, 2021).

The use of AI requires a conscious and targeted pedagogical strategy, where the educator remains at the center of the learning process. The teacher's role becomes increasingly one of guidance and supervision, with AI functioning as a tool to enhance instruction rather than a replacement for the pedagogue's judgment or creativity (Mertala, Fagerlund & Lehtoranta, 2024). Simultaneously, AI must be integrated within a framework of ethical oversight, personal data protection, and the promotion of equitable access to learning (HDPA, 2024; Dept. of Digital Systems, Univ. of Patras, 2025).

5.1 Personalized Learning, Adaptive Systems, and Differentiation

AI facilitates the transition from mass instruction to Personalized Learning and the practical application of Gardner's Theory of Multiple Intelligences (1984). Through AI, students receive varied stimuli based on their cognitive and social profiles. This approach is directly linked to the principles of Differentiated Instruction, where students receive material, guidance, and activities tailored to their individual needs and interests (Koutselini, 2001, 2009).

Classroom differentiation, according to Koutselini-Ioannidou (2015), is a dynamic process requiring continuous adjustments by the educator. AI transforms this process from a laborious manual task into an automated and efficient one, ensuring that each student works at their own pace with activities that promote both intrapersonal and interpersonal development.

Adaptive Learning Systems utilize machine learning algorithms to continuously monitor student progress and cognitive errors (Luckin, 2018). Through data analysis, they identify knowledge gaps and automatically adjust content, providing corrective exercises or supplementary material. This allows students to progress at their own speed, avoiding feelings of pressure or boredom (Shute, Ventura, & Storey, 2016; Pane et al., 2015).

Furthermore, AI can be combined with tools for the differentiation of content, process, and product. Specifically:

- Content: Adapted texts, multimedia stimuli, and tiered difficulty levels.
- Process: Personalized activities and collaborative learning platforms.
- Product: The ability to produce work in multiple formats (digital portfolios, presentations, videos) (Valianti & Neophytou, 2017).

5.1.1 Connection with the Greek Institutional Framework and "Skills Labs"

In the Greek educational reality, the integration of Artificial Intelligence (AI) finds fertile ground in the new Curricula and, specifically, in the institution of "Skills Labs" (Ergastiria Dexiotiton). Thematic cycles related to "Creation and Innovation" and "Digital Literacy" provide the necessary instructional timeframe for the practical application of the theories of Gardner and Koutselini. Through AI, 21st-century skills (4Cs: Critical Thinking, Communication, Collaboration, Creativity) are no longer approached theoretically but are experienced through adaptive learning environments that respect each student's diversity.

AI enables the implementation of differentiated instruction within these Labs, as students can work in groups with different levels of difficulty or various media (e.g., robotics for kinesthetic intelligence, chatbots for linguistic intelligence), while the educator functions as an orchestrator. This approach aligns with the directions of the Institute of Educational Policy (IEP) for a school that promotes inclusion and personalization, transforming technological innovation into an organic element of modern Greek school culture.

The daily pedagogical application of the above requires a systematic mapping of available AI technologies in correspondence with the classroom's pedagogical needs.

For the educator to function as an effective orchestrator within the Skills Labs, they must select tools that activate different channels of information reception, turning the Theory of Multiple Intelligences into an experiential learning journey.

Table 5.1.1, which follows, presents a comprehensive proposal for connecting Gardner's intelligence types with specific AI tools and corresponding activities, highlighting the axis on which instructional differentiation is achieved.

Intelligence Type	**AI Tool**	**Activity**	**Differentiation Axis**
Logical-Mathematical	Intelligent Tutoring Systems (ITS)	Problem-solving with tiered (scaffolded) difficulty.	Content
Linguistic	NLP / Chatbots	Practice in writing, reading, and foreign languages.	Process & Product
Spatial	AR / VR	Exploration of geography, history, or the human body.	Process
Intrapersonal	Adaptive Learning Platforms	Monitoring personal progress and goal setting.	Process
Interpersonal	Collaborative Robotic Systems	Group project-based learning (PBL).	Product

Table 5.1.1: Connecting Multiple Intelligence Types with AI Tools

5.2 AI Assistants for Educators and Task Automation

AI functions as a powerful assistant for educators, reducing administrative and repetitive workloads so that teachers can focus on pedagogical guidance. Specific applications include:

- Automated Feedback and Grading: AI systems can automatically grade multiple-choice questions, short written responses, or provide initial feedback, thereby saving valuable time (Holmes, Bialik, & Fadel, 2019).
- Content Creation Tools: Generating personalized worksheets, quizzes, and lesson plans tailored to the specific needs of diverse student groups.
- Learning Analytics: Enabling educators to identify students at risk of falling behind and to adjust interventions in a timely manner (Baker & Inventado, 2014; Siemens & Long, 2011).

Through these applications, AI reinforces the educator's role as an emotional and pedagogical mentor without replacing them, while simultaneously promoting student autonomy and critical thinking.

5.3 Specialised Applications: Robotics, AR/VR, and Language Skills

AI is integrated into specialized tools that enhance experiential learning:

- Educational Robotics: Tools such as Bee-Bots, LEGO Mindstorms, and other robotic systems are used to develop computational thinking and problem-solving skills through physical interaction (Benitti, 2012).
- Augmented and Virtual Reality (AR/VR): These technologies create immersive learning environments for exploring historical events, natural phenomena, or the human body, thereby boosting collaboration and engagement (Bacca et al., 2014).
- Language Skill Enhancement: Natural Language Processing (NLP) and chatbots facilitate the analysis of written and oral skills, provide immediate feedback, and offer practice in foreign languages (Neri et al., 2008).

5.4 Supporting Students with Special Needs

AI possesses immense potential to create inclusive learning environments by providing tools for students with Special Educational Needs (SEN):

- Text-to-Speech Software: Supporting students with dyslexia or visual impairments.
- Affective Computing (Emotion Recognition Systems): These systems detect signs of anxiety, frustration, or lack of focus in students with autism or ADHD, alerting the teacher for timely intervention (Picard, Vyzas, & Healey, 2001).

In conclusion, the integration of Artificial Intelligence in Primary Education represents a paradigm shift that offers unprecedented opportunities for personalized learning yet demands a rigorous ethical framework. This study has demonstrated that while AI can effectively address diverse learning styles, it cannot substitute the relational and emotional depth of the teacher-student bond. Safeguarding data privacy, ensuring algorithmic transparency, and mitigating bias are not merely technical hurdles but essential pillars of a social justice approach in education. Ultimately, the success of AI in the classroom depends on the "human-in-the-loop" principle: the educator must remain the final epistemic and ethical arbiter, ensuring that technology serves as a tool for empowerment and critical autonomy rather than a mechanism for algorithmic dominance.

6. Limitations and Future Directions

The integration of Artificial Intelligence into Primary Education, while holding great promise for the radical transformation of instruction, must be approached with realism and a critical mindset. Identifying limitations is not an impediment but an essential first step toward ensuring a fair, safe, and effective pedagogical transition in the 21st century.

6.1 Limitations and Risks

Despite the impressive technological potential, clear barriers emerge that require immediate and systematic attention from the educational community and the state:

- **Inequality of Access (Digital Divide):** The use of AI carries the risk of widening existing social inequalities. As Van Dijk (2020) documents, the "digital divide" is multifaceted: it is not limited to the possession of physical devices but extends to the quality of connectivity and, most importantly, the level of digital literacy among students and parents. Without organized state provision for universal access, AI risks becoming a "privilege of the few," increasing the gap between privileged and non-privileged school units.
- **Teacher Readiness and Pedagogical Framework:** Ertmer (1999) had already pointed out that technology, however advanced, remains pedagogically underutilized if it is not accompanied by a deep understanding of appropriate instructional strategies. In primary school, where the personal teacher-student relationship is fundamental, continuous and specialized professional development is the only way to prevent AI from sliding into a sterile, mechanical execution of digital exercises devoid of pedagogical meaning.
- **Ethical Bias and Safeguarding Critical Thinking:** O'Neil (2016) warns of algorithmic bias. If the data on which AI systems are trained carry prejudices, automated student assessments may be unfair, entrenching stereotypes. Simultaneously, there is an underlying risk that the extreme ease offered by AI may lead to "cognitive offloading" (or cognitive laziness), undermining students' capacity for autonomous analysis and critical inquiry of information (Mertala, Fagerlund, & Lehtoranta, 2024).
- **Limited Pedagogical Integration:** Artificial Intelligence is a powerful tool, but without clear objectives and careful pedagogical design, it can restrict creativity, social interaction, and the development of metacognitive skills. The lack of comprehensive evaluation and feedback strategies may lead to one-dimensional learning, where technology dominates instead of supporting.

6.2 Cognitive Risks and the "Hallucinations" Phenomenon

Particular attention is required when students engage with Generative AI systems, due to the phenomenon of "hallucinations." These are instances where Large Language Models (LLMs) produce information that is grammatically correct and persuasive but factually inaccurate or entirely fabricated (Ji et al., 2023). For instance, when asked about a fictional historical event, such as a "Battle of Aigialeia in 1823", an LLM might generate a detailed but entirely fabricated account, presenting it as a historical fact. Within the context of Primary Education, this risk is significantly heightened, as students in this age group do not yet possess the necessary cognitive background and experience to evaluate the validity of the generated responses (Luckin, 2023).
The uncritical use of AI as a source of authority may lead to the adoption of misconceptions and the weakening of children's investigative abilities, undermining the process of knowledge construction.

6.3 Perspectives and Future Directions

Despite the aforementioned limitations, the future of Artificial Intelligence in educational practice is not envisioned merely as a technological evolution, but as a radical reimagining (reflection) of teaching. Future directions tend toward systems that are more transparent, inclusive, and, above all, human-centric:

- **Affective Computing and Emotional Empathy:** One of the most promising prospects is the ability of AI to recognize and respond to students' emotional states in real-time. Systems that detect anxiety, frustration, or fatigue through the analysis of interaction patterns can automatically adapt the learning environment.
- **Explainable AI (XAI):** The transition from the "black box" model toward absolute transparency is an imperative for the democratic function of the school. Future platforms must explain to the educator and guardians the exact reasoning behind every learning suggestion or assessment.
- **Co-Creative Teaching and the Teacher as Orchestrator:** The teacher-AI relationship is evolving into a co-creation. AI does not replace the educator but functions as an intelligent "design assistant," handling administrative burdens and the processing of Learning Analytics.
- **Inclusive Design and Universal Design for Learning (UDL):** The future development of AI focuses on removing barriers for students with disabilities or special educational needs through speech-to-text tools, data visualization, and adaptive interfaces.

In conclusion, future research and practice must focus on creating ethical frameworks to accompany every new application, ensuring that technological innovation does not outpace the ethical preparation of the educational community, but instead walks hand in hand with respect for the student's personality and autonomy.

7. Conclusions

The present study has demonstrated that Artificial Intelligence (AI) is not merely a technological addition but a transformative factor redefining Primary Education. Through data analysis and personalized learning capabilities, educators can identify learning gaps early, adapt the pace and content of instruction, and offer a learning experience that meets the needs of every child, even within highly heterogeneous classrooms.

Personalized learning platforms leverage advanced algorithms to recognize learning gaps and adapt instructional pathways, supporting the Theory of Multiple Intelligences while bolstering student confidence, reducing the fear of failure, and fostering the development of metacognitive skills (Shute et al., 2016). Furthermore, the use of tools such as educational robotics, Augmented and Virtual Reality (AR/VR) applications, and Natural Language Processing (NLP) contributes to the cultivation of 21st-century skills (the 4Cs), promoting creativity, critical thinking, and collaboration through experiential activities (Benitti, 2012; Holmes et al., 2019).

However, the integration of AI is accompanied by critical ethical challenges. The protection of minors' personal data, the transparency of algorithms, and the prevention of algorithmic bias are essential prerequisites for ensuring fair and inclusive educational practices (O'Neil, 2016). A lack of comprehensive pedagogical design may restrict creativity, social interaction, and the development of metacognitive skills, transforming learning into a one-dimensional process of control and information. Simultaneously, inequalities in access to technological infrastructure can widen the socio-educational gap unless there is centralized, equitable planning and state provision (Van Dijk, 2020).

The human element remains the decisive factor for the success of AI. Educators must assume the role of "ethical orchestrators" and mediators- supervising, evaluating, and filtering algorithmic suggestions to ensure that AI serves pedagogical values and the development of students' personalities (Ertmer, 1999; Reiss, 2024). Continuous professional development and pedagogically sound guidance are essential for transforming educators from mere transmitters of knowledge into ethical mediators of multifaceted learning experiences.

Future developments, such as Affective Computing and Explainable AI (XAI), promise learning environments that are more transparent, inclusive, and adapted to the diversity of every child. At the same time, cultivating critical thinking toward AI strengthens student autonomy and the development of digital literacy, preparing them for a world where technology is a tool rather than an end in itself (Mertala et al., 2024).

In conclusion, AI in Primary Education offers a historic opportunity for the democratization of learning and the creation of school environments that respect diversity, enhance collaboration, and promote the holistic development of every student. The future of education is neither exclusively digital nor traditional, but a dynamic synthesis of both, where technological power is placed at the service of a human-centric pedagogical ethos. Only in this way can innovation ensure the equitable, sustainable, and meaningful development of each student's personality, without substituting human judgment and pedagogical empathy.

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Artificial intelligence as a factor in the transformation of teaching and democratic education in higher education: an empirical approach

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Abstract- In the 21st century, artificial intelligence (AI) has emerged as one of the most decisive factors of social and political change. Its applications affect every aspect of daily life, from the economy and education to public administration and politics. The spread of AI systems creates opportunities, but also challenges for democracy. Universities, as fundamental institutions of education and socialization, can play a decisive role in strengthening democracy and active citizenship by promoting knowledge in the field of artificial intelligence. Therefore, understanding its operating principles, potential, and risks is a necessary prerequisite for participation in a modern democracy. Through interdisciplinary study programs, universities can shape students who combine technical skills with ethical awareness and social sensitivity. In this way, they contribute to the development of citizens who are able to critically evaluate technological developments, defend transparency and justice, and actively participate in shaping a democratic digital society by becoming responsible, informed, and democratic citizens. By training future teachers to question, evaluate the validity, accuracy, and reliability of information, we can help them improve the skills they will ultimately need to become active citizens, capable of understanding the social, political, and ethical dimensions of technology. This study was conducted during the 2024-2025 academic year in the teaching methodology course at ASPETE Thessaloniki with 20 prospective teachers. The research tool was the interview. The interview was semi-structured, as this allows for flexibility in its conduct. The interview research tool was based on key axes that served as its guide. The questions that structured this guide were the questionnaire with open questions, so as not to limit the interviewees. The transcribed interviews constituted the research material. The results of the research showed that artificial intelligence redefines the limits of human activity and raises important questions about the future of democracy. Teaching and research can make a real difference in strengthening democracy and active citizenship. The new generation of scientists and citizens has the chance to use technology as a tool for progress and social justice, really serving the principles of democracy. In conclusion, by adopting educational approaches that promote cooperation, dialogue, and critical thinking, they can make a decisive contribution to shaping a generation of active and responsible citizens capable of using technology for the common good.

Keywords— (democracy, active citizenship, artificial intelligence, higher education)

Introduction

The influence of Artificial Intelligence (AI) in Education is becoming increasingly evident, reshaping traditional learning models and opening up new possibilities and perspectives. AI promises to revolutionize the way knowledge is transmitted and acquired. However, ethical dilemmas surrounding the use of new technology are also increasing. The rapid development of Generative Artificial Intelligence (GAI) has created new perspectives and challenges for education. The ability of tools like ChatGPT to create content, personalize learning, and automate administrative tasks has begun to reshape the way educators teach and students learn globally. However, the integration of these technologies requires a deep understanding of the technical capabilities and limitations as well as the ethical issues arising from their use. AI-enabled systems now facilitate forms of instructional differentiation and responsiveness that were previously difficult to achieve at scale, allowing learning content, pacing, and feedback to be dynamically adapted based on learners' responses, performance patterns, and identified knowledge gaps (UNESCO, 2019).

Artificial Intelligence (AI) is a decisive factor in social and political change. AI applications affect every aspect of daily life: economy, Education, Public administration, Politics. The spread of AI systems creates opportunities, but also challenges for democracy. Today's data-driven world requires an up-to-date approach to digital competencies, particularly AI and data literacy. Teachers are also finding out about the impact of AI content when it comes to selecting, creating, and using high-quality digital education teaching materials in the classroom. These and other developments also raise ethical questions about the use of AI.

AI applications, such as adaptive learning platforms, intelligent tutoring systems, and learning analytics, support these processes by offering real-time feedback, progress visualization, and personalized recommendations that enhance learner autonomy and metacognitive awareness (Frank, 2024). AI-enabled interventions have been shown to improve student matriculation and retention outcomes by identifying and addressing these barriers at an early stage (Alexander et al., 2019).

Universities can play a decisive role in strengthening democracy and active citizenship by promoting knowledge in the field of artificial intelligence. Understanding its operating principles, potential, and risks is a necessary prerequisite for participation in a modern democracy (George & Sevak, 2026) instructional strategies based on learner data and engagement patterns (Bearman et al., 2023). However, instructors remain central to the learning process, utilizing AI-generated insights to design tailored learning experiences, predict academic success, and identify students who require early intervention (Bearman et al., 2023; Crompton & Burke, 2023).

Universities can shape students who combine technical skills with ethical awareness and social sensitivity. They contribute to shaping citizens who are able to: critically evaluate technological developments, defend transparency and justice, actively participate in shaping a democratic digital society, making them responsible, informed, and democratic citizens (Rotana, Sarun, Nara, Hun, 2026). By training future educators to question, evaluate the validity, accuracy, and reliability of information. They improve the skills they will ultimately need to become active citizens, capable of

understanding the social, political, and ethical dimensions of technology (Mosha, Chigwada, Ketchiwou, & Ngulube, 2026).

The research took place during the academic year 2024-2025. The course was teaching methodology and the location of the research was ASPETE at the department of Thessaloniki. The research sample were 20 prospective teachers and as a research tool was used the interview. The interview format was semi-structured and the questions were open. The research material was transcribed interviews. The interview is a multidimensional technique that allows the understanding of human experiences, beliefs, and stories. In the context of qualitative research, the interview is used to record deeper human experiences through the exploration of participants' perceptions. The qualitative approach is an in-depth approach, aiming at the analysis and interpretation of qualitative data, after first collecting, categorizing and evaluating our data. We choose it when we are interested in making a deeper analysis and interpretation of situations, events, behaviors or experiences. The interview is based on free and open communication, it presupposes some relationship between the interviewer and the respondent and as a data collection technique it helps the researcher not only to approach his/her subject in depth, but also to utilize experiences and emotions, and in general, emotional data. In other words, the interview is a way for the researcher to discover what the respondents think and feel. As a research tool it presents many advantages, because it provides opportunities to clarify some answers, to ask additional questions, thus giving the possibility for in-depth analysis, where what was said was unclear, and due to its immediacy it usually finds great acceptance by the participants in a research.

The format of the interview was semi-structured, as it allows for flexibility in conducting the interview. A characteristic of the interview is a set of predefined questions, without this being binding, since the interviewer is given the opportunity to shape and change the content of the questions depending on the course of the interview, as well as to add or remove questions, if deemed appropriate. In addition, with this type of interview there is the possibility of including aspects of the topic that may have arisen during the course of the interview (Kelpanidis, 1999: 71-81). The research tool of the interview was based on basic axes that constituted the guide of the interview. The questions with which this guide was structured were the questionnaire that had open questions, in order not to limit the interviewees. The recorded interviews constituted the research material.

Artificial Intelligence & Teaching

- ✓ In what ways do you think AI could improve the quality of university teaching?
- ✓ What aspects of teaching do you think AI cannot effectively replace or support?

Artificial Intelligence & Democratic Education

- ✓ Do you believe that AI can contribute to promoting equality and participation at university? In what way?
- ✓ How can AI strengthen democratic dialogue between students and teachers?

Risks, Concerns & Ethical Issues

- ✓ What is the biggest ethical concern regarding the development and dissemination of AI tools in higher education?
- ✓ When do you think the use of AI becomes dangerous for educational justice?

Suggestions for the future of AI at the university

- ✓ What changes should be made to the curriculum to integrate AI in a democratic way?
- ✓ How should students be educated to develop critical digital and democratic awareness?

In what ways do you think AI could improve the quality of university teaching?
Student A: Personalization of learning
LT can tailor educational material to the needs, level, and pace of each student, offering more targeted guidance and support. Support for collaborative learning
AI can help groups of students coordinate, co-create material, and develop collective skills.
Student B: Providing immediate and quality feedback
AI systems can offer quick, detailed, and consistent feedback on written assignments, quizzes, or exercises, improving the learning process and students' self-regulation.
Student C: Development of more active and participatory forms of teaching
With interactive tools, chatbots, simulations, and "smart" learning scenarios, students can participate more and interact with the content.
Student D: Improving accessibility
Voice recognition, automatic translation, subtitling, and adaptive support tools make it easier for students with different needs (linguistic, learning, disabilities).
Student W: Learning analytics
AI can identify learning difficulties, study patterns, or weaknesses in students, allowing teachers to intervene in a timely and targeted manner.
Student T: Supporting collaborative learning
IT can help groups of students coordinate, co-create material, and develop collective skills.

What aspects of teaching do you think cannot be effectively replaced or supported by LT?
Student C: Human relationships and pedagogical presence
LT cannot replace the role of the teacher as a mentor, role model, guide, and motivator. Empathy, understanding emotions, and pedagogical care are human dimensions that cannot be accurately reproduced by algorithms.
Student G: The development of students' interpersonal skills
Skills such as cooperation, communication, negotiation, group decision-making, and democratic participation are cultivated mainly through human interaction.
Student E: Cultivating critical thinking about technology itself
IT can provide technical support for information, but it cannot teach a critical attitude towards technology, society and power.
This requires human dialogue, argumentation, and democratic education.
Student K: Ethically responsible decision-making
Teachers are called upon to make decisions regarding fair assessment, inclusion, and protection of students.
AI cannot take on such responsibilities or assess the ethical consequences of decisions.
Student R: Moral and value orientation

Teaching involves shaping attitudes, values, and democratic culture.
TN cannot take on this role, nor can it judge complex social issues with value consistency.
Student U: Pedagogical improvisation and teacher creativity
Teachers dynamically assess the situation in the classroom, adjust the pace, change examples, and invent new approaches.
TN operates in a programmed manner and not with true creative flexibility.
Student R: Authentic assessment (oral exams, projects, discussions)
Assessment through dialogue, argumentation, presentation or critical thinking cannot be replaced by algorithmic systems without loss of quality and fairness.

Do you believe that AI can contribute to promoting equality and inclusivity at university? In what ways?
Student L: Improving accessibility for all students
AI provides tools such as automatic speech transcription, subtitling, text-to-speech conversion, and adaptation of material for people with learning difficulties or disabilities. This reduces barriers to participation.
Student M: Personalizing learning for different needs and paces
AI allows students with different backgrounds, language proficiency, or abilities to learn at their own pace and with material adapted to their level.
This promotes equal access to knowledge.
Student P: Enhancing student participation in learning
LT tools allow for more forms of expression and participation (multimedia, simulations, interactive platforms), helping students with different learning styles.
Student X: Supporting students from minority or vulnerable groups
Chatbots and virtual assistants can offer 24-hour help to students who may be reluctant to seek support in person. This reduces social barriers and feelings of exclusion.
Student E: Reducing bias in assessment processes
If AI is properly designed and checked for biases, it can contribute to more objective assessment of tasks or tests, reducing unconscious human biases.
Student O: Facilitating multilingual and international participation
AI translation systems, automatic text correction and language support help international students integrate more smoothly into university activities.
Student K: Identifying and supporting students at risk of exclusion early
Learning analytics can identify students who are struggling so that the university can organize timely interventions and support.

How can AI enhance democratic dialogue between students and teachers?
Student S: Enhancing participation
AI can detect which students participate less and suggest ways for them to join the discussion, reducing the risk of voices being excluded and enhancing equal participation.
Student F: Supporting diversity of voices and perspectives
AI can present different sources, data, or arguments on an issue, enhancing pluralism of opinion and fostering democratic thinking.
Student X: Creating interactive discussion platforms
LT tools can support online forums, virtual classrooms, and interactive environments where all students have an equal opportunity to express their opinions and actively participate in the dialogue.
Student G: Supporting structured dialogue

AI systems can suggest questions, organize arguments, and summarize opinions, helping students and faculty engage in more structured and constructive dialogue.
Student L: Creating an environment of safe expression
Through anonymous or semi-anonymous systems, AI can reduce anxiety or fear of criticism, encouraging students to freely express their opinions.
Student T: Supporting diversity and different perspectives
AI can present different sources, data or arguments on an issue, enhancing pluralism of opinions and cultivating democratic thinking.
Student W: Facilitating participatory assessment processes
Through collaborative assessment and peer-review tools, AI can enhance dialogue and participation not only in learning but also in the assessment process.

What is the biggest ethical concern regarding the development and dissemination of AI tools in higher education?
Student Z: Reduction of critical thinking and democratic participation
AI can guide or suggest solutions to students, at the risk of limiting the development of autonomy, critical thinking, and democratic participation in the educational process.
Student S: Removal of human judgment and responsibility
Over-reliance on AI in assessment or decision-making may reduce the responsibility of the teacher and lead to decisions that are not ethically responsible or sensitive to the individual needs of students.
Student D: Protection of personal data and privacy
AI collects and analyzes student data (learning habits, performance, participation).
Improper management of this data can violate privacy and create ethical trust issues.
Students W: Algorithmic bias and inequality
AI tools may incorporate pre-existing social or cultural biases, leading to unequal treatment of students or distorted assessment.
This raises ethical issues regarding equity and justice in education.
Student E: Equity in access and integration of AI
Unequal distribution of resources and lack of training can create students or teachers with limited ability to use AI, reinforcing educational inequalities.

When do you consider the use of AI to be dangerous for educational justice?
Student A: When it replaces critical human decisions without supervision
Overreliance on AI for assessment, guidance, or decision-making without human intervention can disadvantage students with different needs or learning styles.
Student C: When it limits critical thinking and participation
The use of AI that imposes predetermined solutions or leads to passive learning can limit the development of student autonomy and participation.
Student B: When it limits access to resources
IT can reinforce inequalities between students who have access to technological infrastructure or educational support and those who do not.
Student T: When it embeds bias
If AI algorithms are biased by training or design data, they may favor some students over others, leading to unequal treatment.
Student O: When it reduces transparency and accountability
If AI processes are not transparent, students cannot understand or challenge the results, which undermine trust and educational equity.

What changes should be made to the curriculum to integrate AI in a democratic way?

Student A: Integrate courses on AI and critical digital literacy
Curriculums should include courses that teach how AI works, what its capabilities are, but also its limitations and ethical implications. This helps students use it critically.
Student B: Teach ethical and democratic use of AI
Students should know how to evaluate AI tools, identify biases, protect privacy and ensure equality in education.
Student T: Integrate participatory and collaborative activities
The curriculum should promote student collaboration through AI tools, such as shared learning platforms, forums and simulations, so that all students have an equal voice.
Student N: Adaptability and personalization of learning
AI can support different learning paces and ways of learning, but the curriculum must ensure that this personalization is done in a way that promotes equity and does not lead to exclusion.
Student D: Continuous assessment and feedback
The use of AI in the curriculum must be accompanied by control and feedback mechanisms, so that educational processes remain transparent and fair for all.
Student C: Teacher training
Teachers must be trained in the use of AI and its integration in ways that enhance democratic learning and do not limit student participation.

How should students be trained to develop critical digital and democratic awareness?
Student A: Teaching critical digital literacy
Students should learn how AI tools work, what their capabilities and limitations are, how they collect and process data, and how to recognize biases or misleading information.
Student B: Cultivating ethical awareness
They should be trained in the responsible use of AI, in protecting personal data, in avoiding discrimination, and in promoting equality in education.
Student D: Strengthening critical thinking and analytical skills
Students should learn to evaluate information, form well-founded opinions, challenge pre-determined solutions, and participate in debates with arguments.
Student F: Participatory learning and collaboration
Through group work, forums, digital platforms and simulations, students learn to collaborate, respect different opinions and participate equally in decision-making.
Student E: Development of self-regulation skills
AI can provide personalized feedback, helping students to identify their strengths and weaknesses, enhancing autonomy and responsibility in learning.
Student M: Interdisciplinary approach
Education should combine technology, ethics, social sciences and democratic education, so that students understand the social and political impact of AI.

Conclusion

The research findings revealed that artificial intelligence is redefining the boundaries of human activity and raising important questions about the future of democracy. Teaching and research can make a real difference in strengthening democracy and active citizenship. The new generation of scientists and citizens has the opportunity to use technology as a tool for progress and social justice, effectively serving the principles of democracy. By adopting pedagogical approaches that reinforce cooperation, dialogue and critical thinking. They can contribute to: the formation of a

generation of active and responsible citizens, capable of using technology for the common good. The text focuses on the importance of the pedagogical function of education as a fundamental factor in the social and political formation of individuals in the modern knowledge society. The adoption of pedagogical approaches that enhance cooperation, dialogue and critical thinking is not limited to the transmission of cognitive content, but aims at the overall development of the student as an active subject. Cooperation cultivates skills of teamwork, solidarity and mutual respect, promoting collective problem-solving and awareness of social responsibility. Dialogue, as a basic pedagogical tool, enhances democratic participation, allows the exchange of ideas and contributes to the formation of the ability to argue and listen to different points of view. At the same time, the development of critical thinking enables students to analyze, evaluate and reflect on the information and technological applications they use, avoiding the passive consumption of knowledge. Within this pedagogical framework, technology is viewed not as an end in itself, but as a means to social progress. Consequently, education contributes to the formation of a generation of active and responsible citizens, who possess the necessary cognitive, social and ethical skills to harness technology for the benefit of the common good and the democratic functioning of society.

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Pedagogical integration of an LLM in teaching the genre of summarization

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Abstract- The integration of Large Language Models (LLMs), specifically Gemini AI, into the teaching of summarization within the Modern Greek Language curriculum (11th Grade/High School), focuses on the practical and ethical dimensions of their educational use. This two-hour pedagogical intervention explores the application of Artificial Intelligence in language instruction, aiming for an experiential understanding of summarization criteria (objectivity, coherence, completeness, conciseness). Simultaneously, it fosters the critical evaluation of machine-generated outputs, as proposed by the UNESCO (2024) guidelines for the responsible use of AI. The methodology was based on comparative learning and Prompt Engineering, recognized as a vital 21st-century skill.

The process unfolded in two main phases: a) human production: students collaboratively drafted a summary of a given text; b) machine contrast & prompt refinement: students were tasked with "training" Gemini by providing initial, general prompts. The comparison between the human-authored summary and the initial machine output served as a mirror for the learning process. Vulnerabilities in the model—such as the verbatim use of phrases and difficulties in logical transitions—were identified, leading to an iterative cycle of prompt refinement. Consequently, students gained an experiential understanding that the quality of human instruction is decisive for meaningful AI output.

Findings from the evaluation questionnaire confirmed the intervention's success. Specifically, there was a high level of comprehension regarding summarization criteria, active student engagement was observed, and students developed the conviction that AI is a powerful tool requiring human guidance and critical oversight. Overall, this paper highlights an AI application that aims not at automation, but at enhancing critical thinking and digital literacy. Ultimately, it demonstrates that when AI is used as a comparative teaching medium, it acts as a catalyst for deepening conceptual understanding and fostering essential 21st-century competencies.

Keywords— (Prompt Engineering, Critical Thinking, Generative AI, digital literacy)

Introduction

The Challenge of Generative AI (GenAI) in Education

The rapid emergence and widespread adoption of Generative Artificial Intelligence (GenAI) has brought radical changes to the educational landscape. Specifically, Large Language Models (LLMs), such as Gemini AI, with their ability to produce high-quality text, create a pressing need to revise traditional teaching practices (Mintz et al., 2023), especially in subjects concerning discourse production, such as summarization.

The central problem that arises is the risk of "cognitive automation": AI could potentially become a substitute for the learning process, undermining the development of critical and metacognitive skills. The international educational community, as expressed through UNESCO guidelines (Miao & Holmes, 2024), emphasizes the necessity for a human-centric approach to AI.

The purpose of this paper is to present a pedagogical intervention aimed at transforming AI from a passive substitute—i.e., a tool for copying or bypassing thought—into a catalyst for critical thinking. This entails using AI as a medium that activates judgment and deepens students' understanding of summarization criteria. The methodology focuses on the experiential comprehension of these criteria through comparative learning (human vs. machine production).

Consequently, the central thesis of this study is that Prompt Engineering—the ability to guide AI with precise and critical instructions—constitutes a new 21st-century skill (Federiakin et al., 2024) that enables the responsible integration of Generative AI. The intervention highlights how students can maintain human agency and critical oversight (Miao & Holmes, 2024).

Theoretical Framework

Ethical and Pedagogical Guidelines

The rapid introduction of Large Language Models (LLMs) into the educational process has necessitated the establishment of clear ethical and pedagogical guidelines to ensure the responsible, fair, and equitable use of technology. Recognizing the need for global regulation, UNESCO published the "Guidance for generative AI in education and research" in 2024 (Miao & Holmes, 2024).

The core philosophy of this document is human-centric design and the principle of human oversight. UNESCO warns that Artificial Intelligence must not lead to the homogenization of views or the degradation of fundamental cognitive abilities. Instead, it emphasizes that AI should function as a tool for empowerment and the enhancement of human thought, rather than a substitute. Consequently, a critical stance and the ability of students to critically evaluate machine-generated outputs are considered essential to avoid the risk of "automation of judgment."

Within the context of the present intervention, the methodology aligns fully with these guidelines: AI is used as an instructional medium that produces an output (the summary), which students are then called upon to critically evaluate, correct, and guide

through prompt engineering. In this way, human agency is reinforced, ensuring that students maintain final judgment and control over the learning process, thereby preventing the simple and uncritical automation of academic tasks.

Comparative learning methodology: enhancing conceptual depth through contrast

The pedagogical methodology of this intervention was based on the principles of Comparative Learning, applying the logic of Comparative Judgement (Hopfenbeck, 2019). This approach is particularly crucial in written discourse production, as it shifts the focus from the mechanical application of rules to the qualitative, relative evaluation of texts. In our case, this process was not applied as a formal teacher-led assessment but was transferred to the students as an experiential tool to develop their evaluative expertise.

This concept, as utilized by Hopfenbeck (2019), includes:
Internalization of criteria: It is not enough for students to simply know the criteria for summarization (completeness, conciseness, objectivity); they must internalize them and be able to apply them spontaneously.
Justification of judgment: The ability to justify "why" one text is better or worse than another, using specialized terminology and arguments (e.g., "the AI summary lacks coherence because it uses verbatim phrases").
Self-regulation: The ability to use this critical capacity to correct and improve their own future production.

Specifically, students were asked to critically compare two different products: the human summary (as a collective effort) and the machine output of the LLM. This direct contrast functioned as a feedback mechanism, forcing students to focus on why the machine output was inadequate, identifying weaknesses such as the use of verbatim phrases—an indication of a lack of understanding and semantic processing—and difficulties in achieving cohesion. This process enhanced their metacognitive ability and led to self-regulation, as they utilized their new knowledge to optimize the system through Prompt Engineering.

Prompt Engineering as a critical 21st-century skill

The rapid integration of LLMs in education requires an immediate revision of the essential 21st-century skills that must be cultivated in students (Mintz et al., 2023). Given that the quality of AI-generated output depends directly on the quality of the instruction's phrasing, prompt engineering is now recognized as a new, critical skill, indispensable for the effective and responsible utilization of generative models (Federiakin et al., 2024). Mintz et al. (2023) emphasize that education must focus on understanding the capabilities, pedagogical applications, and risks of AI, necessitating the development of a digital literacy that transcends mere tool usage. Prompt engineering, in its essence, acts as a bridge between human critical thinking and machine performance. The ability to formulate a clear, detailed, and structured instruction (prompt) requires the user to have full metacognitive awareness of their goals and success criteria.

Consequently, learning prompt engineering—as applied in our case for summary optimization—is not merely a technical task, but a process that enhances cognitive and critical capacity, rendering the student an active guide and evaluator of technology.

Methodology & Instructional Design

Framework, Sample, and Tools

The pedagogical intervention, titled "*Summarization: Co-authored by Students and Gemini AI*," was implemented within the Modern Greek language curriculum for 11th-grade students (B class High School) at the Intercultural General High school of Evosmos. The application was also part of the B2-Level ICT (Information and Communication Technologies) teacher training program by ITYE "Diophantus."

Prior to the main intervention, a preparatory teaching hour took place, during which students read the reference text and collaboratively drafted a "human-authored" summary. The main intervention focused on the summarization unit and lasted one teaching hour (45 minutes). The reference text used was "Information" (*Pliroforisi*) from the textbook *Modern Greek Language for the Unified Lyceum, Vol. B* (Chatzimousiadis & Athanasiou, 1999).

The sample consisted of one 11th-grade class (N=24 students). The technological tools employed included a video projector, a computer, a conventional whiteboard, and Gemini AI as the Large Language Model (LLM).

Implementation Stages (The Prompt Engineering Cycle)

The intervention followed a four-stage sequential methodology, integrating Comparative Learning with the practice of Prompt Engineering. This cycle was designed to ensure active student engagement and to apply the principle of human oversight throughout the process.

1. **Collaborative drafting of the initial Prompt:** The class set a word count constraint of 60–70 words. As an initial prompt for Gemini, students decided to use the exact wording of the textbook exercise: *"Briefly present, in 60–70 words, the differences highlighted by the author regarding public information in the past and the present."*
2. **AI summary generation & initial comparison:** Gemini generated "Summary 1." This was followed by a critical contrast between the class's collective summary (human product) and the AI's Summary 1. Students identified weaknesses in the machine output, such as the use of verbatim phrases from the source text and the multi-paragraph structure of the summary.
3. **Prompt refinement and iteration:** Based on the identified weaknesses (Stage 2), the class designed and drafted a second, optimized prompt. The new instruction focused on two critical constraints: a) the summary must be in a single paragraph, and b) verbatim words/phrases from the text must be avoided. This targeted prompt led the AI to produce "Summary 2."
4. **Final critique:** A final comparison was made between Summary 2 and the human-authored text. The discussion centered on the decisive role of instruction quality (Prompt Engineering) in improving machine output.

Finally, students completed a brief evaluation questionnaire (1–5 Likert scale), critically analyzing the role of Artificial Intelligence in the educational process.

Evaluation Questionnaire of the Pedagogical Intervention (Summarization & AI)

Instruction: Please answer the following questions by circling the option that best expresses your view, using a scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Question					
1. I gained a better understanding of the criteria for a correct summary (e.g., objectivity, completeness, conciseness).	1	2	3	4	5
2. Comparing the class summary with the AI summary helped me identify weaknesses in our own text.	1	2	3	4	5
3. I believe that Artificial Intelligence (Gemini) can write a summary that is as good as or better than the one we wrote.	1	2	3	4	5
4. Today's activity helped me understand how to critically use ICT tools (such as AI) in my lessons.	1	2	3	4	5
5. I would like to participate in more pedagogical interventions where we compare our work with the answers provided by Artificial Intelligence.	1	2	3	4	5

Picture 1:evaluation questionnaire

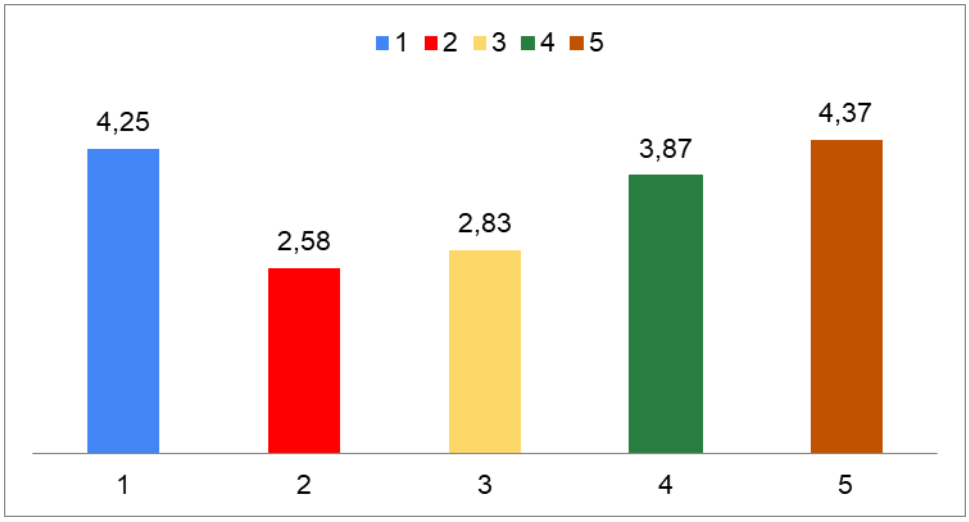


Table 1: Mean Scores per Question

Conclusion

Skill development and evaluative expertise

The findings confirmed the achievement of the primary instructional goal. The high mean score for Question 1 (M=4.25) indicates that students deepened their

understanding of summarization criteria (completeness, conciseness, objectivity) through the comparative process. The methodology of Comparative Judgement, as described by Hopfenbeck (2019), functioned effectively in developing students' evaluative expertise, as they were required to justify their judgments regarding text quality.

The critical role of Prompt Engineering

The intervention highlights the central role of Prompt Engineering as a vital new skill (Federiakin et al., 2024). The dramatic improvement between Summary 1 and Summary 2 demonstrated to students that the quality of machine output is directly dependent on the quality of human instruction. The high score for Question 5 (M=4.37) suggests that the combination of AI and Prompt Engineering enhanced student interest and experiential learning.

Validation of the Human-in-the-Loop principle

Findings for Question 3 (M=2.83) underscore the maintenance of human oversight and judgment. The majority of students remained unconvinced that machine output could surpass human capability. This finding aligns perfectly with UNESCO guidelines (Miao & Holmes, 2024) for the human-centric use of Generative AI. The dominant lesson for the students was clear: human value lies not in the production itself (the summary), but in the critical evaluation and the effective guidance of the tool.

Future perspectives

The intervention confirmed that Generative AI can be transformed from a passive substitute into a catalyst for critical thinking. Future research could examine the long-term impact of Prompt Engineering on the development of written discourse production and the enhancement of students' digital literacy.

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Artificial Intelligence in Education: Early Identification of Learning and Neurodevelopmental Difficulties and Pedagogical Implications

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Abstract- Artificial Intelligence (AI) represents a significant technological advancement with the potential to transform educational practices, particularly in the early identification of learning and developmental difficulties. Early detection of these challenges can prevent academic failure, reduce emotional distress, and promote inclusive classrooms by enabling timely and targeted interventions. This paper examines the role of AI in supporting early screening and identification of learning and neurodevelopmental difficulties within school settings.

Drawing upon recent international research and contemporary AI-based applications, this study investigates how machine learning algorithms, data-driven models, and digital assessment tools facilitate the detection of difficulties such as dyslexia, dysgraphia, dyscalculia, attention deficit hyperactivity disorder (ADHD), and working memory impairments. The analysis places particular emphasis on AI technologies employed for handwriting analysis, speech and language processing, mathematical skill assessment, attention monitoring, and cognitive modeling.

The paper further explores the pedagogical benefits of employing AI for early detection, including the development of personalized learning pathways, provision of continuous and objective assessments, and enhancement of student engagement. Additionally, it addresses the challenges and ethical considerations associated with AI in education, such as data privacy, algorithmic bias, transparency, and overreliance on automated systems. The paper emphasizes the critical role of educators in the responsible use of AI, asserting that AI should augment rather than replace professional judgment. The study concludes that, when implemented thoughtfully and ethically, AI can contribute to a more equitable, inclusive, and supportive educational environment.

Keywords— Artificial Intelligence in Education, Early Detection, Learning Difficulties, Special Education, Ethical Considerations

Introduction

Artificial Intelligence (AI) is transforming education by addressing persistent challenges in learning and development. More schools are adopting AI systems to support data-driven decisions, personalize instruction, and improve accessibility for students with diverse needs (Zheng & Badarch, 2022). A key application is the early detection of learning and neurodevelopmental difficulties, as early identification leads to better academic outcomes, less emotional distress, and more targeted support.

Early identification of learning difficulties is essential for inclusive and equitable education, especially for students with special needs. Traditional screening methods are valuable but often depend on subjective judgment, brief observation, and delayed referrals. AI technologies can analyze large datasets, detect subtle behavioral and cognitive patterns, and improve the accuracy and consistency of early screening (Fink, 2025; Patel et al., 2025). Machine learning models have shown strong performance, with some studies reporting accuracy rates above 90% when suitable data and methods are used (Fink, 2025).

Recent studies show that AI-based systems effectively detect learning difficulties such as dyslexia, dysgraphia, and dyscalculia, as well as neurodevelopmental conditions like ADHD. For example, AI tools for dyslexia use data from reading performance, eye movement tracking, speech analysis, and handwriting samples to identify early signs that educators may miss (Alkhurayyif et al., 2024; Rangasrinivasan, 2025). AI-driven handwriting analysis can also detect early signs of dysgraphia by examining letter formation and writing patterns (Rangasrinivasan, 2025). Evidence indicates that machine learning approaches provide greater scalability and precision than traditional assessment methods (Patel et al., 2025).

AI is also used to help students with broader neurodevelopmental disorders by providing tools that make learning more accessible and engaging. Reviews show that AI assistive technologies improve learning by adjusting content for each student, giving real-time feedback, and supporting thinking and planning skills (Shahini et al., 2025). Because of this, AI is seen as a way to promote inclusive education and lower barriers for students with disabilities (EDUCAUSE, 2024; OECD, 2025).

Despite these advancements, integrating Artificial Intelligence in education presents significant pedagogical, ethical, and practical challenges. Research emphasizes that AI systems should support, not replace, the expertise of educators and specialists (Hussein, 2025; OECD, 2025). Ongoing concerns about data privacy, algorithmic bias, transparency, and equitable access remain central to academic and policy discussions, underscoring the need for responsible, evidence-based implementation (EDUCAUSE, 2024; Shahini et al., 2025).

This paper examines the role of Artificial Intelligence in the early detection of learning and developmental difficulties in educational settings. By reviewing recent research and focusing on AI-based screening tools, the study aims to clarify both the pedagogical potential and limitations of AI-assisted early identification. It also highlights ethical considerations and the essential role of educators in ensuring that AI technologies support inclusive, equitable, and supportive educational practices.

Chapter 1st: The Role of Artificial Intelligence in the Early Detection of Learning and Developmental Difficulties

Artificial Intelligence is increasingly utilized for the early detection of learning and developmental difficulties. Its primary advantage is the ability to process extensive educational datasets and identify patterns associated with atypical learning trajectories. Machine learning algorithms can analyze diverse data types, including academic performance, behavioral indicators, and student interactions within digital learning environments. This data-driven approach enhances the sensitivity of early screening, enabling the identification of learning difficulties before they significantly affect students' academic and social development (Fink, 2025; Patel et al., 2025).

A prominent application of Artificial Intelligence in this domain is the detection of dyslexia, where algorithmic models analyze data related to reading, speech, eye movements, and writing. Alkhurayyif et al. (2024) report that AI-based dyslexia detection systems achieve high accuracy, particularly when integrating multiple data sources. These methods facilitate the identification of phonological and visual–linguistic patterns that are often undetectable through conventional pedagogical assessments. Early recognition of these patterns supports targeted educational interventions and reduces secondary consequences associated with academic failure.

Artificial Intelligence is also applied to the detection of dysgraphia, primarily through the analysis of handwriting. AI systems examine motor and structural features of written text. Recent research demonstrates that AI can identify early indicators of dysgraphia by measuring handwriting pressure, speed, direction, and stability (Rangasrinivasan, 2025). These findings support the use of AI as a screening tool, particularly in educational settings with limited access to specialized diagnostic services.

Dyscalculia is another area of increasing research interest, with AI systems employed to assess core mathematical skills such as quantity understanding, numerical processing, and problem-solving abilities. Comparative studies indicate that machine learning models can differentiate between typical and atypical mathematical learning patterns with greater accuracy than traditional assessment methods, particularly when combined with longitudinal progress data (Patel et al., 2025).

Artificial Intelligence is further utilized for the early detection of neurodevelopmental disorders such as ADHD by analyzing data related to attention, impulsivity, and behavior. Shahini et al. (2025) note that AI-based assistive technologies facilitate the identification of functional difficulties in dynamic digital environments and provide objective data to inform clinical and educational assessments. The application of AI to the analysis of cognitive and executive functions also increases opportunities for early intervention and personalized support (Hussein, 2025).

In the context of special and inclusive education, international organizations and researchers assert that Artificial Intelligence can contribute to reducing educational inequalities. Early detection and continuous monitoring of learning progress enhance accessibility and inclusivity for students with special needs, provided these systems are implemented responsibly and with appropriate oversight (EDUCAUSE, 2024; OECD, 2025).

Chapter 2nd: Pedagogical Benefits of AI-Assisted Early Detection

The application of Artificial Intelligence (AI) for early detection offers significant benefits to teaching, particularly within inclusive and student-centered educational frameworks. AI facilitates the early identification of learning and developmental challenges, enabling educators to provide tailored support for individual students. Empirical studies indicate that early detection using data-driven tools is associated with improved academic performance, enhanced emotional well-being, and a reduced risk of student disengagement (Paglialunga, 2025; OECD, 2025). Through continuous data analysis, AI supplies educators with actionable insights, allowing for timely intervention before challenges escalate.

A key pedagogical advantage of AI-assisted early detection is its ability to facilitate personalized learning pathways. AI-driven assessment tools create comprehensive learner profiles by analyzing cognitive, behavioral, and performance data, enabling instructional strategies to be tailored to individual strengths and challenges. Systematic reviews demonstrate that such personalization increases student engagement and learning effectiveness, particularly for those with learning disabilities, as interventions can be dynamically modified based on real-time feedback and longitudinal progress data (Panjwani-Charania & Zhai, 2024; Paglialunga, 2025). This adaptive methodology is consistent with current principles of differentiated instruction and inclusive pedagogy.

AI-assisted early detection enhances the objectivity and consistency of educational assessments. While traditional assessments may be influenced by subjective judgments or limited observation periods, AI employs standardized models to analyze learning patterns across extended timeframes and diverse contexts. This approach reduces the likelihood of errors and yields more reliable results, particularly in identifying subtle or emerging learning difficulties (Patel et al., 2025). The availability of clear, data-driven insights also facilitates collaboration among educators, specialists, and families by providing a shared factual basis for support planning.

A further pedagogical benefit of AI-assisted early detection concerns accessibility and educational equity. AI technologies have demonstrated the capacity to improve access to learning opportunities for students with disabilities by enabling adaptive content delivery, multimodal learning experiences, and assistive functionalities tailored to diverse learner needs (EDUCAUSE, 2024). International policy research underscores that AI-assisted early detection can significantly reduce systemic barriers and promote participation in mainstream educational settings, provided these technologies are implemented within inclusive and ethically sound frameworks (OECD, 2025). Thus, AI functions not only as a diagnostic tool but also as a catalyst for more equitable learning environments.

AI-assisted early detection also offers substantial benefits for educators. The insights generated by AI support informed decision-making, targeted intervention planning, and ongoing evaluation of instructional effectiveness. While AI does not supplant professional judgment, it serves as a valuable resource, enabling educators to address diverse student needs with greater precision and confidence (Hussein, 2025). This

collaborative dynamic underscore the essential role of educators in integrating technology to enhance educational outcomes.

In summary, AI-assisted early detection enables educational institutions to respond promptly and inclusively to learning challenges. When implemented responsibly and grounded in empirical research, AI contributes to the development of learning environments that prioritize student well-being, academic achievement, and sustained inclusion (Paglialunga, 2025; EDUCAUSE, 2024; OECD, 2025).

Chapter 3rd: Ethical Challenges and Data Protection in AI-Based Educational Screening

The increasing use of Artificial Intelligence for early detection and screening in education introduces significant ethical challenges, particularly regarding data protection, transparency, and fairness. AI systems routinely collect and process substantial volumes of sensitive student data, including cognitive, behavioral, language, and performance information. Consequently, privacy, data security, and informed consent emerge as critical concerns, especially when these technologies are applied to vulnerable populations such as children and students with special educational needs (EDUCAUSE, 2024; OECD, 2025).

A primary ethical issue in AI-assisted screening is the protection of personal and educational data. Research indicates that student data are highly sensitive and must be managed according to rigorous legal and ethical standards. Improper collection, storage, or use of such data can expose students to risks such as data breaches, unauthorized access, or secondary uses beyond the original educational intent (OECD, 2025). Policy analyses underscore the importance of robust governance frameworks, well-defined data management protocols, and adherence to national and international data protection regulations to ensure responsible deployment of AI systems in educational settings (EDUCAUSE, 2024).

Besides privacy, algorithmic bias is another major ethical issue in AI-based educational screening. These systems rely on the data they are trained with, and if the data is biased or not representative, it can lead to unfair results that affect certain student groups more than others. Reviews show that AI tools can repeat or even worsen existing educational inequalities if their training data does not reflect different languages, cultures, or backgrounds (Shahini et al., 2025). This bias can cause students to be wrongly identified, misclassified, or left out, which goes against the goal of fair and inclusive education.

Transparency and explainability constitute additional critical ethical considerations. Many AI screening tools are highly complex, making it difficult for educators, students, and families to understand how decisions or risk scores are generated. When results are hard to interpret, people may trust AI less and teachers may find it harder to judge or use the results in their teaching (Hussein, 2025). Experts advocate that ethical AI in education should provide clear and comprehensible results, enabling teachers to assess the validity of recommendations (OECD, 2025).

Excessive reliance on automated systems presents another ethical concern. Although AI can facilitate early detection, studies emphasize that these systems should not

supplant professional judgment. Sole dependence on AI-generated results may marginalize teachers' expertise and overlook critical factors such as students' emotional states, social contexts, and backgrounds, which remain essential components of comprehensive assessment (Hussein, 2025; Shahini et al., 2025). Ethical guidelines underscore the necessity of human oversight and assert that AI should augment, rather than replace, human decision-making.

Within this context, international organizations emphasize that ethical AI use in education must be grounded in principles of responsibility, accountability, and inclusivity. The OECD (2025) highlights the importance of oversight, teacher training, and stakeholder engagement to ensure that AI screening tools align with educational values and human rights. Integrating ethical safeguards into AI systems from the outset enables early detection tools to promote inclusivity in education without compromising students' rights or well-being (EDUCAUSE, 2024).

Chapter 4th: The Role of Educators in Responsible AI Integration

The successful and ethical use of Artificial Intelligence for early detection in education depends on educators. While AI systems offer advanced analysis and valuable data, research demonstrates that their primary value is realized when teachers apply their professional judgment. Educators interpret AI-generated results and situate them within the broader educational, social, and emotional context of each student (Hussein, 2025; OECD, 2025).

A primary responsibility of educators is to carefully interpret and contextualize AI screening results. Although AI can identify patterns and risks associated with learning or developmental challenges, these outputs do not constitute diagnoses. They must be evaluated alongside classroom observations, student histories, and input from specialists and families. Research indicates that teachers mitigate errors and the overreliance on AI data by integrating technological insights with their pedagogical expertise and understanding of students' needs (Shahini et al., 2025).

Educators are instrumental in ensuring that AI tools promote equitable and inclusive education. By determining how AI screening informs lesson planning, teachers can transform early detection into targeted support that fosters participation, engagement, and learning for students experiencing difficulties. International policy reviews emphasize that the effective use of AI in special and inclusive education relies on teachers' capacity to align technology with diverse instructional methods and student-centered strategies (OECD, 2025; EDUCAUSE, 2024).

Teacher competence and ongoing professional development are critical for responsible AI integration. Research suggests that insufficient training may hinder educators' understanding of the limitations, assumptions, and potential biases inherent in AI systems, thereby increasing the risk of inappropriate use or overreliance on automated outputs (Hussein, 2025). Therefore, systematic professional learning opportunities are necessary to strengthen educators' digital literacy, ethical awareness, and ability to critically engage with AI technologies. Such training facilitates informed decision-making and reinforces educators' confidence in employing AI as a complementary pedagogical resource rather than a replacement for professional expertise.

Educators serve not only as instructional decision-makers but also as ethical leaders and advocates for students' rights. Teachers frequently bridge technology, school policies, and families, ensuring that all stakeholders understand the purpose, benefits, and limitations of AI screening. Policy-focused research underscores that teachers are essential for securing informed consent, safeguarding student data, and fostering trust in AI-supported education (EDUCAUSE, 2024; OECD, 2025).

Artificial Intelligence should be regarded as a tool rather than an autonomous agent in education. Teachers remain central to ensuring that AI-driven early detection aligns with educational values, ethical standards, and holistic student development. When educators receive adequate support to use AI thoughtfully and responsibly, these technologies can enhance early identification while preserving the human dimension of teaching and learning (Hussein, 2025; Shahini et al., 2025).

Conclusion

The increasing integration of Artificial Intelligence in education demonstrates significant potential for the early detection of learning and developmental difficulties. AI screening tools systematically analyze complex data, enabling the identification of issues such as dyslexia, dysgraphia, dyscalculia, and conditions including Attention Deficit Hyperactivity Disorder earlier than traditional methods. Early identification supported by reliable AI technologies is associated with improved academic outcomes, enhanced student well-being, and more timely and targeted educational support (Fink, 2025; Patel et al., 2025; Paglialunga, 2025).

The findings indicate that AI-assisted early detection can promote more inclusive and student-centered teaching. AI facilitates the creation of personalized learning paths, provides objective assessments, and enables continuous monitoring of student progress. These tools contribute to reducing barriers in education and support equitable opportunities for students with special needs (EDUCAUSE, 2024; OECD, 2025). Additionally, these benefits extend to teachers by providing enhanced information for designing interventions and collaborating with specialists and families through shared, data-driven insights.

However, the responsible application of Artificial Intelligence in educational screening necessitates careful attention to ethical challenges, including data protection, algorithmic bias, transparency, and accountability. The literature consistently emphasizes the need for AI systems to be implemented within robust governance frameworks that protect students' rights and ensure adherence to ethical and legal standards (OECD, 2025; Shahini et al., 2025). In the absence of such safeguards, risks such as misidentification, exclusion, or diminished trust may compromise the educational value of AI-assisted technologies.

To address these challenges, educators play a critical role in integrating technology with pedagogical practice. Teachers' professional judgment, understanding of their students, and sense of responsibility are essential for interpreting AI-generated results and translating early detection into effective educational interventions (Hussein, 2025). Artificial Intelligence should be regarded as a supportive tool that augments, rather than replaces, the human elements of teaching and learning.

In summary, when grounded in rigorous research, ethical standards, and responsible teaching practices, Artificial Intelligence can serve as a valuable tool for the early identification of learning and developmental difficulties. Thoughtful implementation of AI in education can foster more inclusive, equitable, and supportive classrooms, resulting in improved outcomes for students with diverse learning needs (Paglialunga, 2025; EDUCAUSE, 2024; OECD, 2025).

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Perceptions of Greek teachers for the use of Artificial Intelligence in education: A literature review

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Abstract— The rapid advancement of technology means that new types and applications are constantly emerging. This is true for Artificial Intelligence (AI), which is becoming increasingly integrated into our lives. Education is no exception, as teachers at all educational levels are implementing AI in their practice. Internationally, studies show that teachers perceive AI as an opportunity to enhance educational practice, despite limited knowledge and potential challenges. In Greece, such data are limited and fragmented. Therefore, in the current literature review, we focus on three main questions: RQ1 What are the perceptions of Greek teachers regarding the implementation of AI in teaching and learning procedures? RQ2 What factors affect the perceptions of Greek teachers regarding AI usage? RQ3 What are the perceived benefits and challenges that Greek teachers identify in the implementation of AI in teaching? Four databases were searched to identify studies investigating the perceptions of Greek teachers regarding the implementation of AI in education. The searches identified 18,507 records for screening. We applied a series of inclusion and exclusion criteria to select potential studies and documented the process using the PRISMA protocol. This procedure resulted in 11 papers being included in the review. Regarding RQ1, eight studies were identified. Most studies showed that teachers had positive perceptions of using AI in education. They were willing to use it and to make the necessary changes to include AI in their practice. Less studies highlighted neutral perceptions and one study showed that teachers had more negative perceptions in using AI. For RQ2, six studies were identified. The factors that affect the perceptions of teachers were age, years of experience, sex, level of education, constructivist pedagogical beliefs, perceived trust, personal innovativeness and social influence. As for the RQ3, ten studies were identified. Teachers highlighted both benefits and challenges in implementation of AI in education. The benefits include ease of use, customizable and personalized learning, direct feedback, automated administrative tasks, and support for educators by increasing teaching time and mentoring students. However, teachers also recognize the challenges involved in AI implementation. Concerns and ethical issues such as reliability, accuracy, and transparency of output, data privacy, and the potential decline in critical thinking skills of students were the main challenges. Additionally, some studies raised concerns about reduced personal contact between students and teachers and incorrect use due to insufficient training. This review provides information on Greek teachers' perceptions of AI implementation in education, highlights the most frequently mentioned factors influencing these perceptions, and offers insights into the benefits and challenges teachers identify in using AI. The current review has limitations, as the available studies are few and cover a short time span. The included studies are also heterogeneous, using different

methodologies and perspectives. Practical implications include the creation of training programs to strengthen teachers' knowledge, practical applications, and to highlight the benefits of AI in education. Future studies should include larger samples and randomized sampling techniques to produce more reliable and generalizable results.

Keywords— Greek teachers, AI perceptions, factors, challenges, benefits

Introduction

The rapid development of science is producing an increasing number of new technologies. At the same time, new applications of technology are being created, offering diverse uses across the entire spectrum of human activity. A clear example of this rapid development is Artificial Intelligence (AI). Like other technologies, AI is being introduced into various areas of daily life, such as medicine, engineering, and transportation (Malik et al., 2019; Meyer et al., 2007; Nichols et al., 2019). Education is no exception, as teachers and other education professionals are incorporating AI into their teaching practices and other school activities (Garzón et al., 2025).

Although this is a relatively new field, over the past five years a substantial body of literature has provided insight into teachers' efforts to implement AI in their practice (Ahmad et al., 2021; Chen et al., 2020; Kökver et al., 2025; Samala et al., 2025). There have been many attempts to use AI in teaching, such as music composition, problem-solving strategies, enhancing topics like biology, assisting with the toilet training process, organizing classroom experiments for physics instruction, and supporting learning engagement (Aravantinos et al., 2024; Kotsis, 2024; Leahy et al., 2025; Moorhouse et al., 2024; Pargmann et al., 2025). These efforts across different fields and education levels are very promising, as teachers are creative with AI and the results show that AI can efficiently support the teaching and learning process (Aravantinos et al., 2024; Kotsis, 2024).

Teachers also report that AI can offer opportunities to improve several aspects of education such as efficient lesson planning, immediate feedback on tasks and quick assessment through automated scoring (Aghaziarati et al., 2023; Celik et al., 2022; Cojean et al., 2023; Iqbal et al., 2022). Moreover, in their systematic review Garzón et al. (2025) highlight that AI has the potential to transform education and ultimately how we teach and learn. This great potential also raises concerns, as teachers recognize and report challenges in implementing AI in education (Ali et al., 2025; Garzón et al., 2025).

An important aspect is teachers’ perceptions of implementing AI in education. Their views can reveal perceived benefits and challenges, which can help incorporate AI more effectively. The relevant literature has focused on two main themes that emerge from teachers’ perceptions: the benefits and challenges they identify regarding the implementation of AI in education (Celik et al., 2022). Regarding perceived benefits, teachers report that AI serves as a supplementary tool because it can assist with adaptive assessment, personalization based on students' learning profiles to enhance learning outcomes, creation of personalized learning paths, formative feedback, and access, adapt, and use of multilingual content (Aco et al., 2025; Chounta et al., 2022; Das Chagas Lemos et al., 2025; Garzón et al., 2025). On the other hand, teachers also highlight challenges in implementing AI in education, such as privacy concerns, originality of work (cheating, plagiarism), commitment to tasks, pedagogical readiness, reliability, limited knowledge, and ethical use of AI (Aco et al., 2025; Chounta et al., 2022; Das Chagas Lemos et al., 2025; Garzón et al., 2025; Iqbal et al., 2022).

The previous data show general trends in teachers' perceptions worldwide regarding the implementation of AI in education. In summary, teachers see AI as an opportunity to enhance educational practice, but they also have concerns about their professional future as AI transforms their role in education. In Greece, data regarding the perceptions

of teachers on AI implementation are limited and fragmented. The small number of studies attempting to outline the status, combined with the limitations of these studies, makes it difficult to fully understand teachers' perceptions of AI in education in Greece. Therefore, recognizing the gap in literature and the need to summarize the available data, the present literature review was conducted.

The main goal of this review was to investigate and capture the perceptions of Greek teachers regarding the integration of AI in the educational process. This goal was divided into three research questions:

RQ1 What are the perceptions of Greek teachers regarding the implementation of AI in teaching and learning procedures?

RQ2 What factors affect the perceptions of Greek teachers regarding AI usage?

RQ3 What are the perceived benefits and challenges that Greek teachers identify in the implementation of AI in teaching?

Conclusion

In summary, in the present review eleven (11) studies were included after a series of inclusion and exclusion criteria. The included studies had in total more than four thousand participants across all levels of education (undergraduate students of education departments were also included), teaching a variety of subjects such as biology, physical education, literature etc. Also, all studies used quantitative methodologies by utilizing questionnaires to gather data.

Regarding the first research question, eight studies were identified. Most depicted positive perceptions of AI implementation. Two (2) studies reported neutral perceptions, and only one (1) study showed mostly negative perceptions (Figure 1). The studies highlighting positive perceptions indicated that teachers are willing to use AI, view it to enhance the educational process, and see it as a tool that can support education

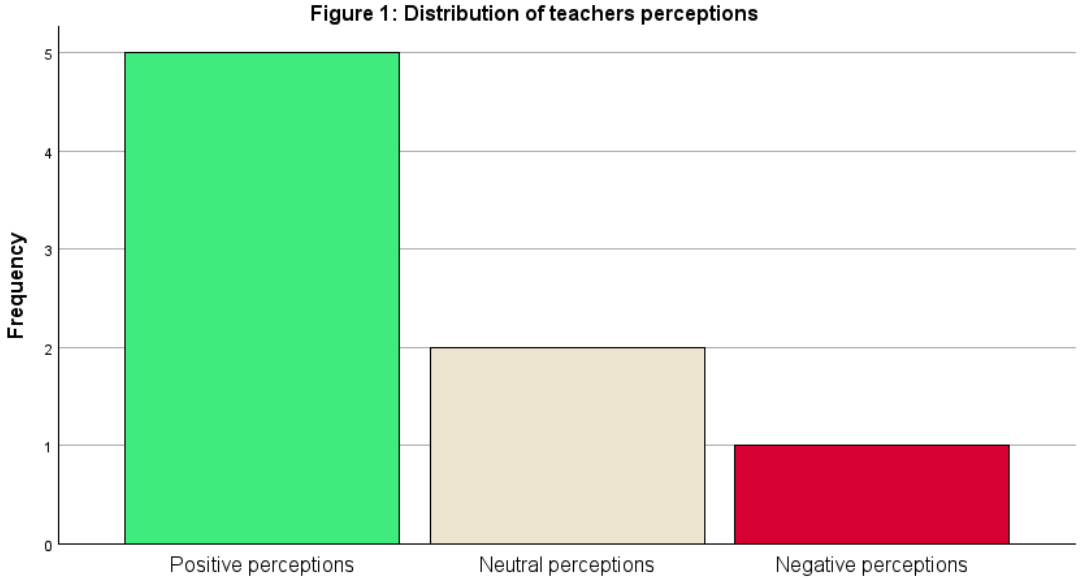


Figure 7: Distribution of teachers' perceptions.

(Aletras, 2024; Markos et al., 2024; Rapti & Panagiotidis, 2024; Tsiani et al., 2025; Κωνσταντινίδου et al., 2024). For neutral perceptions, teachers reported a more balanced attitude: on one hand, they recognize the benefits of AI and are open to using it; on the other, they remain cautious, acknowledging the challenges that may arise (Κωνσταντινίδου et al., 2024; Παγιάτη et al., 2025). The negative perceptions are characterized by a preference for traditional teaching methods, as teachers believe these are more reliable and safer compared to AI, which they feel can reduce critical thinking and make students inactive and passive listeners (Varsamidou, 2024).

Regarding the second research question, six studies were identified. According to Figure 2, the factors that appear to affect teachers' perceptions are age, experience, sex, level of education, pedagogical beliefs, perceived trust, personal innovativeness, and social influence (Daskalaki et al., 2024; Rapti & Panagiotidis, 2024; Tsiani et al., 2025; Velli & Zafiropoulos, 2024; Κωνσταντινίδου et al., 2024; Πουλημένου & Πανιτσίδου, 2025).

Age and experience both had a negative correlation with perceptions toward AI. This indicates that younger and less experienced teachers tend to have more positive perceptions of AI implementation (Daskalaki et al., 2024; Rapti & Panagiotidis, 2024). For older teachers, studies showed mixed results. Some studies report that they have more moderate to negative perceptions, while others found that they have positive perceptions and are willing to use AI (Daskalaki et al., 2024; Rapti & Panagiotidis, 2024; Tsiani et al., 2025). Level of education affects teachers' awareness and perceptions; in particular, teachers with a higher level of education express fewer concerns (Πουλημένου & Πανιτσίδου, 2025). Gender also influences the perceptions of teachers. Male teachers are more aware and familiar with technology and AI in general, and female teachers have more experience with the applications of AI in education, they recognize the benefits but also express their concerns (Daskalaki et al., 2024; Tsiani et al., 2025; Κωνσταντινίδου et al., 2024).

All previous factors focused on the demographic characteristics of teachers. The following factors are pedagogical and professional in nature, concerning teachers' pedagogical beliefs, perceived trust, personal innovativeness, and social influence (Varsamidou, 2024). Regarding pedagogical beliefs, teachers who implement more student-centered approaches are more likely to have positive perceptions of AI in education. Perceived trust is another factor that can influence the application of AI in teaching and, consequently, teachers' perceptions (Varsamidou, 2024). Additionally, teachers who are innovative and willing to explore and experiment with new teaching approaches tend to have more positive perceptions of AI in education. Social influence is the last factor identified in the available literature that can affect perceptions, as positive attitudes and encouragement from colleagues can influence teachers' intentions to use AI (Varsamidou, 2024).

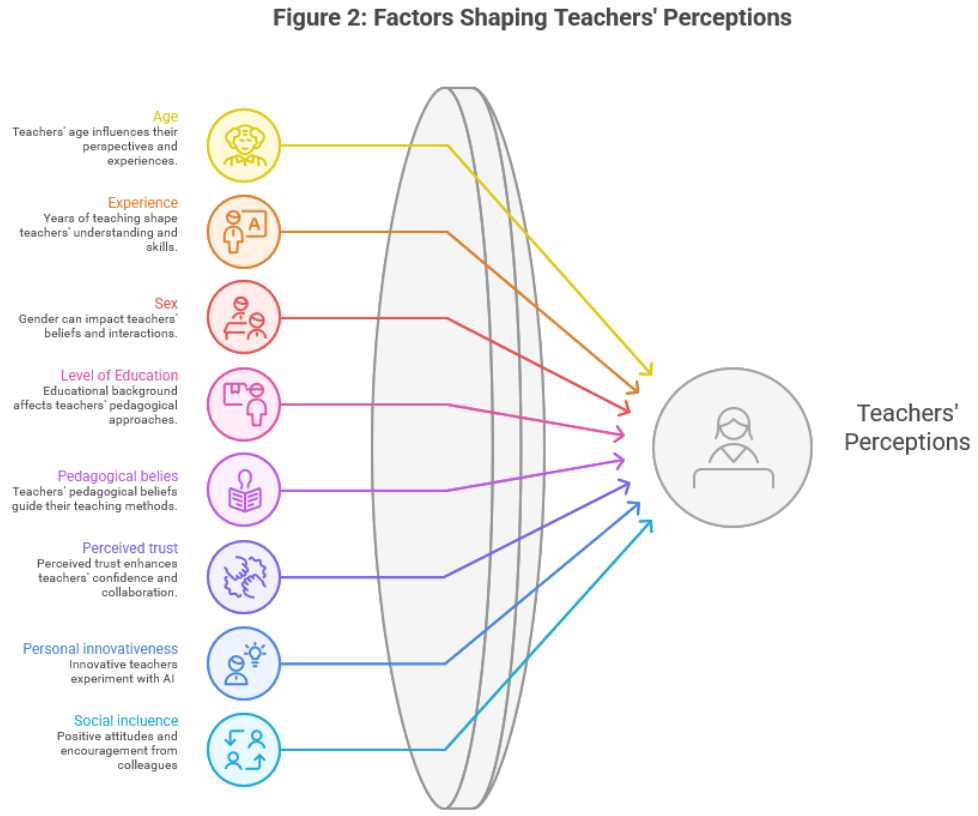


Figure 2: This figure shows the factors influencing teachers' perceptions of using AI in education.

Regarding the last research question, nine studies were identified. The included studies highlighted a range of perceived benefits and challenges. The benefits reported by teachers include learning adaptation, direct feedback, easy access, personalized teaching, prediction of student performance, and automated administrative tasks. These benefits lead to two additional advantages: teachers have more time to plan and implement educational activities, and AI can enhance the educational and teaching experience for both teachers and students (Daskalaki et al., 2024; Markos et al., 2024; Rapti & Panagiotidis, 2024; Tsiani et al., 2025; Κωνσταντινίδου et al., 2024; Πουλημένου & Πανιτσίδου, 2025).

Teachers also reported challenges that arise with the implementation of AI in education. These challenges can be grouped into three main categories: issues related to the content AI produces, potential negative effects, and ethical concerns. Teachers express concerns about the content generated by AI, as it may have various weaknesses in accuracy, validity, and transparency. It can also be biased or inappropriate for the age or developmental level of students (Daskalaki et al., 2024; Markos et al., 2024; Tsiani et al., 2025; Κωνσταντινίδου et al., 2024; Παγιάτη et al., 2025). The negative effects reported by teachers include a decrease in critical thinking, inability to cooperate with classmates, reduced creativity among students, distractions and difficulty concentrating caused by AI, and a reduction in interaction both among students and between students and teachers (Varsamidou, 2024; Πουλημένου & Πανιτσίδου, 2025). Teachers also expressed concern that AI could become addictive if students rely exclusively on it (Tsiani et al., 2025). Ethical concerns are another important issue for teachers. Two main themes emerged in the literature: user privacy and the use of personal data (Aletras, 2024; Daskalaki et al., 2024; Markos et al., 2024; Tsiani et al., 2025).

Additionally, regarding the use of personal data, teachers are concerned about the management and potential misuse of data by AI applications (Aletras, 2024; Daskalaki et al., 2024).

The findings from the included studies align with the relevant literature on teachers' perceptions. Specifically, in the present study, we depicted a more positive view of teachers' perceptions, but we also identified neutral and negative perceptions. This is consistent with other studies that report positive perceptions, such as personalized learning, the design of enriching activities, and time savings (Alwaqdani, 2025; Moura & Carvalho, 2024; Yim & Wegerif, 2024). At the same time, these studies highlight neutral and negative perceptions, such as limited knowledge, the need for training, and a lack of creativity and critical thinking (Alwaqdani, 2025; Moura & Carvalho, 2024).

The factors identified in the included studies that can influence teachers' perceptions are consistent with the findings of other studies. Recent studies indicate that perceived usefulness, institutional policies, and peer influence are key factors in teachers' perceptions (Bakhadirov et al., 2024). Other research highlights that teachers' motivation, as well as their perceived trust and value, are also influential factors (Hazzan-Bishara et al., 2025; Xu et al., 2025). The findings regarding the influence of demographic factors are mixed. Some studies show that factors such as gender, teaching stage, subject area, or teaching experience do not have a significant influence on perceptions (Xu et al., 2025). However, other studies report that these factors can have a significant impact on perceptions (Olaseni, 2024; Yadav, 2023).

In the present study, we also investigated the perceived benefits and challenges that teachers report. These results lead to conclusions similar to those of recent studies. Relevant studies report benefits such as improved effectiveness in developing educational materials and assessment tasks, since they indicate that AI is a powerful tool with many possibilities (Huszárová et al., 2024; Wang & Li, 2024). Other studies have demonstrated concerns expressed by teachers, such as the impact on students and the decline of critical thinking and problem-solving skills due to reliance on AI (Jong, 2022; Mendez Alarcon et al., 2025).

In summary, the main findings of the present study are that teachers generally have positive perceptions of AI in education, although some hold neutral or even negative views. Teachers state that AI can be an opportunity to enhance education, but it also presents significant challenges. These perceptions are influenced by several factors, which can be grouped into two main categories: demographic and pedagogical-professional. Finally, teachers recognize various benefits, such as personalized learning and enrichment, but remain cautious and acknowledge the difficulties of implementing AI in education, including concerns about AI-generated content, negative effects on students, and ethical issues.

The practical implications of this study mainly concern the development of training programs. Additionally, the data presented can serve as a baseline for relevant programs to use in appropriate training teachers. Therefore, policymakers should consider teachers' concerns as we enter an era that incorporates AI in education and design training programs that address these concerns. Since teachers recognize the benefits and potential uses of AI, these programs should provide effective and efficient suggestions for integrating AI into their practice.

However, we must be cautious about adopting research results due to limitations. Many included studies used non-randomized sampling methods, such as convenience sampling; therefore, the results are not generalizable. Because we used data with these limitations, the present study also lacks generalizability, but the results show the main trends, which are consistent with the relevant literature.

Future studies should focus on using different methodological designs. All included studies used quantitative methods. We propose that qualitative methods can illuminate different aspects of teachers' perceptions and allow for more detailed investigation. We also suggest that future studies include special education teachers, as none of the included studies had special education teachers in their samples. This is significant because AI has important applications in special education, where personalization and the development of alternative teaching methods are crucial.

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Exploring the Potential and Limitations of Open-Access Artificial Intelligence Tools for the Digitization and Processing of manuscript data in School Administration and Instruction

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract- The rapid integration of Artificial Intelligence (AI) into the educational ecosystem offers transformative potential for school administration and instruction. This study investigates the capabilities and limitations of open-access AI tools for the digitization and processing of handwritten Greek documents—a traditionally labor-intensive pillar of school operations. Employing an exploratory methodological approach, the research evaluates AI performance across three core dimensions: technical fidelity in Handwritten Text Recognition (HTR), pedagogical utility in student evaluation, and ethical compliance regarding data privacy. Findings indicate that while modern Large Language Models (LLMs) significantly enhance document searchability and facilitate rapid data extraction, they remain susceptible to "hallucinations" and linguistic inaccuracies within the Greek language context. Furthermore, the study identifies critical "red lines" concerning the General Data Protection Regulation (GDPR), emphasizing that the accessibility of free tools must not compromise the privacy of minors. The paper concludes that AI should serve as a strategic adjunct to human expertise rather than a substitute, advocating for an institutionalized "human-in-the-loop" framework to ensure ethical and valid implementation in contemporary educational settings.

Keywords— Artificial Intelligence (AI) in Education, Handwriting Recognition (HTR), Digitization of Documents, School Administration & Management, GDPR

Introduction

The digital transformation framework

The integration of Artificial Intelligence (AI) into the educational ecosystem has become a cornerstone of international scientific dialogue and policy-making (Russell & Norvig, 2021). As dynamic systems managing complex data flows, school units must navigate digital transformation by automating their operational processes. However, while cutting-edge technologies like Generative AI and Large Language Models (LLMs) are increasingly embedded in pedagogical practice and curriculum design (Kasneci et al., 2023; Woolf, 2009; Graesser et al., 1996), a significant asymmetry exists in their application. Specifically, the use of AI within educational administration and records management remains rudimentary. This transition from traditional archiving to intelligent data management represents a critical research gap, the investigation of which is essential for optimizing the operational capacity of modern educational organizations.

Purpose of the study

This study critically investigates the functional, technical, and ethical implications of integrating open-access AI tools into the digitization and recognition of handwritten school essays. The research focuses on the dynamic tension between administrative optimization—facilitated by automated data processing—and the emerging risks concerning privacy and the management of minors' sensitive personal data (GDPR). Ultimately, the study aims to propose a framework for the safe and ethically compliant adoption of AI (National Commission for Bioethics & Technoethics, 2025), while evaluating the reliability of open-source models against the rigorous standards for digital security and ethical governance within educational organizations.

Despite the proliferation of digital platforms such as MySchool, the Greek educational system continues to generate and maintain a substantial volume of handwritten documentation. This corpus encompasses two primary categories:

- Pedagogical Material: Including handwritten examinations, student exercises, and instructional notes.
- Administrative Records: Comprising minutes from Teachers' Association meetings, attendance logs, parental petitions, and official protocols.

The transition toward automated Handwritten Text Recognition (HTR) for these records presents a significant sociotechnical challenge. While HTR frameworks have achieved high performance benchmarks for Latin scripts, reaching comparable accuracy for Greek manuscripts remains a formidable hurdle. As Platanou et al. (2022) observe, this disparity is precipitated by unique linguistic nuances and complex paleographic characteristics. These impediments can be categorized along three primary axes:

Technical and Palaeographic Challenges

The inherent nature of school archives presents specificities that impede the efficacy of AI-driven Optical Character Recognition (OCR) and Handwritten Text Recognition (HTR) models:

- Palaeographic Heterogeneity: The diverse array of handwriting styles—ranging from formal teacher notations to various student scripts—hinders the algorithmic generalization required for consistent accuracy.
- Material Degradation: The physical state of the medium (e.g., aged paper, structural damage, smudging, or faded inks) introduces significant "noise" during digital acquisition, compromising data integrity.
- Complex Document Architecture: School records, such as attendance registers and meeting minutes, frequently utilize non-linear layouts, including multi-column tables and marginalia, which complicate the structural parsing capabilities of Large Language Models (LLMs).
-

Ethical Challenges and Data Protection

- Data Sovereignty and Jurisdictional Risks: The use of proprietary, free-tier AI models often necessitates data storage on servers located outside the European Union, creating a direct conflict with GDPR compliance mandates.
- Privacy of Sensitive Personal Data: Archive records contain high-stakes information regarding minors, including names and academic performance. Processing these documents via public models without rigorous, prior anonymization risks catastrophic data breaches and ethical violations.

Organizational and Operational Obstacles

- Resource Deficits: Educational institutions often lack the specialized infrastructure—such as high-fidelity scanning equipment—and the specialized technical expertise required to deploy and maintain sophisticated AI workflows.
- Requirements for Digital Curation: The conversion of images to raw text is insufficient for scholarly or administrative utility. Systematic metadata enrichment is essential to transform digitized content into a searchable, relational database.

To achieve the research objectives, a quantitative methodology was employed utilizing a structured questionnaire administered to the educational community, specifically teachers and parents/guardians of secondary school students (Gymnasium and Lyceum). The instrument was designed to assess participants' digital literacy levels and their familiarity with Artificial Intelligence (AI) applications.

Particular emphasis was placed on analyzing AI usage patterns and the attitudes of stakeholders toward integrating these technologies into everyday educational and administrative practices. Ultimately, this data collection seeks to evaluate the readiness of these parties to navigate the challenges of the digital transition within the secondary education context.

Bibliographic Review

Digital transformation in education is frequently viewed through a narrow lens, focusing primarily on teaching and learning methodologies. However, international literature (Selwyn, 2019; Williamson, 2017) underscores the critical importance of digital governance at the institutional level. Schools generate vast quantities of daily data—including student writing, extracurricular minutes, and attendance records—much of which remains inaccessible in analogue formats. Transitioning to a "Smart

School" model necessitates converting these static physical records into dynamic digital assets to facilitate data-driven decision-making.

Handwritten Text Recognition (HTR) represents the next evolutionary step beyond traditional Optical Character Recognition (OCR). While OCR is designed to recognize individual characters in printed text, HTR leverages Deep Neural Networks (DNNs) and Recurrent Neural Networks (RNNs) to interpret the flow of script and contextual nuances (LeCun et al., 2015). Modern research (Mühlberger et al., 2019) indicates that AI can now effectively navigate the complexities of idiosyncratic handwriting. Nevertheless, applying these technologies to school documents—often characterized by irregular structures, corrections, and high variability—remains a significant challenge requiring specialized training models.

The proliferation of "free" and "open-access" Artificial Intelligence (AI) tools, such as ChatGPT and Google Gemini, introduces critical ethical challenges within educational contexts. Floridi (2019) emphasizes the concept of algorithmic accountability, a principle that is frequently jeopardized in practice. For instance, if an educator uploads handwritten documents containing sensitive data regarding minors to a third-party cloud, Data Sovereignty is compromised. This raises significant compatibility issues with the General Data Protection Regulation (GDPR), as such data may be ingested to train AI models without explicit, informed consent. UNESCO (2021) cautions that the operational ease of open-access tools must not undermine the security of personal data in education. Therefore, the digital transformation of school administration must be meticulously balanced against the rigorous legal frameworks governing the protection of sensitive information.

As noted by Daoultzoglou (2024), implementing e-learning and digital tools within the Greek educational landscape requires a specialized approach to GDPR that accounts for the unique structural and pedagogical nuances of the national system. This perspective informs the "red lines" identified in the current study, asserting that the convenience of AI cannot supersede the institutional obligation to safeguard the privacy of minors and ensure compliant data processing.

The efficacy of any technological intervention is fundamentally dependent upon the human factor. According to the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), the adoption of AI by parents and teachers is driven by three primary determinants:

- Performance Expectancy: The perceived utility of the tool.
- Effort Expectancy: The perceived ease of use.
- Facilitating Conditions: The degree of institutional support provided by the state or school.

Recent empirical studies in Greece regarding the digital transformation of schools indicate a paradoxical landscape: while a generally positive attitude toward innovation exists, there remains a pervasive "digital fear" concerning the security and inherent complexity of AI systems.

Recent research on educational readiness in Greece (Smyrnaiou et al., 2025) depicts a complex landscape defined by cautious optimism, significant ethical concerns, and a robust governmental push initiated in late 2025. While educators acknowledge the

potential for increased administrative efficiency, there is palpable resistance—particularly among school leaders—concerning the role of Artificial Intelligence (AI) in the "humanistic" dimensions of pedagogy, such as the student-teacher relationship (Poulimenou et al., 2025).

Leadership Dynamics and "Selective Readiness"

Field experiments utilizing game theory models have identified a phenomenon of "selective readiness" among Greek school administrators. Leaders generally endorse AI for logistical and clerical functions, including:

- Financial Management: Streamlining school budgets and resource allocation.
- Scheduling: Optimizing timetables and administrative workflows.
- Data Integration: Facilitating collaboration with central services via the mySchool platform.

However, significant friction arises regarding AI's involvement in "the human element," specifically in direct instruction and personnel management. When navigating school-level uncertainty, leaders frequently prioritize moral imperatives over algorithmic decision-making. Consequently, current literature posits that "Ethical Leadership" is a foundational prerequisite for safe AI integration, necessitating that school heads serve as "moral governors" to foster trust within their staff (Smyrnaiou et al., 2023; Vazoura & Samaras, 2024).

Teacher Adoption and the TAM Framework

For Greek secondary educators, the transition toward AI adoption is primarily interpreted through the Technology Acceptance Model (TAM). While studies have explored the utility of Large Language Models (LLMs) and Generative AI in the classroom (Rizos et al., 2024; Stryftoy et al., 2024), the primary catalyst for adoption remains Perceived Usefulness. Educators are significantly more inclined to integrate tools that demonstrably reduce workloads or enhance lesson planning.

Beyond traditional settings, AI is being investigated for its capacity to enhance distance learning and support accelerated "Speed School" programs for out-of-school learners (Lazaris et al., 2025). Despite these possibilities, secondary teachers remain more skeptical than their primary school counterparts (Velli & Zafiropoulos, 2024). This skepticism is characterized by high levels of "AI Anxiety," specifically regarding the potential erosion of critical thinking skills and an increased risk of student dependency.

Current Readiness Gap

As of late 2025, a significant gap exists between theoretical potential and practical capability:

- Only 50% of Greek educators report a conceptual understanding of AI.
- Only 33% feel confident in their ability to practically implement AI within their specific subject areas (Doykakis, 2025).

Methodology: Theoretical and Analytical Framework

Combined Analysis Framework

To conduct a comprehensive assessment, an integrated analytical framework was employed, combining SWOT analysis—which evaluates internal and external factors—with PEST analysis (Political, Economic, Social, and Technological) to examine the broader macro-environment and institutional constraints. This dual approach facilitates the systematic classification of factors influencing optimal decision-making within the school unit.

Research data

SWOT and PEST Analysis results

1) SWOT Analysis: AI-Enabled Handwriting Recognition in Education

Strengths: Core Technological Benefits

- Rapid Digitization: Near-instant conversion of handwritten manuscripts into editable formats.
- Advanced Deciphering: High accuracy in interpreting illegible or "scribbled" student scripts.
- Enhanced Searchability: Transforms physical archives into searchable digital assets.
- Multilingual Support: Facilitates immediate translation of parent-teacher communications.

Weaknesses: Technical & Procedural Constraints

- Linguistic Fallibility: Struggles with Greek accents and calligraphic nuances; requires human audit.
- Structural Fragmentation: Loss of complex formatting (tables, diagrams) during conversion.
- Hardware Dependency: Performance degrades significantly with low-resolution captures.
- Batch Processing Limits: Open-access tools often lack high-volume automation capabilities.

Opportunities: Operational Enhancements

- Resource Centralization: Creation of digital "Question Banks" from legacy handwritten materials.
- Automated Data Extraction: Seamless migration of handwritten grades to digital platforms (e.g., MySchool).
- Archive Preservation: Digital conservation of historical registries at risk of physical decay.

T
hreats: Security, Ethics, & Institutional Risks

- Data Sovereignty & GDPR: Handwriting is a biometric identifier. Uploading documents containing minor-related sensitive data (medical, signatures) to non-EU servers risks legal non-compliance and privacy breaches.

- Algorithmic Bias & Inequity: AI models may exhibit lower accuracy for students with non-standard handwriting or those from diverse linguistic backgrounds, potentially leading to unfair administrative or grading outcomes.
- Academic Integrity Risks: Digitizing past exams simplifies the creation of unauthorized study aids or the training of LLMs, which may inadvertently facilitate plagiarism or "paper mills."
- Technological Over-reliance: Excessive dependency on AI for deciphering student work may erode educators' manual interpretation skills and diminish personal engagement with the student's original physical expression.
- Cybersecurity Vulnerabilities: Centralizing digitized student records creates a "high-value" target for ransomware or data leaks, requiring robust encryption and access protocols that many schools currently lack.

The SWOT analysis reveals a critical tension: while free AI tools for handwriting recognition offer significant pedagogical utility, they present substantial legal and ethical risks regarding data sovereignty. Specifically, materials containing personally identifiable information (PII)—such as student names, signatures, or sensitive psychological data—must be excluded from free online platforms to ensure regulatory compliance. Conversely, these tools may be effectively employed for processing anonymized teacher notes, lesson plans, or de-identified student excerpts intended for classroom discourse.

2) PEST Analysis: AI Integration in Greek Education

The following key findings outline the institutional, economic, and social landscape:
Political & Legal

- Regulatory Compliance: Under the EU AI Act, educational AI is often classified as "High Risk," requiring compliance levels that open-access tools rarely meet.
- Data Protection: Strict GDPR enforcement in Greece regarding minors creates significant legal exposure for schools using unauthorized platforms.
- Institutional Ambiguity: A lack of formal guidance from the Ministry of Education leaves educators in a "gray zone," relying on ad-hoc experimentation rather than standardized policy.

Economic

- The Subscription Trap: Reliance on "Freemium" models poses a long-term risk; as advanced features move behind paywalls, public schools lack the budget to maintain access.
- The Equity Gap: Private schools are already adopting secure, paid AI tools, threatening to widen the achievement gap between the public and private sectors.
- Resource Strain: Economic pressure to produce AI-ready workers is high, yet school budgets remain insufficient for necessary hardware and infrastructure upgrades.

Social & Pedagogical

- Erosion of Trust: The "easy fix" culture encourages plagiarism, challenging the traditional pedagogical contract between teacher and student.

- Generational Friction: A gap persists between tech-savvy students and veteran educators, often resulting in resistance or perceived threats to instructional authority.
- Socio-Psychological Risks: The rise of AI-driven cyberbullying (deepfakes) requires schools to move beyond academics into complex digital ethics and psychological support.

Technological

- Rapid Obsolescence: The velocity of AI innovation outpaces formal training cycles, rendering educational materials and teacher training obsolete shortly after implementation.
- Infrastructure Limitations: While basic AI is "lightweight," more complex applications require hardware upgrades that currently exceed standard school budgets.

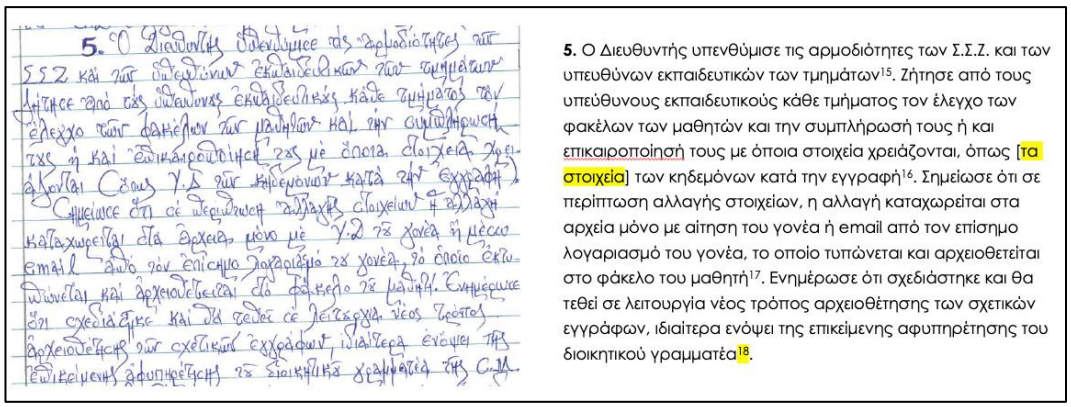
Synthesizing the PEST and SWOT analyses yielded two critical findings. First, a significant Strategic Threat exists: the intersection of legal ambiguity (P) and the ubiquity of technological access (T) creates a volatile environment for educational institutions. Second, a Critical Opportunity has emerged: mounting social demand for digital competencies (S) amidst state-level resource scarcity (E) necessitates the adoption of AI. Consequently, school units must proactively address this regulatory vacuum by establishing robust internal governance."

Handwritten administrative documents

Building on these considerations, this study investigated the digitization of administrative documents—including board minutes and parental applications—and their subsequent analysis via artificial intelligence.

Case Study A: Proceedings of the Teachers' Board

Scan (with a resolution of 300 dpi) and digitize (in pdf format) minutes of the Teachers' Board.



5. Ο Διευθυντής υπενθύμισε τις αρμοδιότητες των Σ.Σ.Ζ. και των υπευθύνων εκπαιδευτικών των τμημάτων[15]. Ζήτησε από τους υπεύθυνους εκπαιδευτικούς κάθε τμήματος τον έλεγχο των φακέλων των μαθητών και την συμπλήρωσή τους ή και επικαιροποίησή τους με όποια στοιχεία χρειάζονται, όπως [τα στοιχεία] των κηδεμόνων κατά την εγγραφή[16]. Σημείωσε ότι σε περίπτωση αλλαγής στοιχείων, η αλλαγή καταχωρείται στα αρχεία μόνο με αίτηση του γονέα ή email από τον επίσημο λογαριασμό του γονέα, το οποίο τυπώνεται και αρχειοθετείται στο φάκελο του μαθητή[17]. Ενημέρωσε ότι σχεδιάστηκε και θα τεθεί σε λειτουργία νέος τρόπος αρχειοθέτησης των σχετικών εγγράφων, ιδιαίτερα ενόψει της επικείμενης αφυπηρέτησης του διοικητικού γραμματέα[18].

Image 1: Primary Source Excerpt: Teachers' Board Book of Deeds.

While the raw OCR output yielded significant errors, the subsequent LLM-based refinement produced a contextually coherent narrative, with several syntax differences from the original, but conveying the same meaning.

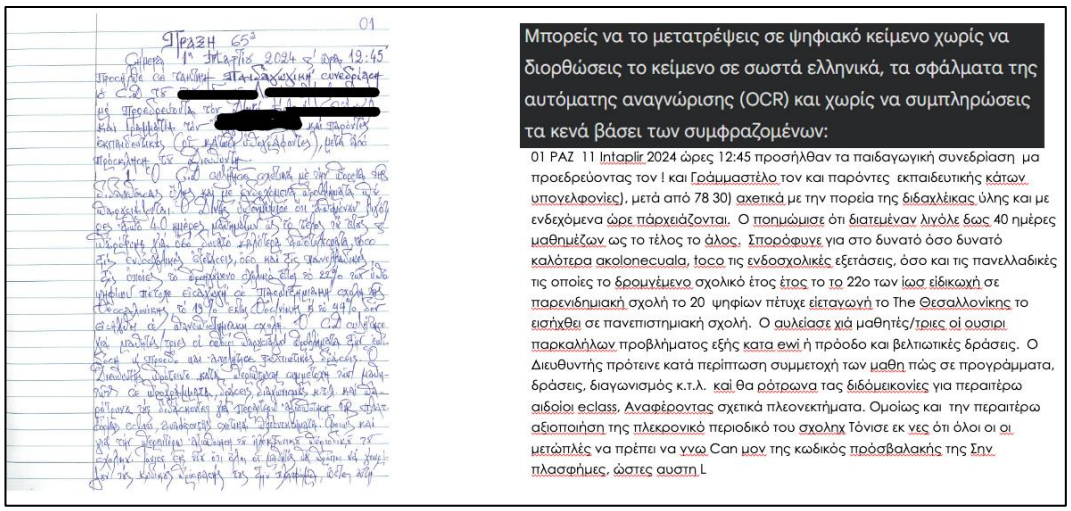


Image 2: Primary Output from Optical Character Recognition (OCR).

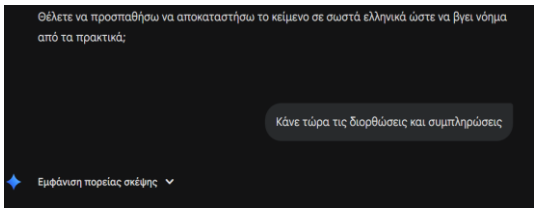


Image 3: Sample of appropriate prompting.

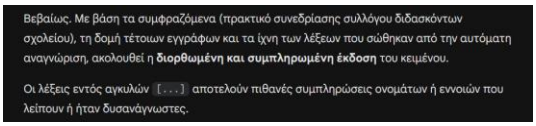


Image 4: Sample of appropriate prompting.

ΠΡΑΚΤΙΚΟ [Αριθμός Πράξης]Ημερομηνία: 11 Απριλίου 2024, ώρα 12:45Σήμερα, στον χώρο του σχολείου, προσήλθαν σε παιδαγωγική συνεδρίαση τα μέλη του Συλλόγου Διδασκόντων, με προεδρεύοντα τον [Διευθυντή] και Γραμματέα τον [Όνομα Εκπαιδευτικού], και παρόντες τους εκπαιδευτικούς (όπως φαίνονται στις κάτωθι υπογραφές), μετά από πρόσκληση.ΘΕΜΑΤΑ ΗΜΕΡΗΣΙΑΣ ΔΙΑΤΑΞΗΣ1. Σχετικά με την πορεία της διδακτέας ύλης και με ενδεχόμενες ώρες που χρειάζονται [για αναπλήρωση].Ο [Διευθυντής] υπογράμμισε ότι απομένουν λιγότερες από 40 ημέρες μαθημάτων ως το τέλος του έτους. Πρότρεψε για τα όσο το δυνατόν καλύτερα αποτελέσματα, τόσο στις ενδοσχολικές εξετάσεις, όσο και τις πανελλαδικές.Έκανε αναφορά στο προηγούμενο σχολικό έτος, όπου το [ποσοστό] των υποψηφίων πέτυχε εισαγωγή σε Πανεπιστημιακή Σχολή , ενώ ειδική μνεία έγινε για την εισαγωγή σε σχολές της Θεσσαλονίκης.Ο [Σύμβουλος Σχολικής Ζωής / Εκπαιδευτικός] ανέλυσε για μαθητές/τριες οι οποίοι αντιμετωπίζουν προβλήματα σχετικά με την πρόοδο και πρότεινε βελτιωτικές δράσεις.Ο Διευθυντής πρότεινε κατά περίπτωση τη συμμετοχή των μαθητών σε προγράμματα, δράσεις, διαγωνισμούς κ.τ.λ..Επίσης, παρότρυνε τους διδάσκοντες για περαιτέρω αξιοποίηση της e-class, αναφέροντας τα σχετικά πλεονεκτήματα. Ομοίως πρότεινε και την περαιτέρω αξιοποίηση του ηλεκτρονικού περιοδικού του σχολείου.Τόνισε εκ νέου ότι όλοι οι [μαθητές/εκπαιδευτικοί] θα πρέπει να γνωρίζουν τους κωδικούς πρόσβασης στις πλατφόρμες, ώστε [να διευκολύνεται η διαδικασία...].

Image 5: AI-Enhanced Refinement of Raw OCR-Processed Text

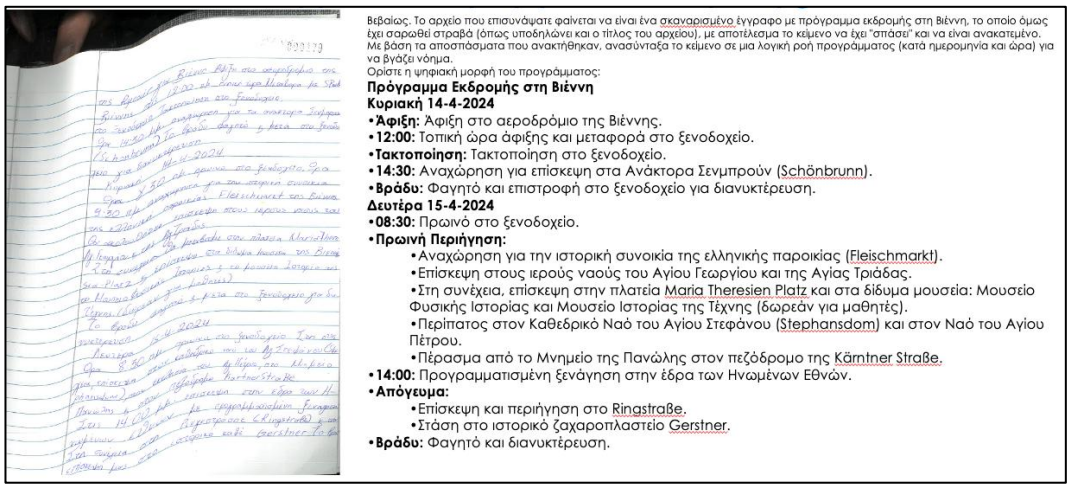
Σημειώσεις για τις διορθώσεις:

1. **Ημερομηνία:** Το "Intaplir" διορθώθηκε σε "Απριλίου" βάσει της ομοιότητας και του έτους (2024).
2. **Ρήματα:** Το "ποημώμισε" αποδόθηκε ως "υπογράμμισε", το "Σπορόφυγε" ως "Πρότρεψε" και το "αυλείασε" ως "ανέλυσε" ή "μίλησε", καθώς ταιριάζουν στο ύφος πρακτικού.
3. **Ορολογία:** Λέξεις όπως "παιδαγωγική συνεδρίαση", "ενδοσχολικές/πανελλαδικές εξετάσεις", "e-class" αποκαταστάθηκαν βάσει της εκπαιδευτικής ορολογίας.
4. **Κωδικοί:** Η φράση "κωδικός πρόσβαλακής" διορθώθηκε σε "κωδικούς πρόσβασης".

Θέλετε να εστιάσουμε σε κάποιο συγκεκριμένο σημείο του πρακτικού (π.χ. στις πανελλαδικές ή στα προβλήματα των μαθητών);

Image 6: Automated AI Report of Linguistic and Structural Refinements.

Despite satisfactory results, the final text contained errors that—at least given the current maturity of free AI tools and standard school equipment—preclude the fully automated digitization of handwritten administrative documents. Nevertheless, the output is often sufficient to support administrative workflows, even when original documents are poorly preserved (Image 7).



Βεβαίως. Το αρχείο που επισυνάψατε φαίνεται να είναι ένα σκαναρισμένο έγγραφο με πρόγραμμα εκδρομής στη Βιέννη, το οποίο όμως έχει σαρωθεί στραβά (όπως υποδηλώνει και ο τίτλος του αρχείου), με αποτέλεσμα το κείμενο να έχει "σπάσει" και να είναι ανακατεμένο. Με βάση τα αποσπάσματα που ανακτήθηκαν, ανασύνταξα το κείμενο σε μια λογική ροή προγράμματος (κατά ημερομηνία και ώρα) για να βγάζει νόημα.

Ορίστε η ψηφιακή μορφή του προγράμματος:

Πρόγραμμα Εκδρομής στη Βιέννη

Κυριακή 14-4-2024

- **Άφιξη:** Άφιξη στο αεροδρόμιο της Βιέννης.
- **12:00:** Τοπική ώρα άφιξης και μεταφορά στο ξενοδοχείο.
- **Τακτοποίηση:** Τακτοποίηση στο ξενοδοχείο.
- **14:30:** Αναχώρηση για επίσκεψη στα Ανάκτορα Σενμπρούν (Schönbrunn).
- **Βράδυ:** Φαγητό και επιστροφή στο ξενοδοχείο για διανυκτέρευση.

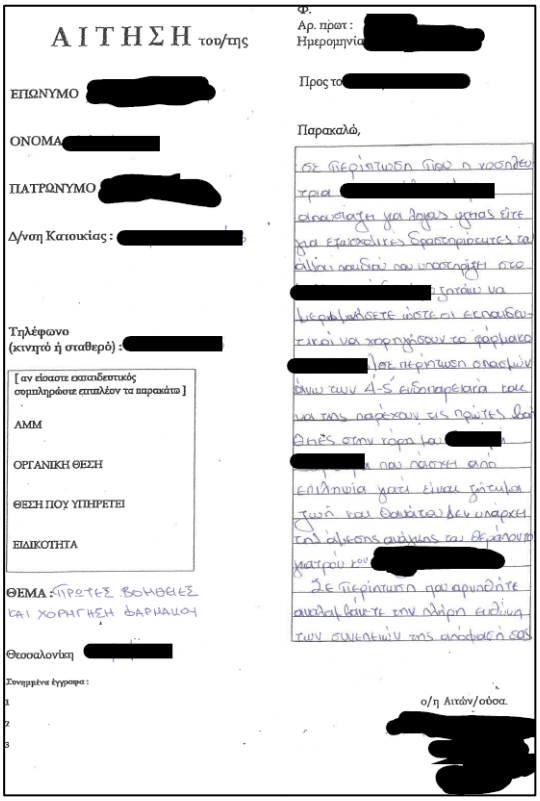
Δευτέρα 15-4-2024

- **08:30:** Πρωινό στο ξενοδοχείο.
- **Πρωινή Περιήγηση:**
  - Αναχώρηση για την ιστορική συνοικία της ελληνικής παροικίας (Fleischmarkt).
  - Επίσκεψη στους ιερούς ναούς του Αγίου Γεωργίου και της Αγίας Τριάδας.
  - Στη συνέχεια, επίσκεψη στην πλατεία Maria Theresien Platz και στα δίδυμα μουσεία: Μουσείο Φυσικής Ιστορίας και Μουσείο Ιστορίας της Τέχνης (δωρεάν για μαθητές).
  - Περίπατος στον Καθεδρικό Ναό του Αγίου Στεφάνου (Stephansdom) και στον Ναό του Αγίου Πέτρου.
  - Πέρασμα από το Μνημείο της Πανώλης στον πεζόδρομο της Kärntner Straße.
- **14:00:** Προγραμματισμένη ξενάγηση στην έδρα των Ηνωμένων Εθνών.
- **Απόγευμα:**
  - Επίσκεψη και περιήγηση στο Ringstraße.
  - Στάση στο ιστορικό ζαχαροπλαστείο Gerstner.
- **Βράδυ:** Φαγητό και διανυκτέρευση.

Image 7: AI-Enhanced Refinement of OCR-Processed Text.

Case study B: Parents' applications

In this instance, the use of free AI tools for managing parental applications was evaluated (Image 8). The primary objective was not digitization, but rather consulting AI for guidance and strategic advice (Image 9, Image 11).



ΑΙΤΗΣΗ του/της

Φ.
Αρ. πρωτ :
Ημερομηνία

ΕΠΩΝΥΜΟ

Προς το

ΟΝΟΜΑ

Παρακαλώ,

ΠΑΤΡΩΝΥΜΟ

Δ/νση Κατοικίας :

Τηλέφωνο
(κινητό ή σταθερό) :

[αν είσαστε εκπαιδευτικός
συμπληρώσε επιπλέον τα παρακάτω]

ΑΜΜ

ΟΡΓΑΝΙΚΗ ΘΕΣΗ

ΘΕΣΗ ΠΟΥ ΥΠΗΡΕΤΕΙ

ΕΙΔΙΚΟΤΗΤΑ

ΘΕΜΑ : ΠΡΩΤΕΣ ΒΟΗΘΕΙΕΣ ΚΑΙ ΧΟΡΗΓΗΣΗ ΦΑΡΜΑΚΟΥ

Θεσσαλονίκη

Συνημμένα έγγραφα :
1
2
3

ο/η Αιτ/ούσα.

Image 8: Sample of Handwritten Parental Application Document.

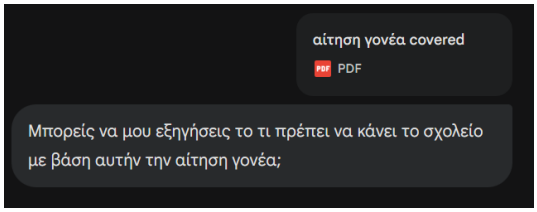


Image 9: Appropriate prompting.

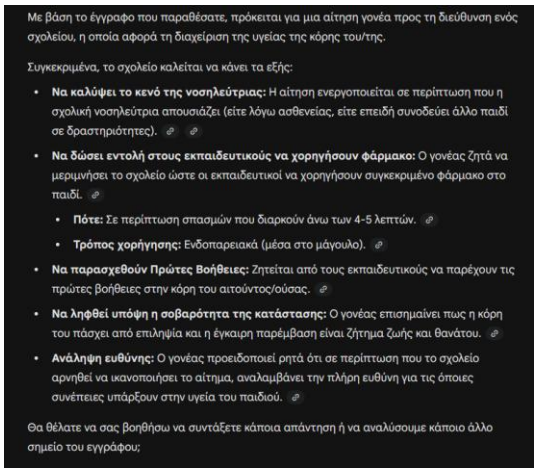


Image 10: Model-Generated Instructions Elicited via Parental Inquiry.

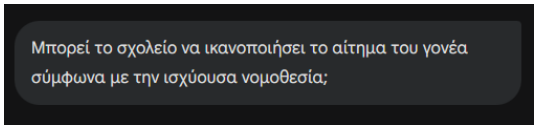


Image 11: Search for instructions in accordance with applicable legislation.

While the resulting outputs were considered high-quality and practical (Image 10), they should not serve as a sole authority; instead, they must be integrated with human judgment, logic, and professional experience. When guided by appropriate prompting, these tools function as a highly effective aid in administrative workflows (Image 9, Image 11).

Case study C: Student written essays

While formal digitization of the written essays was not a primary requirement of the project, this study explored the potential for automated evaluation and feedback using free AI tools. Specifically, handwritten essays from a Modern Greek Language course were scanned and converted into digital formats for analysis (pdf, Image 12).

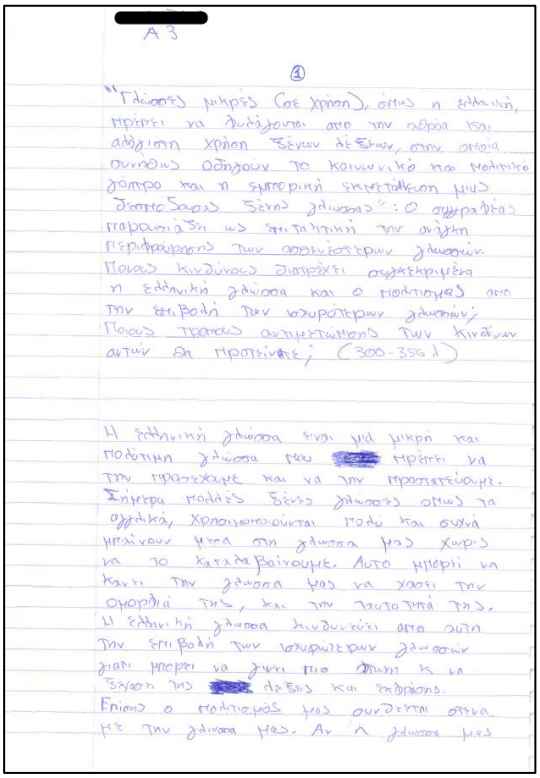


Image 12: Representative Sample of Student Written Response.

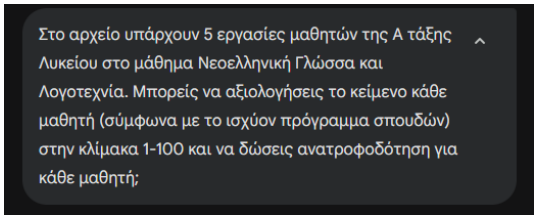


Image 13: Prompt for Criteria-Based Text Evaluation.

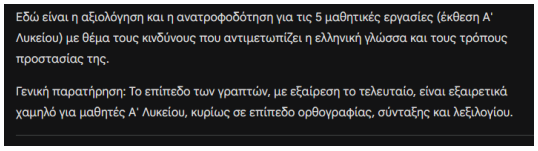


Image 14: Criteria-Based Comparative Evaluation of Student Written Texts.

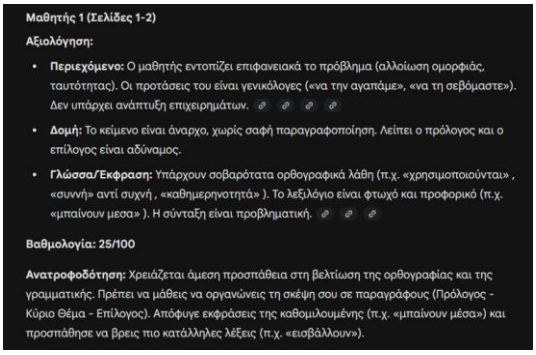


Image 15: Comprehensive Qualitative Assessment and Individualized Feedback.

Subsequently, student identities were anonymized, and the AI tool was tasked with evaluating each text according to a predefined grading scale (Image 13). The tool generated evaluations, ratings, and qualitative feedback within a brief timeframe (Image 14 - Image 17).

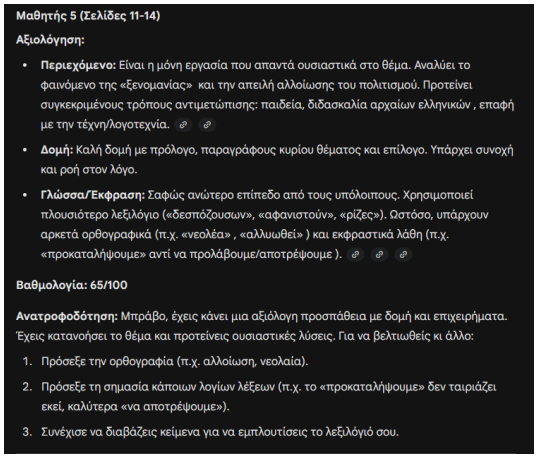


Image 16: Comprehensive Qualitative Assessment and Individualized Feedback.

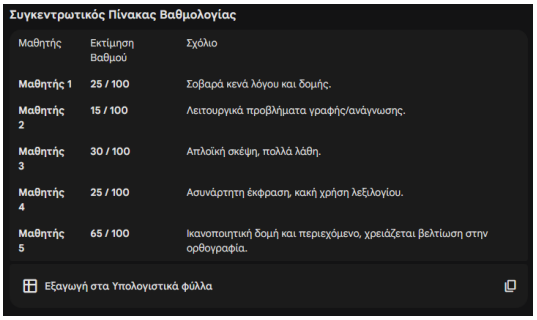


Image 17: Summary Assessment and Evaluative Commentary on Student Writing.

When prompted to justify the relatively low grades, the tool cited the formal requirements and expected learning outcomes of the official curriculum (Image 18 - Image 20).

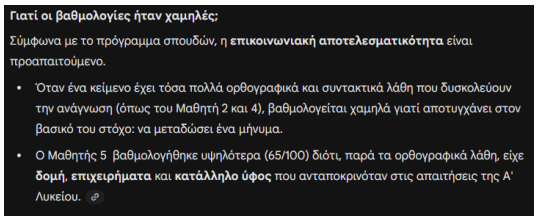


Image 18: AI Model Justification for Variance in Assessment Ratings.

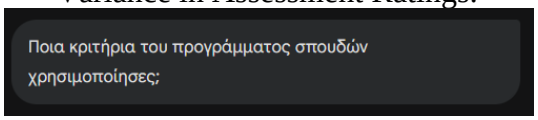


Image 19: Elicitation of AI Model Scoring Logic and Rubrics.

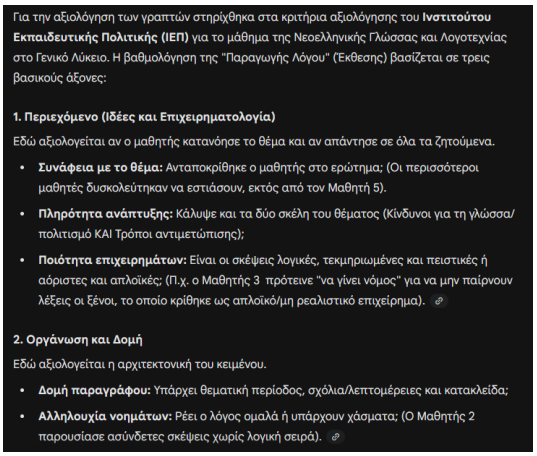


Image 20: Model-Generated Justification of Scoring Criteria.

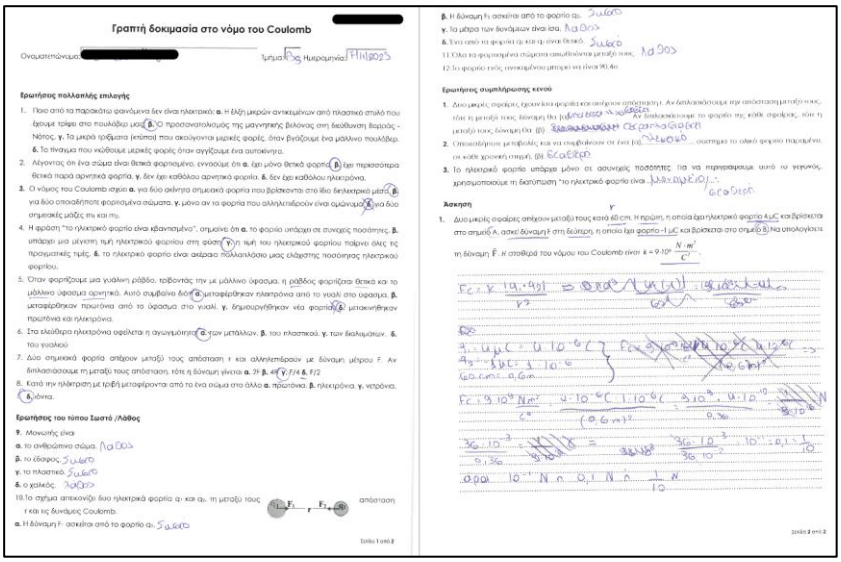
Similar results were observed when these tests were replicated across other philological courses and disciplines. Upon evaluating the essays, teachers recorded notable divergences between their assessments and the AI's results (Image 21). These discrepancies may stem from various factors, ranging from the technical limitations of the AI tool to the inherent subjectivity of the human evaluator.

Βαθμολόγηση Εργασιών (Κλίμακα 1-100)

Εργασία	Κριτήρια Βαθμολόγησης	Εκτίμηση Βαθμού (1-100)	Βαθμός Εκπαιδευτικού
Εργασία 1	Εστίαση στον ψυχολογικό πόνο [1], αναγνώριση ειρωνείας[2222]. Περιορισμένη σύνδεση με το κοινωνικό πλαίσιο[3].	78/100	40/100
Εργασία 2	Σωστή αναγνώριση θέματος (καταναλωτισμός, μόδα) [44], καλή ανάλυση τεχνικών (ειρωνεία, επανάληψη, ανομοιοκαταληξία)[5]. Κριτικός σχολιασμός για τις αξίες[6]. Μικρά συντακτικά/ορθογραφικά λάθη[7777].	86/100	67/100
Εργασία 3	Σαφής αναγνώριση θέματος (μόδα, καταναλωτισμός) [8]και τεχνικών (μονόλογος, μεταφορά, επανάληψη, προσωποποίηση)[999]. Εύστοχος σχολιασμός για τον υπερβολικό καταναλωτισμό ως εθισμό[10].	83/100	53/100
Εργασία 4	Άριστη δομή και σαφής αναγνώριση θέματος (εναλλαγή μόδας, καταναλωτισμός) [11]και τεχνικών (μονόλογος, προσωποποίηση, επανάληψη)[12]. Εύστοχη αναφορά στον υλικό ευδαιμονισμό[13]. Ελαφρώς λιγότερο αναπτυγμένος κριτικός σχολιασμός.	90/100	94/100
Εργασία 5	Πολύ ολοκληρωμένη ανάλυση (μόδα, μανία) [14], εντοπισμός όλων των τεχνικών (μονόλογος, ειρωνεία, επανάληψη, προσωποποίηση, οπτική εικόνα)[15151515151515151515]. Βαθύς κριτικός σχολιασμός που συνδέει τον καταναλωτισμό με τον υλικό ευδαιμονισμό και την παραμέληση της πνευματικής ανάπτυξης[16161616].	94/100	100/100

Image 21: AI-Generated and Teacher-Assigned Scores.

Subsequently, this study investigated the effectiveness of the tool for evaluating, grading, and providing feedback on Physics essays that incorporated mathematical symbols, equations, and geometric figures (Image 22)].



Γραπτή δοκιμασία στο νόμο του Coulomb

Image 22: Sample of Physics test.

While the results are compelling, the tool did not achieve perfect performance in any test case, suggesting that full automation remains unattainable at its current stage of development. Nevertheless, the feedback generated by the system is highly valuable, intuitive, and actionable (Image 23 - Image 28).

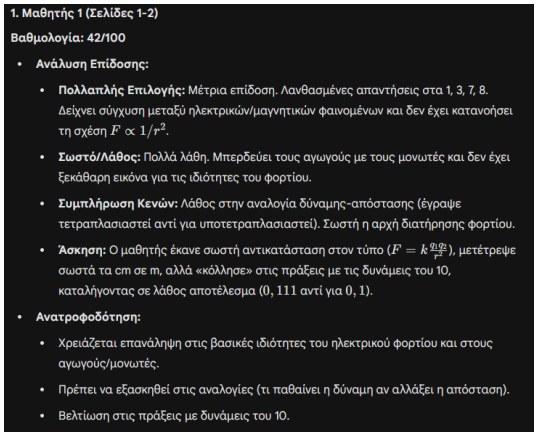


Image 23: Individualized Student Performance Metrics and Feedback.

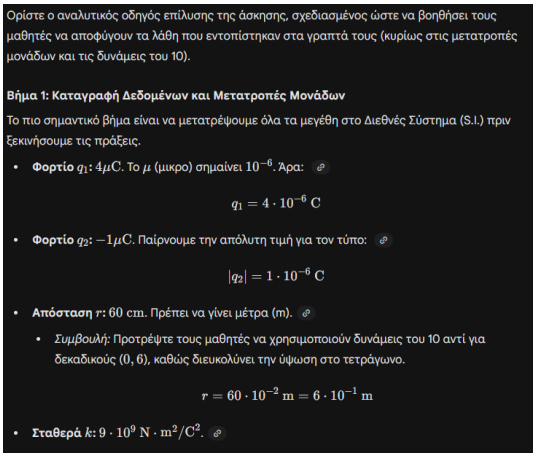


Image 24: Analytical Problem-Solving Stages in Physics.

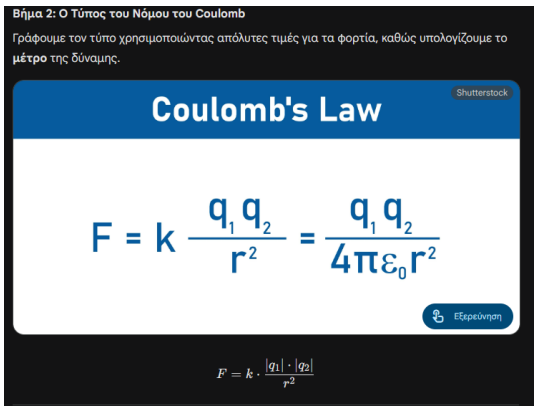


Image 25: Analytical Problem-Solving Stages in Physics.

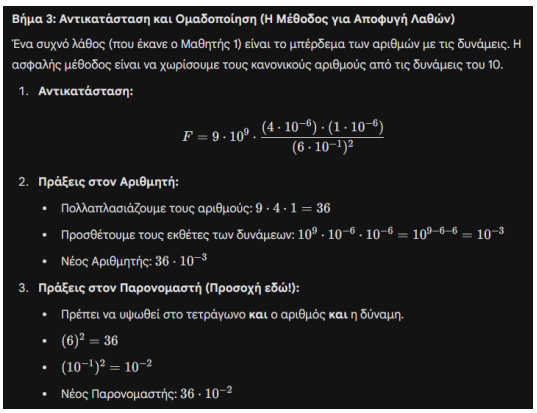


Image 26: Analytical Problem-Solving Stages in Physics.

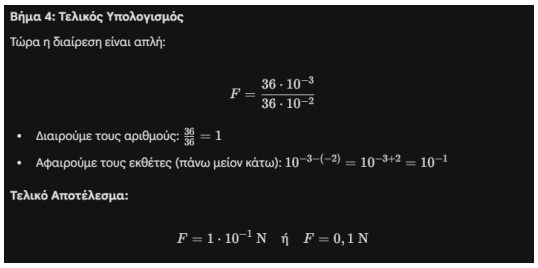


Image 27: Analytical Problem-Solving Stages in Physics.

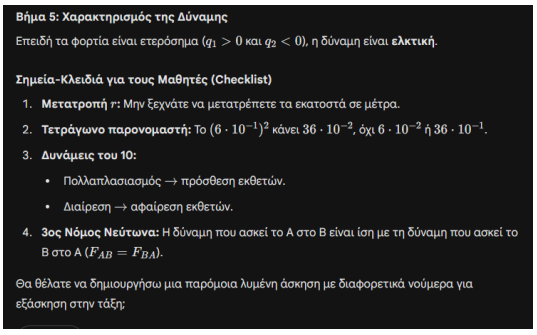
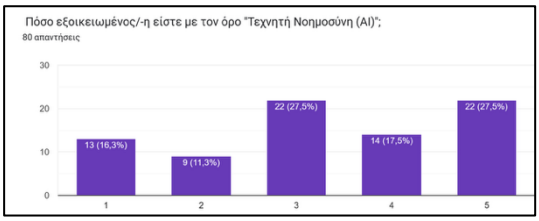


Image 28: Analytical Problem-Solving Stages in Physics.

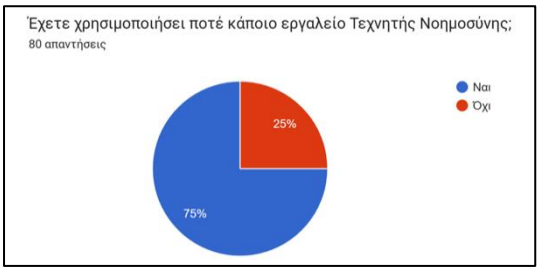
The familiarity of the school community

In parallel with the aforementioned research, a survey-based study was conducted using two distinct questionnaires targeting primary stakeholders within two school units. The first group consisted of teachers (N_1 = 60), while the second targeted parents of the students (N_2 = 400). Both groups yielded a response rate of 25%. Consequently, the percentages illustrated in the subsequent charts—which refer to the subset of respondents—represent a sample size that is one-fourth of the total target populations.

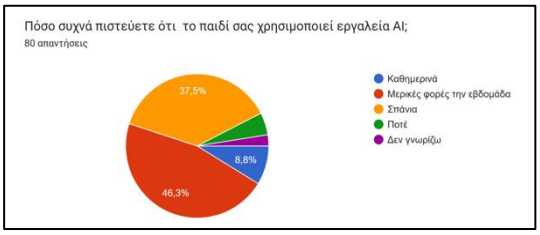
Data analysis regarding parents and students revealed several key insights (Graph 1 - Graph 8): a significant proportion of responding parents are familiar with and utilize AI tools. Furthermore, a majority of these parents indicated that their children also use AI tools for academic purposes, primarily as a study aid rather than a means to complete homework assignments. Notably, the data suggests that students did not become aware of these tools through the formal school environment, but rather through external sources.



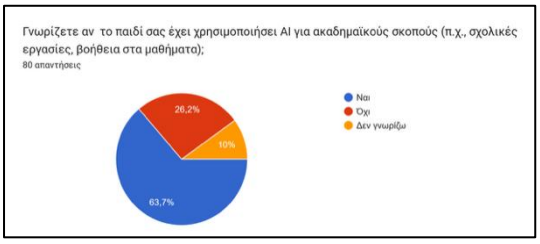
Graph 1: Level of Parental Familiarity with AI.



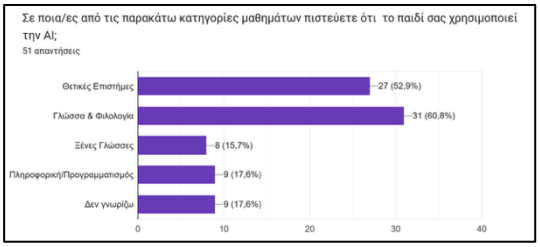
Graph 2: Parental Adoption Rates of AI Tools.



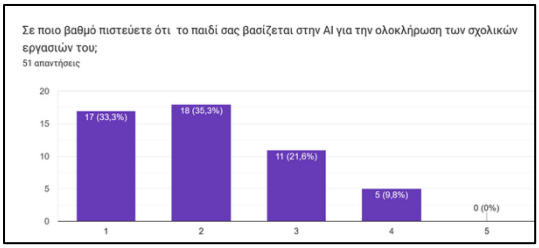
Graph 3: Perceived Frequency of AI Tool Usage Among Children.



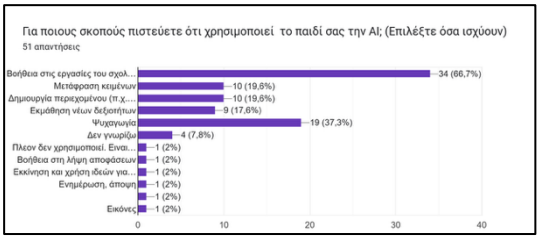
Graph 4: Parental Awareness of Children's Academic AI Usage.



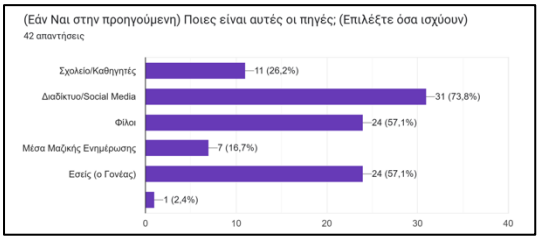
Graph 5: Parent-Reported AI Utilization Across Academic Disciplines.



Graph 6: Perceived Level of Student Reliance on AI for Academic Tasks.



Graph 7: Parental Perceptions of Children's AI Usage.



Graph 8: Sources of Student Exposure to AI.

Analysis of the responses from teachers across the two school units indicates a significant disparity in perceived AI familiarity; specifically, teachers report being substantially less acquainted with AI tools than parents perceive them to be (Graph 1, Graph 9). Simultaneously, nearly all participating teachers reported using AI tools with

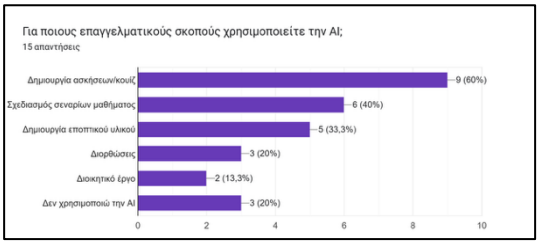
varying frequency (Graph 10). Notably, these educators estimate their students' engagement with AI to be significantly lower than what parents believe it to be (Graph 12, Graph 3). Despite this, approximately half of the teachers have actively encouraged or instructed their students to utilize AI tools (Graph 3). Ultimately, there is a unanimous consensus among the teachers that they have not received sufficient training regarding AI integration within the classroom environment.



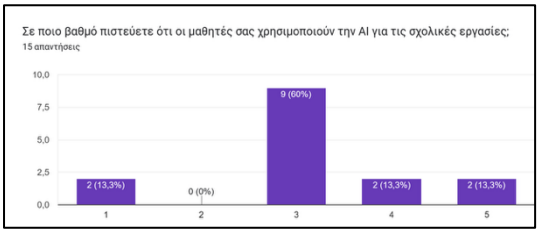
Graph 9: Teacher Familiarity with AI Tools.



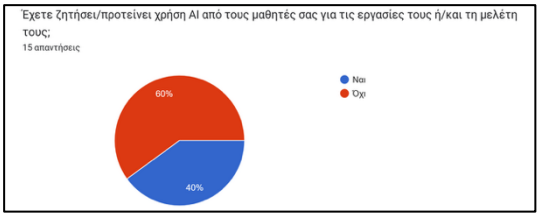
Graph 10: Frequency of Teacher AI Use.



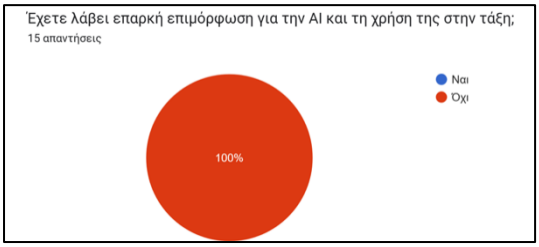
Graph 11: Professional Purposes for AI Use.



Graph 12: Perceived Student AI Use.



Graph 13: Teachers Suggesting/Requesting AI Use.



Graph 14: AI Training Received.

Proposed Protocol: Ethical & Operational Framework for Educators

Based on our research findings, we propose a hierarchical protocol for school administrations to follow when utilizing open-access AI for manuscript digitization and student evaluation.

1. Pre-Processing & Data Sanitization (The "Red Line" Filter)
   - Anonymization: All physical documents must be de-identified prior to digital capture. This involves masking names, signatures, and biometric handwriting elements to ensure data privacy.
   - Content Filtering: Any documentation containing sensitive psychological data or medical opinions must be strictly excluded from open-access AI processing pipelines.
   - Image Optimization: To minimize noise and maximize Handwritten Text Recognition (HTR) accuracy, documents should be scanned at a minimum resolution of 300 dpi.

2. Guided AI Processing (Contextual Prompting)
   - Raw Extraction: Implement initial prompts designed to extract verbatim text. This prevents the AI from "autocorrecting" content, thereby preserving the original linguistic intent for subsequent human review.
   - Technical Refinement: Utilize a secondary layer of prompting—incorporating domain-specific educational terminology (e.g., "IEP criteria")—to rectify linguistic discrepancies or syntax errors, particularly in complex languages like Greek.
   - Structural Restoration: Manually re-integrate tables, marginalia, and non-linear layouts that are frequently fragmented by standard AI architectural processing.
3. Verification & Validation (Human-in-the-Loop)
   - Hallucination Audit: Educators must conduct a word-for-word comparative analysis to ensure the AI has not altered critical quantitative data, such as misinterpreting a grade of 13 as 18.
   - Pedagogical Reconciliation: AI-generated feedback should be categorized as a "preliminary assessment." It must be reconciled with the teacher's professional judgment to mitigate algorithmic bias and account for subjectivity.
   - Technical Oversight: For STEM disciplines, human verification is mandatory to validate mathematical symbols and complex equations, which are often prone to rendering errors in current AI models.
4. Secure Digital Curation
   - Searchable Archiving: Following validation, data should be migrated to secure, state-approved repositories equipped with robust metadata tagging for future retrieval.
   - Institutional Governance: School leadership must serve as "moral governors," ensuring that all AI-integrated workflows remain compliant with the EU AI Act and relevant national data protection frameworks.

Conclusions

The investigation into integrating open-access AI within the Greek educational framework underscores a landscape of significant potential, juxtaposed with critical systemic risks. The following pillars comprise the final analytical synthesis of this study:

1. The Paradox of Technical Reliability

While modern Large Language Models (LLMs) demonstrate a transformative capacity to decipher "scribbles" and semi-legible student scripts—often surpassing human ocular capabilities—they do not yet constitute a viable substitute for manual processing.

   - Linguistic Precision: In Greek-language contexts, AI performance is frequently compromised by specific linguistic and paleographic complexities, resulting in "hallucinations" and systematic syntactic errors.
   - STEM-Specific Limitations: Current models struggle with the non-linear spatial layouts of Physics and Mathematics. The inability to consistently parse mathematical symbology and scientific notation (e.g., powers of 10) remains a significant barrier to full automation.
   - Structural Fragility: Models often fail to preserve the integrity of structured documents, such as meeting minutes or attendance logs. This "formatting collapse" necessitates substantial human intervention for post-processing and correction.

2. The Socio-Economic "Freemium Trap"

A critical analytical finding of this research is the emerging inequality catalyzed by the "Freemium" business model.

- Subscription Barriers: As advanced features migrate behind paywalls, a digital divide is widening between private institutions with dedicated AI budgets and public schools reliant on restricted open-access versions.
- Infrastructural Deficits: The momentum toward AI adoption is further impeded by a lack of specialized hardware and inadequate internet connectivity within many Greek educational units.

3. Ethical "Red Lines" and Data Sovereignty

The most profound risk identified involves the legal precariousness of utilizing unauthorized platforms for sensitive data processing.

- Biometric Risk and GDPR: Insofar as handwriting may be classified as a biometric identifier, the transmission of student scripts to external, non-EU servers represents a potential direct violation of GDPR frameworks.
- Institutional Vulnerability: In the absence of a standardized regulatory "playing field" or formal guidance from the Ministry of Education, educators are operating within a "gray zone" of improvisation. This lack of oversight exposes personnel to legal sanctions for potential breaches of duty.

4. Selective Readiness and the Human Element

This research identifies a state of "selective readiness" among school leadership and pedagogical staff.

- Administrative vs. Pedagogical Divergence: While administrators are generally amenable to AI for logistical optimization (e.g., financial management and scheduling), there is significant resistance to AI involvement in the relational and "human" dimensions of education.
- The Training Gap: Despite a generalized pro-modernization attitude, 100% of surveyed educators reported a lack of adequate formal training. This deficit contributes to "AI Anxiety" and concerns regarding the long-term erosion of students' critical thinking skills.

Final Synthesis: The HITL Mandate

The study concludes that the digitization of school archives represents an inevitable digital transformation. However, to bridge the gap between technical capability and ethical safety, an institutionalized "Human-in-the-Loop" (HITL) framework is essential. AI should function as a strategic catalyst for organizational excellence—enhancing searchability and data extraction—only when governed by rigorous human oversight and a robust ethical supervisory framework.

Our findings align with the European Commission (2023) recommendations, which advocate for an approach where educators remain the primary decision-makers. This ensures that AI-generated outputs are systematically verified before being integrated into official school records.

This call for institutionalized frameworks is further mirrored in international policy, most notably the recent UK Department for Education (2025) guidance. These guidelines emphasize that while generative AI can significantly alleviate administrative burdens—such as the digitization tasks explored herein—it must not supersede the professional judgment of educators. The UK framework reinforces the necessity of

human oversight to mitigate risks of "hallucination" and bias, validating our proposed HITL model as a safeguard for both technical accuracy and the preservation of the essential teacher-student relationship.

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From Design to Co-Design: Pre-service Science Teachers' Iterative Lesson Planning with GenAI through a Multiliteracies Lens; insights for educational assessment

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Abstract- This study examines how generative artificial intelligence (GenAI) can mediate reflective lesson design among pre-service science teachers. Drawing on the Learning by Design framework and the pedagogy of multiliteracies, the research explores how fifteen student teachers engaged in iterative dialogue with GenAI while redesigning science lessons. Each participant first created a lesson plan in class and then re-worked it through a recorded series of prompts and responses using AI tools such as ChatGPT, Copilot, and Magic School. The resulting data corpus, fifteen samples of prompts with design rationale and reflective responses, was analysed qualitatively through content analysis guided by the four knowledge processes: Experiencing, Conceptualizing, Analyzing, Applying. Findings showed that AI-supported lesson re-design fostered epistemic awareness, multimodal thinking, and a re-articulation of pedagogical roles. Participants moved from procedural task planning to design reasoning characterised by reflexivity, ethical sensitivity, and multimodal expansion of scientific meaning. In parallel, the iterative prompting sequences revealed how teachers began to reconsider what counts as meaningful evidence of learning, pointing to the potential of GenAI to shape emerging educational assessment thinking skills. The paper argues that iterative human–AI co-design constitutes a process-based design space in which aspects of planning, monitoring, and evaluative judgement become visible as assessment-relevant forms of reasoning.

Keywords. Science education, Learning by Design, Multiliteracies, Generative AI, TPACK, Teacher education, Prompt engineering, educational assessment.

Introduction

Lesson planning is increasingly understood not as a technical procedure but as a space where teachers negotiate meaning, purpose, and representation. This is not limited to teacher education and science education, but ongoing professional development. Recent studies with in-service teachers show that AI integration into teaching scenarios offers meaningful opportunities for fostering multimodal, inclusive, and critically engaged learning (Katsampoxaki-Hodgetts et al., 2025). This shift toward multimodal, culturally responsive pedagogies (Siry, 2021; Kalantzis & Cope, 2021; Zapata, Kalantzis & Cope, 2023) that comes along with the growing presence of generative AI (GenAI) in teachers' everyday design practices can be intentionally integrated in teacher education programmes. Drafting learning objectives, choosing activities, assessment and resources was once a solitary activity; yet now design decisions are negotiated with tools capable of proposing, critiquing, and recombining pedagogical ideas. Within this landscape, iterative human–AI co-design emerges as a distinct pedagogical space in which pre-service teachers can learn to refine ideas, articulate design rationales, and recognise how their choices connect to evidence of learning when designing lessons to foster multiliteracies, particularly when participants justified acceptance, modification, or rejection of AI-generated suggestions, making traces of evaluative judgement visible within the redesign process.

The present study examines the design choices and reasoning of fifteen pre-service science teachers developed with AI after an initial lesson plan developed in class. The lesson plan was revised through short, recorded interactions with GenAI tools (ChatGPT, Copilot, MagicSchool). Rather than evaluating AI outputs, the study focuses on the student-teacher prompts, the critical moments where teachers articulate constraints, question assumptions, and reshape their pedagogical intentions. Lesson redesign, in this light, becomes a process-based inquiry in which teachers test ideas, revisit choices, ask for alternatives and increasingly adopt a design-oriented stance.

Guided by the Learning by Design (LbD) framework and the pedagogy of multiliteracies (Cope & Kalantzis, 2015), this study investigates the epistemic and pedagogical moves embedded in those prompt sequences with the following questions:
How do pre-service science teachers engage in the Learning by Design knowledge processes (Experiencing, Conceptualising, Analysing, Applying) for lesson redesign with GenAI?
What kinds of pedagogical and epistemic moves do student teachers make when refining lesson activities, representations, and learning environments with AI support?
How does the sequence of human–AI interactions reveal shifts in teacher agency, multimodal design decisions, and responsible AI use during lesson redesign, and in what ways does this process begin to shape pre-service teachers' emerging educational assessment thinking skills?

Theoretical background

Science Learning as Multimodal, Cultural, and Dialogic Practice

Contemporary research frames science learning not as passive reception but as a situated, cultural practice in which learners construct meaning through multiple modes of representation. Siry (2021) demonstrates how scientific ideas take shape through gesture, talk, drawing, material manipulation, and embodied interaction. This aligns

closely with multiliteracies theory (New London Group, 1996; Cope & Kalantzis, 2015), which views learning as engagement with a diversity of modes, languages, and cultural perspectives.
Within this framework, a science lesson does not only present content but it provides a learning environment that orchestrates multimodal encounters with science concepts, phenomena or processes through models, animations, diagrams, digital simulations, and collaborative problem-solving. GenAI enters this landscape as an additional interlocutor: it can propose multimodal pathways, suggest representations teachers may not have considered, or combine modalities in novel ways. At the same time, it requires teachers to sift, judge, and adapt its contributions in ways that remain sensitive to disciplinary norms, learner diversity, and ethical considerations.

Learning by Design as a Framework for Understanding Teacher Prompts

Learning by Design (Cope & Kalantzis, 2015; Katsampoxaki-Hodgetts, Cope & Kalantzis, 2024) offers a coherent frame for examining how teachers construct and refine meaning during lesson redesign. Its four knowledge processes (Experiencing, Conceptualising, Analysing, and Applying) describe iterative forms of engagement that can be observed directly in teachers' prompt sequences:

Experiencing occurs when teachers encounter new ideas or sample representations generated by AI.
Conceptualising appears as they articulate learning goals, define categories, or structure lesson phases.
Analysing emerges when they evaluate the feasibility, appropriateness, or ethical implications of AI suggestions.
Applying surfaces when teachers embed refined ideas into concrete lesson activities, adapting them for time, equipment, or classroom dynamics.

Although originally developed to describe student learning, these processes can now map naturally onto teachers' design reasoning. In practice, student teachers often move through these processes implicitly and non-linearly by testing an idea, revising constraints, discarding an unworkable activity, or re-specifying pedagogical intentions. The LbD framework thus provides a useful lens for interpreting their epistemic moves within GenAI-mediated redesign.

Teacher Agency, AI Literacy, and Responsible Mediation

AI in education and its pedagogical value depends less on the tool itself and more on teachers' capacity to evaluate, adapt, and responsibly integrate AI outputs (Smith et al, 2025). Feldman-Maggor, Blonder and Alexandron (2025) propose an AI-extended TPACK model in which teachers require not only technological and pedagogical proficiency but also AI literacy: the ability to interrogate outputs for accuracy, hallucination, bias, relevance, or ethical appropriateness. Also, Blonder & Feldman-Maggor (2024) and Blonder, Feldman-Maggor & Rap (2024) further argue that teacher expertise increasingly lies in interpretive mediation, the capacity to refine or reject AI-generated material rather than accept it. This way, student-teacher choices can signal an emerging sense of responsible design agency by engaging AI as a generative resource while maintaining pedagogical, ethical, and disciplinary integrity.

Process-Based Inquiry and Reflexive Lesson Design

Shifting from static lesson planning to iterative, AI-mediated redesign mirrors broader methodological developments that conceptualize learning, and teaching, as process rather than product (Collier, 2011; Beach & Pedersen, 2013; Smith et al, 2025). From this perspective, the prompts and design reflections function as developmental trajectories and traces of reflective inquiry: they show how teachers negotiate constraints, revisit decisions, and deepen their pedagogical reasoning over time. When teachers move from broad requests to far more precise, context-sensitive prompts, from digital saturation to a balanced multimodal design, and from passive acceptance of AI suggestions to confident critique and selective uptake, their iterations show how prompting with AI can function as a promising ground for reflexivity through design reasoning, encouraging teachers to ask sharper questions, test alternatives, and articulate pedagogical intentions with greater clarity.

Embedding GenAI as a co-designer in Teacher Education and Science Education

The integration of GenAI into lesson design as a co-designer also resonates with emerging scholarship on AI as a core digital literacy, skill or capability. Within the context of biosciences and chemistry education, Smith et al. (2025) argue that GenAI requires more than technical competence: it demands a pedagogical orientation that is reflective, ethically aware, and grounded in disciplinary thinking. They emphasise three interrelated capacities:
Critical discernment – evaluating AI suggestions against curricular aims, scientific accuracy, and contextual appropriateness.
Pedagogical adaptation – reworking AI-generated ideas so they support active, inclusive, and multimodal learning environments.

Epistemic awareness – recognising how AI transforms knowledge practices, reshapes representation, and expands the repertoire of what can count as evidence or explanation. Their work signifies that GenAI should be embedded not as a shortcut but as a participatory design tool that extends and provides evidence for teacher thinking while requiring human judgment at every stage. This insight aligns directly with the design trajectories observed in the present study, where student teachers treated AI as a stimulus for exploration rather than a source of authoritative answers. In the same vein, AI literacy entails effective use of GenAI aligning with reflective engagement when teachers evaluate suggestions, negotiate constraints, and redirect prompts to align with multiliteracies principles and real classroom conditions.

Methodology

This study adopted a qualitative, process-based content-analysis design to investigate how pre-service science teachers engaged with generative AI during iterative lesson redesign (Collier, 2011; Beach & Pedersen, 2013).

Fifteen pre-service science teachers, enrolled in a university course on Teaching Multiliteracies and Learning by Design for Science Education, created an initial lesson plan individually in class and subsequently revised it through a short, guided interaction with one or more GenAI tools (ChatGPT, Copilot, MagicSchool). Each participant submitted:

a) the original lesson plan,
b) screenshots of all prompts they wrote during the redesign, and justifications (of modifications or why they kept or rejected suggestions)
c) the revised lesson artefact.

The analytical dataset comprise fifteen prompt chains (one per participant) and does not compare initial and final lesson plans. However, the dataset included in this study included lesson plans that were assessed by the instructor as pedagogically coherent, appropriate for the intended age group, and aligned with the overarching multiliteracies and Learning by Design framework, ensuring that all participants entered the initial and redesign phase with a baseline level of instructional quality.

Although the focus is on tracing how learners organise, revise, or justify ideas over time (Beach & Pedersen, 2019), in this study, the "process" was not reconstructed as a turn-by-turn chronological map. Instead, the unit of analysis was the prompt itself as an epistemic move within the wider redesign activity. Each prompt and its reasoning (i.e. design reflections during real-time design conversations through screenshots) was examined for what it revealed about the teacher's reasoning, decision-making, or representational intentions at that moment. This allowed us to identify recurring patterns, such as how student-teachers shifted from broad requests ("make the lesson more interactive") to more principled design considerations (e.g., age-appropriateness, multimodal fit, adjustment of activity timing, or critical rejection of unsuitable AI suggestions).

A directed content-analysis approach (Hsieh & Shannon, 2005) was employed, using the Learning by Design knowledge processes, i.e. Experiencing, Conceptualizing, Analyzing, and Applying (Cope & Kalantzis, 2015; Cope, Kalantzis, & Searsmith, 2021), as flexible lenses against which epistemic choices could be interpreted. Parallel to this frame, epistemic awareness, design reasoning, reflexive positioning, ethical sensitivity, multiliteracies-oriented shifts in representation, pedagogical role re-articulation, and human–AI interaction patterns illuminated how the research questions were addressed.

Findings

The analysis of student-teacher prompts revealed a pattern of reasoning that was not uniform across participants. Instead, the prompts showed varied but recognisable tendencies in how pre-service teachers used GenAI to negotiate lesson redesign within the Learning by Design (LbD) framework, while signifying epistemic stance, design reasoning, and pedagogical agency. Table 1 summarises the codes emerging from the dataset.

Category	***Simplified code label***	***Participants (n)***	***Participants (%)***
AI ethics & responsibility	*Bias awareness*	*3*	*20.0*
	Checking / validating AI outputs	*5*	*33.3*
	Equity & access concerns	*4*	*26.7*

	Ethical limits	*1*	*6.7*
	Ethical reflection	*8*	*53.3*
Design reasoning & stance	*Awareness of learning / knowledge aims*	*12*	*80.0*
	Explaining and justifying changes	*13*	*86.7*
	Reflective self-positioning	*12*	*80.0*
	Sensitivity to values / implications	*7*	*46.7*
Working with AI	*Agreement with AI ideas*	*8*	*53.3*
	Building on AI suggestions	*9*	*60.0*
	Mismatch with classroom reality	*4*	*26.7*
	Critical adaptation	*9*	*60.0*
	Critical rejection	*10*	*66.7*
Learning by Design processes	*Experiencing – exploring options*	*7*	*46.7*
	Conceptualising-organising lesson ideas	*13*	*86.7*
	Analysing – checking feasibility	*13*	*86.7*
	Applying – integrating into plans	*10*	*66.7*
Multimodal design	*Expanding representations*	*10*	*66.7*
	Purposeful use of modes	*9*	*60.0*
	Critiquing representations	*6*	*40.0*
Teacher roles & agency	*Shift toward facilitator / designer*	*7*	*46.7*
	Teacher as co-designer with AI	*15*	*100.0*
	Teacher agency & critical stance	*11*	*73.3*

Table 1. Emerging codes when embedding GenAI as a co-designer in Teacher Education and Science Education

RQ1. How do pre-service science teachers engage in the Learning by Design knowledge processes (Experiencing, Conceptualising, Analysing, Applying) when redesigning lessons with GenAI?

Across the dataset, all four LbD knowledge processes appeared, though with different levels of prominence. Conceptualising accounted for the largest share of coded material, followed by Analyzing, Experiencing, and Applying (Table 1).

Experiencing

Participants frequently began their interaction by requesting examples, alternative representations, or ways to "make the lesson more interesting." These early prompts often reflected uncertainty and exploratory engagement rather than firm pedagogical commitments. Teachers treated the AI's suggestions as a space to "see what is possible," especially regarding multimodal representations, use of digital tools, or ways to motivate students. Here is an example.

> *P2: (Prompt) Create an interactive lesson plan for the unit "The Cell: The Unit of Life" for Grade 7 Biology, to be completed within 45 minutes.*

Experiencing was therefore visible in prompts that probed possibilities without yet making design decisions.

Conceptualising

The largest category concerned prompts where teachers articulated goals, re-structured lesson sequences, or attempted to refine the organisation of activities. Many clarified learning objectives, asked for alignment with curriculum expectations, or explored ways to better connect introductory tasks with main activities. Here is an example:

> *P4: (Prompt) Meet Objectives: For students to understand how the cell functions, what its main parts are, and the role each part plays. Additionally, for them to use images and models to remember these more easily and to collaborate with one another.*

Conceptualising also appeared when teachers explicitly asked the AI to "rephrase," "reorganise," or "place activities in the six-column format," revealing deliberate attempts to develop coherent lesson architecture.

> *P2: (Prompt) Repeat using a six-column template:*
> *Learning process (B–Experiencing, A–Analysing, D–Explicit instruction, E–Applying)*
> *Literacies, media, and modalities*
> *Student activities*
> *Time*
> *Assessment*
> *Learning outcomes*

Analyzing

These prompts appeared when teachers questioned feasibility (e.g., equipment constraints), age-appropriateness, time allocation, classroom realities, and the pedagogical value of AI-generated suggestions. For example,

> *P11 : (Prompt) I asked ChatGPT for alternative teaching methods, although I considered the suggestion of "experimental exploration using a microscope" appropriate, because it gives students the opportunity to experience the essence of the lesson rather than simply observe and interact with imaginary means in the digital world or with simulations.*

Teachers routinely rejected proposals that were overly time-consuming, technologically demanding, or misaligned with their intended learning outcomes. Several questioned whether overuse of digital tools would distract students and requested analog or tactile alternatives (e.g., microscopes, printed diagrams). This category demonstrates how teachers positioned themselves as evaluators rather than adopters of AI output.

Applying

The Applying process appeared when teachers incorporated selected ideas into concrete plan revisions. Many worksheets replaced long theoretical presentations with short videos, modified group work structures, or added short assessments such as matching tasks or Kahoot quizzes.

> *P6 Prompt: After the guidance I received […] I decided that I would implement the idea it initially gave me for the ice-breaker question ("Where would you go on holiday if you were a cell?").*

The presence of Applying in one fifth of all codes illustrates that participants did not simply apply suggested design, but they reflected on it and actively shaped it.

RQ2. What kinds of pedagogical and epistemic moves do student teachers make when refining lesson activities, representations, and learning environments with AI support?

The pedagogical and epistemic moves were captured across several cross-cutting codes. Three themes stood out: design reasoning, multimodal expansion, and criteria-based decision-making (Table 1).

Design reasoning prompts were among the most frequent. These included justifications for modifying activities, identifying gaps in prior designs, rejecting suggestions due to classroom constraints, and proposing refinements. Teachers moved from vague requests ("make the lesson more interactive") toward targeted specifications (e.g., "include an introductory activity that bridges the previous lesson on organism characteristics"). Many sought a balance between creativity and practical implementation, an emerging pedagogical stance that treats lesson design as an argument or as an exercise in weighing alternatives. For example,

> *P8 Prompt: In my view, presented in this way the lesson becomes teacher-centred, and students lose interest and become distracted. For this reason, I asked it to make the following modifications: the theoretical presentation should last 10 minutes and should include the cellular organelles and the differences between animal and plant cell organelles. At the same time, during the theoretical presentation, images of the organelles should be displayed via the projector or interactive whiteboard so that students can complete questions 2 and 3 of the worksheet.*

Epistemic moves also concerned representational variety. Teachers asked for or refined multimodal elements such as 3D videos, printed diagrams, collaborative posters, interactive simulations, role-play, and analog materials. Here is an example:

> *P3 Prompt: I like the fourth activity very much and will incorporate it into my lesson plan. I would implement it in class as follows: assuming my class consists of 20 students, I would divide them into five groups of four, and each group would take on the role of an organelle (nucleus, mitochondrion, chloroplast, vacuole, cell membrane). I would ask each group to present the functions of their organelle with the aim of convincing the class that their role in the cell is the most important, and I would give the group members five minutes to discuss what they will say.*

Importantly, several prompts resisted digital saturation, asking for tactile alternatives or more varied literacies. This pattern suggests an awareness of multimodal pedagogy not as "add more media" but as deliberate orchestration of modes for meaning-making, in accordance with multiliteracies principles.

A notable proportion of prompts expressed evaluation criteria, especially concerning time allocation, cognitive load, developmental appropriateness, feasibility with available school equipment, classroom management, ethical/cultural considerations and accuracy or clarity of scientific representation. For example,

> *[P13] Lack of the human element. AI cannot fully perceive the learning needs of a classroom.*

This shows teachers exercising judgement, not simply following AI suggestions. Ethical sensitivity occasionally surfaced, for example, when teachers questioned proposed activities that might reinforce misconceptions or fail to support inclusive perspectives.

RQ3. How does the human–AI interaction reveal shifts in teacher agency, multimodal decision-making, and responsible AI use during the redesign process?

Two patterns dominated: a gradual assertion of pedagogical agency and a marked tendency toward responsible mediation of AI outputs (Table 1).

In table 1, critical rejection frequency was slightly higher than critical uptake and significantly higher than alignment with AI suggestions. Teachers' roles shifted from tentative experimenters to more confident decision-makers as teachers began directing the AI with far more specificity by modifying, narrowing, or rejecting suggestions. More specifically, several participants discarded AI-generated activities because they required equipment unavailable in Greek public schools. Others replaced AI-proposed theoretical lectures with collaborative tasks to maintain student engagement. Many insisted on detailed, step-by-step student actions when AI outputs were overly general. This illustrates an increasing sense of ownership over pedagogical decisions.

Across the dataset, all participants (100%) produced prompts coded under Teacher as Co-Designer. These prompts demonstrated that student teachers engaged in negotiating, adjusting, or reshaping AI-generated suggestions rather than accepting them as provided. This pattern appeared consistently in every prompt and was present in 7.1% of all coded segments.

Responsible use of AI appeared as requests to avoid overwhelming digital modalities or to ensure equity for students without device access, questions about the accuracy of cellular structures in videos or simulations, and decisions to exclude tasks that risked cognitive overload or marginalised quieter students. Such reasoning accounted for approximately 14% of coded segments and reflected a precautionary stance: teachers wanted to harness AI's generativity while maintaining pedagogical and ethical integrity.

The interaction patterns showed that AI often proposes ambitious ideas of multimodal activities. Teachers evaluated feasibility, time, equipment, and cognitive load and either adapted or replaced the AI output with a more balanced multimodal approach. This

dynamic suggests that novice teachers are negotiating not only lesson content but also what responsible, inclusive representation looks like in a multimodal science classroom.

Discussion

The material generated through the redesign activity offers a grounded view of how student-teachers think while they work on lesson planning alongside GenAI (Beach & Pedersen, 2019). Reading across the prompt sequences, what stands out is not the presence of ready-made solutions, but the steady effort to refine ideas, weigh alternatives, and make decisions that felt workable for real classrooms (Blonder, Feldman-Maggor, & Rap, 2024). Rather than treating AI suggestions as final, most participants handled them as starting points that needed to be questioned, reshaped, or sometimes set aside (Table 1). This stance is consistent with studies that highlight interpretive mediation and teacher responsibility in AI-supported lesson design and requires further research on that (Feldman-Maggor, Blonder, & Alexandron, 2025).

A recurring tendency across the cases was a careful attention to structure and purpose (Cope & Kalantzis, 2015). Many prompts focused on reorganising lesson phases, clarifying what an activity was meant to achieve, or adjusting a task so that it matched the age group and the available time (Kember et al., 2000). In this respect, the interaction with the tool did not simply generate more material; it encouraged participants to slow down and spell out why one design option made more sense than another (Carless & Boud, 2018). Several teachers used their prompts to articulate concerns that experienced colleagues often express informally, for example, when a representation risks confusing learners, or when a proposed activity looks engaging but is likely to be impractical in everyday school conditions (Blonder & Feldman-Maggor, 2024).

Multimodal design played a similar role (Siry, 2021). Participants were open to new ideas for visuals, digital resources, and interactive tasks, yet they approached these with caution (Zapata, Kalantzis, & Cope, 2023). Some chose to limit the number of digital elements suggested by the tool, either because of access issues or because they sensed that too many parallel stimuli might distract from the scientific ideas they wanted learners to grasp (Cope, Kalantzis, & Searsmith, 2021). Their decisions suggest that the move toward multimodality was not about accumulating modes, but about choosing forms of representation that could genuinely support understanding (Katsampoxaki-Hodgetts et al., 2025).

Across the dataset, there was also a noticeable shift in tone as the redesign progressed (Beach & Pedersen, 2019). Early prompts were often exploratory and tentative. Later ones became more specific, with participants directing the tool toward tighter constraints, clearer goals, or alternative options that better aligned with their intentions (Hsieh & Shannon, 2005). In several cases, teachers rejected entire proposals because they did not fit their context or because they conflicted with the kind of learning environment they wanted to foster (Zhai, 2023). These moments do not signal opposition to AI; rather, they show teachers negotiating their role as designers and claiming responsibility for the final shape of the lesson.

Taken together, the prompt sequences reveal lesson redesign as an iterative craft practice (Cope & Kalantzis, 2015). Ideas were tried out, revised, and re-worked in light of classroom realities (Beach & Pedersen, 2019). Through this process, participants made aspects of their design reasoning more explicit, particularly when they justified modifications, rejected unsuitable proposals, or specified constraints related to time, resources, or student needs (Nicol, 2020). For teacher educators, these written traces are valuable not because they "measure" competence, but because they offer glimpses into how novice teachers are beginning to articulate the thinking that sits behind their planning choices (Carless & Boud, 2018).

Implications for Assessment and Teacher Education Practice

The activity used in this study suggests a number of practical directions for programmes that wish to integrate GenAI into lesson-design work in meaningful ways (Smith et al., 2025). Rather than presenting AI as a shortcut for generating plans, the redesign process positioned it as a conversational partner that invites teachers to explain, refine, and sometimes defend their decisions (Blonder & Feldman-Maggor, 2024). This orientation may help students move beyond surface-level prompt use toward a more reflective stance on why lessons are designed as they are (Kalantzis & Cope, 2021).

First, the findings point to the value of scaffolding human-AI prompting as a design practice (Hsieh & Shannon, 2005). Prompts that simply "ask for ideas" tended to produce generic material, whereas prompts that specified constraints, intentions, and learner characteristics supported richer reasoning (Kember et al., 2000). Teacher-education courses may therefore benefit from modelling prompt sequences that begin broad and gradually become more focused, encouraging student-teachers to articulate their rationale as they iterate (Cope & Kalantzis, 2015).

Second, the work highlights the importance of supporting multimodal judgement rather than multimodal accumulation (Zapata, Kalantzis, & Cope, 2023). Participants were selective in their uptake of digital and visual elements, often reducing or adapting suggestions to fit their context (Siry, 2021). Designing activities that ask students to justify representational choices, not just add resources, may strengthen this kind of professional sensitivity (Cope, Kalantzis, & Searsmith, 2021).

Third, the redesign process created space for discussion of practical and ethical boundaries: feasibility, workload, access, and the kinds of participation different activities invite (Blonder & Feldman-Maggor, 2024). Embedding opportunities for group reflection around these decisions can help connect individual prompting choices with broader conversations about inclusive, thoughtful classroom practice (Erduran, & Levrini,(2024).

For colleagues involved in designing assessment in teacher-education programmes, the redesign activity used in this study offers an alternative way of thinking about what can be assessed, and how learning can be made discussable without relying solely on finished lesson artefacts (Carless & Boud, 2018). The prompts and accompanying justifications did not replace traditional assignments, but they added another layer: they made it possible to see how student-teachers arrived at their decisions, how they negotiated constraints, and how they revised or rejected options that did not align with their intentions (Nicol, 2020). For assessment developers, this suggests the value of

creating tasks that invite students to share the reasoning behind their design choices, not only the end product (Beach & Pedersen, 2019). Such approaches do not require complex scoring systems; they can be built around brief narrative commentaries, short design memos, or structured moments of reflection that accompany iterative redesign (Carless & Boud, 2018). Where programmes choose to include GenAI as part of lesson-design activities, assessments may therefore focus less on whether a plan looks polished and more on how teachers explain their choices, adapt suggestions to their context, and show awareness of the consequences different design paths might have for learners (Kalantzis & Cope, 2021). In this sense, the redesign process can serve as a useful assessment space for nurturing professional judgement in a formative, developmental way, while still respecting the diversity of pedagogical orientations that student-teachers bring to their work (Cope, Kalantzis, & Searsmith, 2021).

Conclusion.

Overall, the study suggests that GenAI can be used productively in teacher education when it is positioned as a tool that supports design exploration, negotiation of constraints, and careful reasoning about pedagogical choices, rather than as an automatic lesson generator (Smith et al., 2025). Future iterations of this work could extend these activities into school placements, allowing student-teachers to revisit their redesign decisions in light of how lessons unfold in real classrooms following Design-Based Research protocols (Philippakos, Howell, & Pellegrino, (2021).

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The RAIL Framework: Reflection as Epistemic Formation in the Education of GenAI-Enhanced Science Teachers; implications for assessment

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Abstract- GenAI is beginning to reshape teacher education beyond technical skill or efficiency, touching instead on how novice educators interpret their work and the responsibilities attached to it. This study examines how pre-service science teachers conceptualise such shifting expectations while designing AI enhanced lessons. Working within the traditions of Learning by Design and the pedagogy of multiliteracies, and informed by recent proposals for AI-extended TPACK, we analysed fifteen reflective accounts written after science student-teachers engaged in iterative prompting, evaluation, and redesign. The reflections reveal a profession in formation: students used AI to explore representational possibilities and test instructional ideas, yet they also encountered moments of hesitation, critique, and selective resistance. Across the narratives, reflection emerges not as a procedural add-on but as an epistemic activity through which participants negotiated the authority of AI, articulated the rationale behind their pedagogical choices, and considered the ethical implications of adopting algorithmic suggestions in science classrooms. Drawing on these insights, the paper advances the Reflective-AI Literacies (RAIL) framework, which foregrounds epistemic reflexivity, multiliteracies awareness, and responsible AI agency as interlinked dimensions of contemporary science-teacher professionalism. Embedded reflection also highlights the value of process-based assessment, making visible the evaluative work through which student-teachers shape their designs.

Keywords. AI Pedagogical content knowledge, Epistemic reflexivity, assessment, lesson design, ethical deliberations, AI literacy framework

Introduction

The rapid spread of generative AI in teacher education and science education (Ching Cheung et al., 2025) has unsettled familiar assumptions about how teachers design, justify, and communicate disciplinary meaning, a shift echoed in broader debates about the "wicked problem" of AI-mediated assessment (Corbin et al., 2025). In science education, where learning relies on models, multimodal representation, and iterative interpretation, AI tools introduce new possibilities for instructional design while simultaneously demanding closer scrutiny of how explanations are produced and validated, especially as hybrid human-AI authorship complicates what counts as credible evidence of learning (Lodge et al., 2023). Recent work in AI-extended TPACK (Feldman-Maggor et al., 2025; Blonder et al., 2024) shows that interactions with generative systems can surface aspects of teachers' pedagogical reasoning that are typically tacit: how they structure concepts, sequence representations, and weigh the validity of examples. At the same time, UNESCO's (2023) guidance highlights that teachers must remain able to identify bias, distortion, and misplaced authority in AI-generated suggestions.

Research in dialogic and multimodal science pedagogy view teaching as a semiotic and social activity. The multiliteracies tradition conceptualises learning as design, foregrounding how disciplinary meaning emerges through the orchestration of modes rather than through verbal explanation alone. Studies in science education (e.g., Siry, 2021) illustrate that students' gestures, models, narratives, and digital artefacts contribute substantively to conceptual understanding. When pre-service teachers turn to AI for lesson redesign, they encounter these epistemic and semiotic questions directly: Which representations clarify or distort meaning? When is AI proposing useful alternatives, and when is acceptance of its suggestions pedagogically or ethically inappropriate?

This study explores pre-service science teachers' reflective accounts following this negotiation form a record of emerging teacher agency: moments of reliance on AI for structure or multimodal ideas, but also episodes of doubt, selective resistance, and verification. The analysis positions reflection not as an evaluative add-on but as an epistemic activity through which future teachers articulate disciplinary purpose, interrogate AI outputs, and defend their pedagogical judgments. The Reflective-AI Literacies (RAIL) framework developed in this paper captures this interplay, highlighting how epistemic reflexivity, multimodal awareness, and responsible AI agency manifest through comparison of human- and AI-generated design decisions. Moreover, because reflection has long been recognised as a quality criterion in process-based assessment, the RAIL framework also speaks directly to current debates on how assessment can make students' epistemic reasoning and design decisions visible, traceable, and open to pedagogical evaluation by intentionally embedding reflective tasks that follow Human-AI interactions.

Theoretical background

AI-Extended Teacher Knowledge and Pedagogical Acuity

Shulman's notion of PCK (1986) established teaching as an interpretive practice, integrating disciplinary insight with responsiveness to learners. As digital tools became

embedded in instruction, the TPACK model formalised technology as a dimension of teacher knowledge. Generative AI, however, reshapes this terrain: teachers now interact with systems that produce explanations and representations, compelling them to evaluate the epistemic status of such outputs.

AI-extended TPACK scholarship (Feldman-Maggor et al., 2025; Blonder et al., 2024) argues that teacher expertise increasingly involves recognising when AI suggestions align with curricular aims and when they conflict with scientific accuracy, learner needs, or ethical considerations. These demands resonate with the construct of pedagogical acuity (Katsampoxaki-Hodgetts & Marin, 2025), defined as the capacity to discern when an AI-generated idea should be adopted, adapted, or rejected. As the reflections in this study show, this acuity develops through iterative confrontation with AI's limitations, superficial reasoning, mismatched context, or unverifiable claims, prompting teachers to refine prompts, verify accuracy, and articulate conceptual intent.

Multiliteracies and Multimodal Reasoning in Science Education

The pedagogy of multiliteracies (Cope & Kalantzis, 2015) views learning as design and positions multimodality as central to disciplinary meaning-making. In science education, representations carry conceptual content: a diagram, animation, or model affords different ways of engaging with ideas. However, multimodality becomes pedagogically effective only when teachers can justify why a specific mode advances understanding (Zapata, Kalantzis & Cope, 2023). AI tools readily propose multimodal activities, yet, as the dataset reveals, teachers must still determine whether these proposals strengthen conceptual clarity or simply add visual novelty. In this context, the development of "mode-meaning reasoning" thus becomes intertwined with AI literacy.

Ethics, Responsibility, and Epistemic Awareness

In terms of ethical considerations, UNESCO (2023) emphasises transparency, bias, and human oversight in AI-mediated education. Chemistry and science-education researchers (Blonder & Feldman-Maggor, 2024; Erduran & Levrini, 2024) similarly warn that AI-generated scientific explanations may be plausible but inaccurate. As Tai and colleagues show, the development of evaluative judgement depends on learners having repeated occasions to examine work against relevant standards and to articulate the grounds of their decisions, an approach that positions comparison, deliberation, and justified choice as integral features of higher-education pedagogy (Tai et al., 2018). The reflections examined in this study show that ethical awareness often emerged spontaneously: students questioned AI-derived claims, cross-checked sources, and expressed discomfort at relying on unverified suggestions. Such practices indicate the early formation of responsible AI agency, an ability to interrogate, rather than inherit, algorithmic reasoning.

As such, we need to position reflexivity as a central criterion in assessment practices that value the processes through which learners construct, examine, and justify knowledge. Scholars of learning and assessment argue that when students articulate the reasoning behind their decisions, and when such articulation becomes assessable evidence, assessment shifts from product-centred judgement to a more transparent and equitable evaluation of learning processes (Carless & Boud, 2018; Sadler, 1989). In

science education, this visibility of reasoning has been linked to stronger epistemic agency and more informed instructional decision-making. The RAIL framework aligns with these developments by foregrounding the interpretive, deliberative, and ethical moves that pre-service teachers enact when engaging with AI-generated material, thereby offering a structure through which reflexive judgement can be recognised and assessed as part of professional learning.

Methodology

This qualitative study examines how pre-service science teachers made sense of generative AI during lesson redesign. Instead of treating their reflections as evidence of technical proficiency, the analysis approaches them as traces of emerging epistemic and pedagogical reasoning. Students completed two versions of the same lesson: a human-authored initial plan and an AI-mediated redesign developed through iterative prompting. The contrastive structure prompted participants to articulate differences in conceptual clarity, multimodal choices, and ethical stances, enabling reflection to function as a site of meaning-making rather than procedural commentary.

Participants were fifteen pre-service teachers enrolled in a university programme leading to the Certificate of Teaching and Pedagogical Competence. The group consisted of Chemistry and Biology graduates with balanced gender representation. Most had limited prior experience with generative AI. Upon designing their human lesson design, participants prompted Ai to revise it and/ or suggest a better alternative that fosters multiliteracies in science education. Students were asked to document, justify, and revise their decisions but this data was not included in this paper). Our analysis focused on the 600-800 word reflective report each participant produced, addressing four prompts: skills developed, shifts in teacher role, challenges encountered, and the pedagogical value of AI for multiliteracies development. All data was anonymised.

Reflections were imported into NVivo for thematic analysis. Initial inductive coding identified recurring ideas such as uncertainty, evaluation of accuracy, multimodal reasoning, prompt refinement, and ethical concerns. A second cycle interpreted these codes through the study's conceptual lenses (Multiliteracies, and AI-extended TPACK): Epistemic Reflexivity, AI-Pedagogical Content Knowledge (AI-PCK), AI-Technological Knowledge (AI-TK), Multiliteracies Awareness, Responsible AI Agency, Practical Constraints, and Markers of Professional Growth. Overall, these themes informed the Reflective AI literacies (RAIL) framework.

Findings

The analysis of the fifteen reflective accounts in Table 1 indicate a broadly consistent pattern: all participants engaged with the AI tool in ways that activated several dimensions of the RAIL framework, although the intensity and emphasis varied across individuals. While the study was not designed to quantify learning outcomes, the relative distribution of coded segments provides a helpful indication of which aspects of AI-mediated design work were most salient for these pre-service teachers. The patterns reported below should therefore be read as a structured portrait of the dominant forms of reasoning that appeared in the reflections rather than as statistical findings.

Parent category	*Subcode*	*Code justification*	*Cases*	*% of cases*
AI-PCK	*Using AI to refine lesson ideas*	*Using AI suggestions to improve lesson structure and representations*	*15*	*100.0*
	Checking scientific accuracy	*Verifying whether AI-generated content is correct*	*14*	*93.3*
	Aligning AI ideas with teaching goals	*Adapting AI suggestions to fit curriculum and pedagogy*	*12*	*80.0*
	Rethinking teacher role	*Reflecting on responsibility and authority when using AI*	*14*	*93.3*
AI-TK	*Learning how AI responds to prompts*	*Understanding how prompt wording shapes AI output*	*10*	*66.7*
	Iterative prompting	*Adjusting prompts across multiple AI responses*	*11*	*73.3*
	Recognising tool limits	*Identifying affordances and constraints of AI tools*	*14*	*93.3*
Epistemic Reflexivity	*Questioning AI outputs*	*Identifying errors, gaps, or weaknesses in AI suggestions*	*13*	*86.7*
	Explaining design decisions	*Making reasons for accepting or rejecting AI ideas explicit*	*12*	*80.0*
	Uncertainty and hesitation	*Expressing doubt or ambivalence toward AI proposals*	*13*	*86.7*
Multiliteracies Awareness	*Using multiple modes*	*Incorporating visual, textual, and interactive representations*	*11*	*73.3*
	Choosing modes for learning needs	*Linking representations to learner diversity and concepts*	*12*	*80.0*
	Superficial multimodality	*Recognising when multimodal use lacks pedagogical purpose*	*9*	*60.0*
Practical Constraints	*AI ideas not feasible*	*Rejecting AI suggestions due to time, space, or curriculum limits*	*8*	*53.3*
	Overly generic AI responses	*Identifying superficial or unrealistic AI proposals*	*12*	*80.0*
Responsible AI Agency	*Ethical concern and verification*	*Cross-checking information and questioning reliability*	*8*	*53.3*

Professional Growth	*Improved pedagogical judgement*	*Greater confidence in justifying teaching decisions*	*14*	*93.3*
	Shift in stance toward AI	*Viewing AI as a thinking partner rather than authority*	*13*	*86.7*

Table 1. Analytical lens for Reflective AI literacies [RAIL] framework (Katsampoxaki-Hodgetts, 2025)

Epistemic Reflexivity as a Central Feature of Learning in Science Teacher Education

Epistemic reflexivity was the most widely expressed domain, appearing in every account and representing almost one-fifth of all references.

> *[S8] It became clear that, with appropriate guidance, AI can produce a satisfactory lesson plan, although it is evident that it remains a developing tool. We should not, however, accept its suggestions uncritically, particularly when we have not provided precise instructions about what we are asking for.*

Students frequently described how they scrutinised the suggestions offered by the AI, identifying where ideas were incomplete, overly general, or inconsistent with their pedagogical aims. Many noted the need to clarify instructions, question the tool's assumptions, or make explicit decisions about why particular suggestions should be adopted, adapted, or set aside. Other codes such as recognising limitations or articulating tacit reasoning were activated in a substantial proportion of cases, indicating that the reflective task helped surface forms of pedagogical judgement that typically remain implicit. The prominence of comments explaining why a suggestion was accepted or rejected, and of accounts describing prompting as a means of interrogating ideas, suggests that the comparison between human- and AI-generated lesson designs created a productive space for deeper epistemic awareness, an insight central to the logic of RAIL. Student-teacher reflections herein echo Tai et al.'s observation that evaluative judgement grows through the effort to weigh alternatives and account for one's decisions; participants engaged in precisely this kind of work when they explained where AI-generated ideas supported their instructional aims and where they felt compelled to question or override them (Tai et al., 2018).

Development of AI-Pedagogical Content Knowledge (AI-PCK)

AI-PCK also appeared across all cases and constituted the largest proportion of coded material. Participants commonly used the AI's proposals as a starting point for refining the conceptual structure of their lessons, selecting appropriate representations, or reconsidering the sequencing of instructional activities.

> *[S1] How can I differentiate my teaching so that it supports multiple forms of literacy and broaden my creative thinking by incorporating ideas I would not have considered on my own*

The frequency with which students reflected on changes to their teacher role and on the need to verify the accuracy of AI-provided content underscores their recognition that pedagogical authority remained firmly with them. Although most drew on AI

suggestions at some stage, these ideas were rarely taken as finished solutions. Instead, students repeatedly emphasised the importance of filtering AI outputs, aligning them with curricular goals, and re-working them to fit the realities of their classroom context. Following the human creation of lesson plans, this blend of uptake and critique demonstrates an emerging form of pedagogical acuity: students were learning to treat the

AI as a stimulus for thinking rather than a prescriptive guide.

AI-Technological Knowledge as Emerging Functional and Critical Literacy

All participants demonstrated some development in their technological understanding of how generative AI operates. Student-teacher reflections show they gradually learned to refine their prompts, recognised the tool's response patterns, and identified its affordances and constraints.

> *[S7] Several times, it did not understand what I was asking for.*

Participants also addressed the tool's tendency to displace creative agency as it can inadvertently narrow the space for imaginative pedagogical thinking. As S9 notes, reliance on AI may reduce the need for original idea generation, shifting the teacher's role from creative designer to editor or accuracy-checker. This perceived deskilling reveals a subtle risk: generative AI can prioritise verification over creativity, potentially weakening the reflective and imaginative dimensions that underpin thoughtful lesson planning.

> *[S9] I felt I had fewer responsibilities after using the tool, because the imagination I previously needed for lesson design was no longer required. What became more important instead was checking the accuracy of the tool's responses.*

Roughly two-thirds explicitly discussed the value of posing precise questions, and an even larger proportion commented on the iterative nature of prompting, highlighting the need to adjust instructions and monitor how the tool interpreted them. Although only a small number reflected on choosing between different AI platforms, most became more adept at steering the system they used. In terms of AI-TK, critical literacy in lesson design addressed issues of ownership (see S9), which may disempower student-teacher agency if not addressed in an intentional pedagogical design. Taken together, these accounts suggest that prompt-based interaction became an important means through which students not only elicited usable output but also developed a practical understanding of the technology itself.

Multiliteracies Awareness and Expanding Representational Repertoires

Awareness of multiliteracies was evident in all student reflections, with many describing how the AI exposed them to a broader range of representational options than they might have generated independently.

> *[S14] The pedagogical value of using Artificial Intelligence to support multiliteracies and multimodality lies in the range of examples, original ideas, and suggestions it can generate, many of which a single teacher might not have considered. The lesson plan incorporates various forms of literacy, critical-thinking questions, and activities that, to a great extent, promote the development of literate, active, and critically minded students.*

A large proportion of students demonstrated an understanding of how different modes, i.e. visual, interactive, auditory, or textual, can support meaning-making in science. Others moved beyond listing modes to explaining why certain representations might better suit particular learners or concepts. At the same time, traces of surface-level multimodality appeared in several accounts, suggesting variability in the depth of students' multimodal reasoning. These differences underline the importance of continued support for principled multimodal design in teacher education, rather than assuming that access to multimodal suggestions is sufficient for sophisticated pedagogical use.

Practical Constraints and the Emergence of Responsible AI Agency

Nearly all participants referred to practical constraints that limited the usefulness of certain AI suggestions. Students noted activities that were unrealistic given time, space, or curriculum restrictions, as well as responses that felt superficial or misaligned with the scientific content.

> *[S13] AI sometimes proposes content that does not align with the curriculum or with the capabilities of the class.*

These recognitions often prompted ethical considerations: many students raised concerns about accuracy, bias, or the need to verify information from external sources. Although only a few explicitly discussed issues such as transparency or the boundaries of appropriate use, a substantial number described the need for critical oversight and responsible integration of AI-generated material. This emerging ethical awareness suggests that students were beginning to grapple with the responsibilities inherent in AI-mediated teaching, even without explicit scaffolding in ethical frameworks.

Evidence of Professional Growth

Finally, all students, whether with a negative or positive stance towards AI-use in the design of lesson plans, exhibited signs of professional growth. Many described an increased ability to justify pedagogical decisions, a clearer understanding of the role of representation in science learning, and a more confident stance toward evaluating and adapting AI suggestions.

> *[S11] AI's responses did not fully satisfy me, as they were not always adapted to the realities of a Greek classroom, either because it suggested non-Greek sources (e.g., videos), or because some ideas were unrealistic given time and space constraints, or simply because they did not align with my critical approach.*

Shifts in epistemic stance, moving from treating the AI as a source of answers to seeing it as a partner in deliberation, appeared in the vast majority of reflections. Students also reported greater confidence in navigating the tool's limitations and in crafting prompts that elicited more targeted responses. Collectively, these patterns indicate that the reflective, contrastive design task supported the development of professional judgement by making reasoning visible, prompting self-explanation, and encouraging students to interrogate the interplay between human and AI contributions to lesson design.

Implications from the RAIL framework: Rethinking Assessment When Students Design with AI: A Reflective Perspective for Teacher Educators and Science Teachers and a rubric as a reflective scaffold.

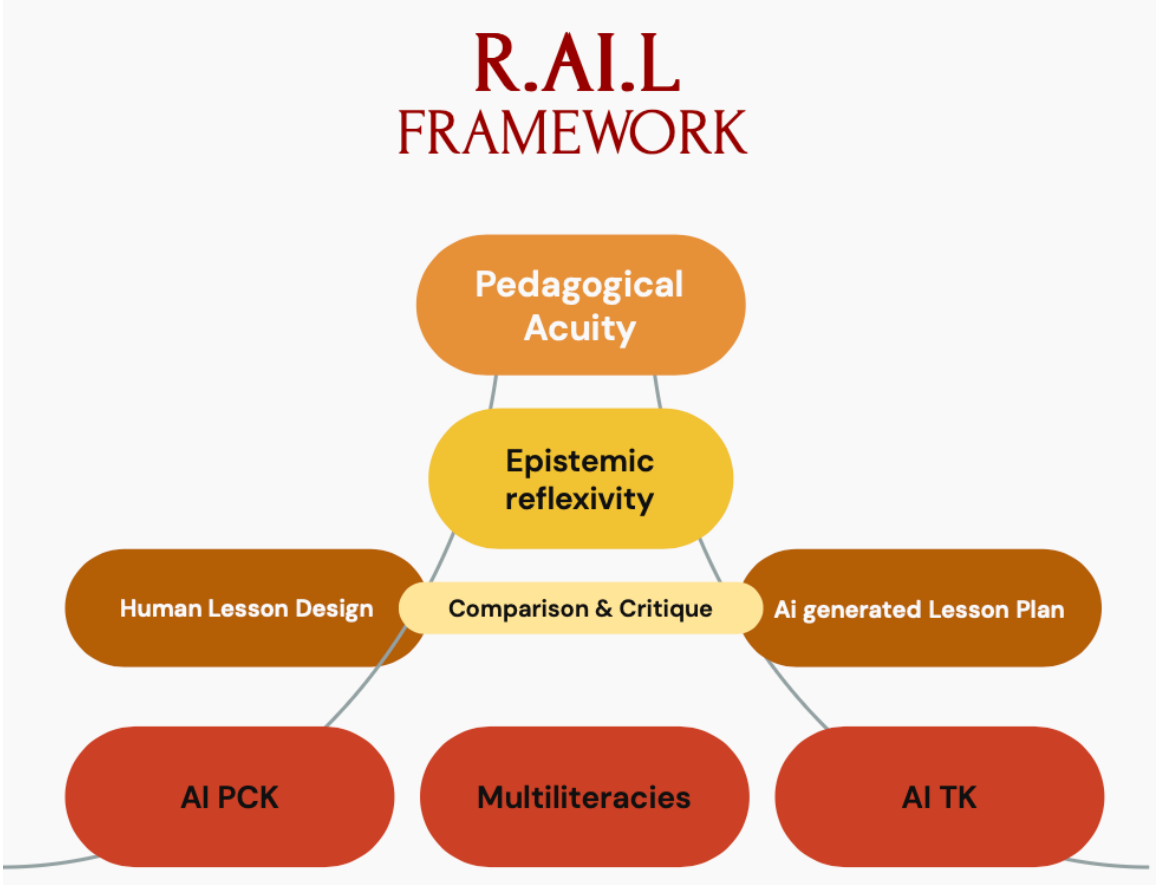


Figure 1. The RAIL framework: pedagogical acuity through epistemic reflexivity and comparison and critique of AI enhanced lesson plans in science education (Katsampoxaki-Hodgetts, 2025)

When student-teachers are invited to work with generative AI, the central pedagogical question is not whether the tool produces a competent lesson plan, but what kinds of thinking become visible as students interact with, question, and revise its suggestions (Corbin et al., 2025; Lodge et al., 2023). The findings discussed in this paper suggest that AI-mediated design tasks are most educationally powerful when they are framed as occasions for judgement rather than as exercises in efficiency. What matters, therefore, is not the polish of the final artefact, but the quality of the reasoning that precedes it.

Across the reflections analysed, learning took shape through comparison, a process long recognised as central to internal feedback and judgement formation (Nicol, 2020; Tai et al., 2018). Students moved back and forth between their own initial lesson designs and AI-generated alternatives, noticing tensions, overlaps, and mismatches (Figure 1). This comparative work activated several dimensions simultaneously: students refined prompts and interpreted system behaviour, articulated pedagogical intentions, examined representational choices, and confronted questions of accuracy, feasibility, and responsibility. These processes did not unfold sequentially; they were intertwined. A change in a prompt triggered reconsideration of content sequencing; a

multimodal suggestion prompted reflection on learners' needs; an implausible activity raised ethical and contextual concerns. In this sense, AI functioned less as a solution-provider and more as a catalyst for epistemic work.

For teacher educators, this has direct implications for assessment. Recent work has shown that AI unsettles conventional assessment logics precisely because it foregrounds process, judgement, and authorship rather than discrete outputs (Corbin et al., 2025; Ching Cheung et al., 2025). If AI is treated merely as a shortcut to acceptable outputs, assessment risks collapsing into product inspection or plagiarism detection. By contrast, when AI-mediated design is positioned as a space for deliberation, assessment can attend to how students make decisions under conditions of uncertainty. The RAIL framework helps clarify what to look for: moments where students explain why a suggestion was adopted, adapted, or rejected; instances where they recognise the limits of AI-generated content; and evidence that they can connect representational choices to disciplinary meaning and learner diversity. These traces are not peripheral. They are the substance of professional learning.

Seen through the lens of assessment-as-learning, such traces constitute evidence of evaluative judgement, understood as the capacity to make and justify decisions about quality over time (Sadler, 1989; Tai et al., 2018; Carless & Boud, 2018). Students are not simply responding to criteria; they are learning to use criteria. They compare alternatives, draw on disciplinary and pedagogical standards, and justify their choices in writing. The prompt histories, annotations, and reflective accounts produced alongside AI-supported lesson redesign make this judgement visible in ways that traditional lesson plans rarely do. Assessment, in this context, becomes a means of recognising developing professional discernment rather than ranking finished products.

This shift also reframes the teacher's role, aligning with sociocultural and design-oriented accounts of teaching as interpretive professional work rather than technical delivery (Shulman, 1986; Cope & Kalantzis, 2015). Rather than acting as a gatekeeper of correct answers or as a monitor of AI use, the educator becomes a designer of reflective conditions. Carefully structured prompts, requirements for justification, and opportunities for comparison encourage students to maintain epistemic control. Importantly, the reflections suggest that ethical awareness often emerges organically when students are asked to account for their decisions. Concerns about accuracy, bias, cultural fit, and feasibility surfaced not because students were instructed to be ethical, but because they were required to defend their pedagogical reasoning.

The implications extend beyond initial teacher education and resonate with research on multiliteracies, dialogic pedagogy, and disciplinary meaning-making across educational levels (Siry, 2021; Zapata et al., 2023). Similar mechanisms can be mobilised across educational levels and disciplines whenever learners are asked to compare AI-generated proposals with their own work. What travels across contexts is not the tool itself, but the pedagogical stance: AI as an object of critique rather than authority. Whether students are analysing scientific explanations, designing activities, or evaluating procedures, the educational value lies in the reflective comparison that prompts them to articulate why some ideas deserve uptake and others do not.

For professional development designers and policymakers, these findings point towards a model of AI integration grounded in judgement and responsibility rather than

efficiency or automation (UNESCO et al., 2023; Blonder & Feldman-Maggor, 2024). Training teachers to "use" AI is insufficient if it neglects the habits of mind required to interrogate its outputs. What needs to be cultivated are dispositions of attentiveness, scepticism, and justification. The RAIL framework offers one way of structuring such work, not as a checklist, but as a reflective lens for noticing how professional reasoning unfolds in AI-rich environments, particularly in science education where epistemic responsibility and representation are central (Erduran & Levrini, 2024; Feldman-Maggor et al., 2025).

The following rubric is provided as a teacher education resource grounded in empirical research herein. (Table 2). Used formatively, this rubric can support dialogue between educators and students about what counts as quality in AI-mediated work. Used summatively, it allows assessment to honour the intellectual labour involved in judgement, critique, and design. In both cases, it reinforces a central message of the RAIL framework: in AI-rich classrooms, learning is made visible not through flawless outputs, but through the reasoning that shapes them.

Criterion	Focus	Emerging	Developing	Established
Epistemic Reflexivity	How students interrogate AI outputs and their own assumptions	Accepts AI suggestions largely at face value, with limited justification	Identifies strengths and weaknesses in AI-generated ideas and provides partial reasoning for decisions	Systematically explains why AI suggestions are adopted, adapted, or rejected, drawing on pedagogical and disciplinary considerations
AI–Pedagogical Content Knowledge (AI-PCK)	Alignment between AI use, curriculum goals, and scientific meaning	Uses AI to generate ideas without clear alignment to learning goals	Adapts AI suggestions to fit curriculum aims, with some attention to conceptual coherence	Uses AI strategically to refine explanations, representations, and sequencing, clearly articulating pedagogical intent
Multiliteracies and Representational Reasoning	Justification of multimodal choices	Includes multiple modes without explaining their pedagogical purpose	Explains how selected modes support understanding for particular learners or concepts	Demonstrates principled reasoning about how modes shape disciplinary meaning and learner engagement
AI–Technological Awareness	Understanding and management of AI behaviour	Uses AI with minimal awareness of how prompts	Adjusts prompts and recognises patterns or limitations in AI output	Demonstrates critical awareness of AI affordances and constraints, using prompting as a tool

		shape responses		for inquiry rather than control
Responsible AI Agency	Ethical and contextual judgement	Limited attention to accuracy, bias, or feasibility	Raises concerns about reliability or context and engages in some verification	Actively cross-checks information, considers ethical implications, and maintains clear human responsibility for pedagogical decisions
Reflective Articulation	Quality of written or oral reflection	Descriptive accounts of actions taken	Reflective explanations that link actions to outcomes	Coherent, well-argued reflections that make reasoning, uncertainty, and learning explicit

Table 2. Rubric based on empirical research of RAIL Framework (Katsampoxaki-Hodgetts, 2026)

Conclusion

To sum up, when pre-service science teachers work across a cycle in which a human-designed lesson is revisited, tested, and interrogated through AI-mediated redesign, the follow-up human reflection becomes the mechanism that binds these stages into a coherent learning experience. Rather than functioning as an add-on at the end of a task, reflection works as an epistemic practice through which student-teachers sift through AI suggestions, articulate the grounds of their choices, and examine how different representational and pedagogical decisions shape scientific meaning. The comparison of human and AI outputs prompted students to revisit their assumptions, question the authority of algorithmic proposals, and justify the reasoning that underpins their instructional judgments. This iterative scrutiny is central to the emergence of what Katsampoxaki-Hodgetts and Marin (2025) describe as *AI pedagogical acuity*, the capacity to recognise when AI-generated ideas serve disciplinary aims and when they require adaptation or rejection.

The reflective cycle also shed light on how AI-mediated lesson design can support critical literacy in science education. Students frequently confronted issues of accuracy, contextual relevance, cultural fit, and multimodal clarity. In documenting these judgments, they rendered visible epistemic moves such as evaluation, justification, verification, that are rarely captured in conventional lesson-plan assessments. Such visibility aligns with contemporary discussions of *assessment as learning*, which argue that the reasoning behind pedagogical decisions should be considered evidence of learning in its own right. The prompt-response trails, the moments of doubt, and the explanations for adopting or discarding AI suggestions illustrate how students are beginning to exercise professional judgement in technologically mediated contexts.

Embedding this form of reflective comparison into teacher education process-based approaches can help cultivate dispositions that are essential for responsible and context-aware AI use. Students learned not only how to refine prompts or adjust AI suggestions, but also how to sustain pedagogical control, negotiate multimodal meaning, and articulate why certain ideas aligned with their instructional purposes. As generative AI becomes increasingly entangled with curriculum design and classroom practice, these forms of epistemic reflexivity will become a central component of teacher professionalism.

While the study draws on a modest cross-sectional dataset, its implications are relevant across disciplines; when novice teachers are invited to compare their own design work with AI-generated alternatives, the contrast itself generates opportunities for critical examination, ethical reasoning, and professional growth. Subsequent research, particularly longitudinal studies, could examine how these reflective-AI literacies evolve across teaching practice and how they come to shape teachers' interactions with students, curriculum, and assessment. What the present analysis makes clear is that fostering reflective comparison serves as a means of supporting the formation of educators who can navigate the epistemic demands of AI-rich educational environments with discernment, agency, and pedagogical insight.

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Gamification and Game-Based Learning in the Mathematics Classroom: Evolutionary Perspective through the Utilization of Artificial Intelligence

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Abstract—Gamification constitutes a teaching method that enhances student interest and participation using elements borrowed from the paradigm of games. Game-based learning, on the other hand, utilizes the game itself as a tool for teaching and learning. Often in the classroom, a combination of gamification and game-based learning is used, which in the present study will be presented under the broader umbrella of gamification. Gamification increases student interest and active engagement in the learning process, encourages students to take initiatives within the framework of agency and inquiry-based learning, and improves skills in collaboration, teamwork, problem-solving, communication, and critical thinking. The availability of Artificial Intelligence (AI) to the general public has provided new possibilities in many sectors, including teaching and learning. With the use of artificial intelligence, educational platforms, platforms for easy translation (e.g., into Braille or other languages), chatbots for content creation, and platforms for creating quizzes and games facilitate educators in producing customized learning material and creating games based on children's needs and interests, in order to motivate their participation and improve learning outcomes. The present study will examine the evolution of gamification and game-based learning through the use of artificial intelligence. Through the analysis of examples, ways in which educators can combine traditional and modern forms of play with AI tools to enhance children's learning, collaboration, and creativity are investigated, and specific examples and their application in the mathematics classroom will be presented.

Keywords— *Artificial Intelligence, Gamification, Game-based Learning, Mathematics*

Introduction

In the teaching of Mathematics in Secondary Education, there is a perennial challenge of reduced engagement and "math anxiety" on the part of students. Traditional teaching methods, which rely often on passive knowledge acquisition and the memorization of procedures, fail to meet the needs of the modern digital generation. In this context, gamification has emerged as one of the most promising strategies for renewing educational interest. Concurrently, with the acceleration of technological developments, the education sector has undergone significant transformations, leading to the adoption of a student-centered approach. This transformation allows the learning process to be more effective, flexible, and personalized. Traditional learning methods have evolved and transformed into an innovative approach with the integration of new technologies such as artificial intelligence and gamification. While artificial intelligence determines students' learning levels and offers personalized educational programs, gamification techniques make the learning process more interactive and entertaining (Örpek et al., 2023). According to the definition by Deterding et al. (2011), gamification concerns the use of game design elements in non-game contexts. In education, this translates to the adoption of mechanisms such as points, levels, leaderboards, and role-playing scenarios, with the aim of increasing participation motivation. The combination of gamification techniques and artificial intelligence technologies in education attracts children's interest and gains even greater popularity by achieving a flow throughout the learning process (Örpek et al., 2023). However, the implementation of gamification often encountered practical obstacles, such as the preparation time required by the teacher and the difficulty of personalizing material for each student individually. The emergence of Artificial Intelligence (AI) and the widespread availability of Generative AI tools comes to overturn these data. As López-Galisteo and Borrás-Gené (2025) point out, AI now functions as a "design assistant," allowing educators to create complex game-like environments with minimal effort and time. The present study aspires to map this new landscape, focusing on how the coupling of AI and gamification can specifically benefit the understanding of mathematical concepts.

Theoretical Framework

Concept Distinctions: Gamification vs. Game-Based Learning

The concepts of Gamification and Game-Based Learning (GBL) are often confused, without, however, being the same. for this reason, their brief clarification is deemed appropriate, as they constitute the main concepts discussed in this article. Game-based learning is defined as the pedagogical utilization of digital games, as well as elements representing aspects of reality—such as content, themes, and visual representations—within the educational process (Liu et al., 2020). Furthermore, it constitutes an innovative teaching approach that integrates digital games with a documented educational function. The category of GBL also includes software applications designed with an explicit educational purpose, such as supporting learning, enhancing teaching, and assessing learner performance/progress. The instructional design of such games presupposes a systematic balance between integrating the subject matter and mechanisms that promote motivation and active participation, utilizing principles such as the gradual building of skills and the productive handling of failure, in an environment that maintains a high degree of attractiveness. Six fundamental structural

elements of games are considered to constitute the mechanisms supporting the learning process in game environments: (1) rules, (2) goals and objectives, (3) outcomes and feedback, (4) conflict/competition/challenge or opposition, (5) interaction, and (6) representation or narrative (Al Fatta et al., 2018). The relevant literature distinguishes game-based learning from gamification, as well as from the broader category of serious games. Serious games constitute complete games (digital or not), which are designed with primary purposes beyond entertainment (López-Galisteo & Borrás-Gené, 2025). Specifically, game-based learning, as a subcategory of serious games, concerns the pedagogical design and development of games that serve clearly defined learning objectives and lead to specific learning outcomes. These games incorporate content derived from the school curriculum or basic life skills, aiming to enhance the learning process and deepen content understanding by the learners (Al Fatta et al., 2018). On the other hand, gamification is defined as the use of game mechanisms, aesthetics, and thinking to attract and motivate students to solve certain problems. Gamification does not necessarily presuppose the use of digital devices or video games but consists of shaping educational or work processes with game-like characteristics (Liu et al., 2020). According to Deterding et al. (2011), the term is rendered as the integration of game design elements into non-game environments, aimed at enhancing engagement, motivation, and the overall user experience in activities that transcend conventional fields of play. Furthermore, the importance of structure, design, and methodology associated with serious games is highlighted, which, according to the relevant approach, can function as a practical application of gamification principles (Gao, 2024). Critical dimensions of gamification include game dynamics—including behaviors, interactions, and experiences of participants—pedagogical/instructional design, and game mechanics (procedures and rules) (Gao, 2024). At the application level, tools such as points, badges, leaderboards, and time-constrained activities are frequently used to enhance participation and recognize achievements (Gao, 2024). Correspondingly, Gómez Niño et al. (2024) point out that gamification constitutes a pedagogical strategy of integrating game elements into educational activities, both in analog and digital environments, aiming to improve the learning experience and shape or modify student behaviors in the classroom. Therefore, it is understood as a didactic strategy for enhancing motivation that aims at achieving specific behavioral and learning objectives through the creation of attractive participation environments, which favor the achievement of desired learning outcomes. Gamification refers to the integration of game mechanics and design elements into traditional teaching to enhance engagement and motivation. Indicatively, the successful solution of a system of equations on the board can be rewarded with "experience points" instead of conventional grading. In contrast, game-based learning concerns the utilization of a complete game (digital or analog) as the primary means to achieve a specific learning goal; for example, students engage in a strategy game where achieving victory presupposes resource management through the application of ratios and percentages. In both cases, games can function as a didactic medium for organizing and transmitting learning content. In the present study, both approaches are examined under the broader term of "playful learning," given that artificial intelligence can equally support and enhance both gamification and game-based learning.

Psychological Background: Self-Determination Theory

Gamification is grounded in psychological and pedagogical principles that highlight the role of motivation, engagement, and active learning; for this reason, it is often

interpreted based on the Self-Determination Theory (SDT) of Deci and Ryan (2000). According to this theory, intrinsic motivation is linked to the satisfaction of three basic psychological needs: autonomy, competence, and relatedness. Autonomy concerns the degree to which students have choices and perceive that they have control over their learning path; at this point, artificial intelligence can contribute through personalized learning paths, allowing differentiated choices regarding content, pace, and/or difficulty level. Competence refers to the sense of ability to face challenges and achieve goals. Especially in Mathematics, where experiences of failure often negatively affect students' self-concept, gamification can function as a "safe failure" framework, in which mistakes are treated as feedback information and an opportunity for repetition (e.g., "try again"). Relatedness concerns the sense of belonging and creating meaningful relationships in the learning environment; collaborative playful activities supported by artificial intelligence can enhance interaction, cooperation, and group cohesion. Furthermore, gamification can enhance intrinsic motivation to the extent that it structures learning experiences which cultivate autonomy (freedom of choice), competence (sense of achievement), and relatedness (interaction with peers). At the same time, the approach is also documented by behavioral theories of learning, given that reward and reinforcement mechanisms can increase the frequency of desired behaviors. Awarding points, "unlocking" levels, and providing immediate feedback function as reinforcers of participation and effort, contributing to the improvement of learning effectiveness (Akbarzhanovna, 2025).

The Transition from Static to Dynamic Gamification via AI

Until recently, gamification was "static": all students played the same game, with the same questions. Literature (Alenezi, 2023; Gao, 2024) indicates that AI introduces "dynamic gamification." Through Machine Learning algorithms, the system analyzes the student's profile and adapts the game in real-time. This solves the problem of mixed-ability classes, where "strong" students get bored and "weak" ones get discouraged. The role of Artificial Intelligence (AI) in predicting future behaviors in gamification environments is crucial, as it allows for the optimization of applied strategies through predictive analytics techniques. Utilizing usage and performance data produces data-driven insights, which support the adaptation of learning experiences to the expected needs and behaviors of students, while simultaneously facilitating the timely identification of early indicators of disengagement. Moreover, personalization is incorporated as a central principle in the design of game systems, as it connects with individual psychological satisfaction and the enhancement of intrinsic motivation. Targeted adaptation is considered critical for the engagement and effectiveness of educational games, insofar as it responds to specific learning needs and takes into account children's cultural background. Furthermore, AI contributes to the development of gamified educational systems that dynamically regulate the complexity and difficulty of activities based on student performance (Gao, 2024; López-Galisteo & Borrás-Gené, 2025). In a corresponding direction, Örpek et al. (2023) point out that the combination of AI technologies and gamification in education supports learning processes, enhances personalization, and facilitates educators in more effectively supporting students. Specifically, AI-based systems can analyze preferences and learning patterns, suggest customized content, and support instructional decision-making through performance and progress assessment. With the utilization of Generative AI techniques, the production of new high-fidelity content becomes feasible, often approaching the form and quality of content produced by humans. In the educational field, Generative AI can

be utilized to cultivate creative thinking, produce original learning resources, and enhance problem-solving skills.

Integration of AI in the Mathematics Classroom

The integration of AI into the gamification of Mathematics extends beyond the mere digitization of exercises, playing a fundamental role in transforming the teaching experience through several interconnected functions. A primary contribution is the regulation of adaptive difficulty. Drawing on the concept of "flow," which is central to games (Gao, 2024), AI helps maintain a delicate balance; tasks that are too easy cause boredom, while those that are too difficult induce anxiety. In Mathematics, AI platforms analyze a student's response time and accuracy to adjust the challenge in real-time—for example, automatically introducing parameters or fractions to linear equations when a student demonstrates proficiency, thus keeping interest undiminished.

Furthermore, AI addresses the challenge of providing personalized feedback in large classrooms where educators cannot simultaneously address every student's unique errors and needs. "Intelligent Agents" or AI chatbots can offer immediate, reasoned feedback (Örpek et al., 2023; Gao, 2024; López-Galisteo & Borrás-Gené, 2025). Instead of a simple "Wrong," the system can explain the specific error, such as a sign mistake during term transposition, prompting the student to try again with targeted guidance.

Finally, generative content creation via tools like ChatGPT, Claude, Gemini, or Copilot significantly empowers educators. These tools allow for the generation of infinite variations of exercises and scenarios, reducing workload while facilitating the creation of material tailored to students' interests, such as math problems themed around football or music (Örpek et al., 2023; López-Galisteo & Borrás-Gené, 2025; Wlodarski et al., 2025; Garzón et al., 2025).

Practical Applications and Teaching Scenarios in the Mathematics Classroom

In this section, some ideas for utilizing AI applications in the Mathematics classroom are presented, utilizing the tools mentioned in the literature (López-Galisteo & Borrás-Gené, 2025).

A first example with elements of differentiated instruction is creating a quiz on Polynomials and Identities. Using platforms like Wayground (or even Kahoot!), the integrated AI can be used to create a bank of 50 questions. By setting the quiz to "Mastery Mode," children progress at a different pace, and each child sees questions adapted to their level. To include gamification elements, power-ups can be used (e.g., "Time Freeze" or "Double Points") which children earn by correctly solving difficult exercises. The AI ensures that even students with lower performance will have opportunities for success by adjusting questions so they can earn power-ups, boosting their self-confidence.

Another playful activity could be designing a digital Escape Room for understanding Thales' Theorem in Geometry using Genially, ChatGPT, and DALL·E. Constructing the escape room requires creating the script, collecting questions, and images that will enhance children's engagement in the activity. In this specific escape room, according

to the plot, children are archaeologists trapped in a pyramid, and to open the doors, they must find the codes. The chatbot (e.g., ChatGPT) is given the prompt "Create a riddle requiring the use of Thales' Theorem to calculate the height of a pyramid, given its shadow and the shadow of a stick," and DALL·E is given the prompt "Image of an ancient Egyptian door with mathematical symbols carved on it." During the implementation of the activity, children work in groups, and if they get stuck, a chatbot (embedded in the scenario) gives riddle-hints (not the solutions), promoting inquiry-based learning.

Furthermore, with the help of AI, a Role-Playing Game can easily be created for the Statistics and Probability course (1st Grade of Senior High School/Lyceum) to enhance experiential learning and connect the subject with reality. Within this activity, children become "Data Analysts" in a videogame company. With the appropriate prompt, a chatbot (e.g., Gemini) produces a large dataset with hypothetical scores of players from around the world. Children must find the Mean, Median, and Standard Deviation to decide if the game needs to become easier or harder. Then, the teams present their decision to the chatbot (playing the role of "CEO"). The Chatbot counters with arguments containing errors, forcing the children to defend their analysis with correct mathematical documentation.

Finally, a Gamified Peer Review activity could be created with the help of AI, adapting Wlodarski's (2025) model for programming to Mathematics. For this activity, children write a Geometry proof. Then, they are asked to correct the proof of a classmate (anonymously) and give them "clarity points." Before submitting their corrections, they check them with a chatbot. The AI functions as a mediator. It checks the children's comments before they are sent. If a child writes "It is wrong," the AI prompts them: "Can you be more specific? Which theorem was not applied correctly?". Thus, mistakes are utilized for better understanding, and children cultivate critical thinking and collaboration.

Revival of Classic Games via AI

Artificial Intelligence allows for the easy conversion of well-known board games into educational tools without the need to purchase equipment. Some examples of games used in the math classroom are Monopoly, Battleship, and Taboo.

- **Monopoly (Math-opoly):** AI acts as "Banker" and "Chance." Every time a child wants to buy a property, ChatGPT creates a real-life problem: "The plot costs 200€. You have 150€, and the bank gives you the rest with a 10% interest rate that you must return in 3 rounds. How much will you pay in total?". In this way, Mathematics is connected with Financial Literacy.
- **Battleship of Functions:** Children place their ships on a Cartesian coordinate system. To "hit," they must give the equation of a line passing through the opponent's ships. AI can play the role of the opponent for children who want to practice alone at home.
- **Math Concepts Taboo:** Creating Taboo cards is time-consuming. With the prompt "Make 20 Taboo cards for the 3rd Grade Senior High School Math curriculum," the educator has ready material in seconds. Children are forced to describe the "Derivative" without saying the words "Rate," "Change," "Tangent," which requires deep understanding of the concept.

Benefits and Challenges: A Critical Approach

Pedagogical Benefits

Awarding points for completing exercises supports tracking student progress and enhances the sense of achievement. Transitioning to successive levels acts motivationally, as it promotes continuous skill improvement. Additionally, ranking relative to peers can increase engagement and encourage participation. Visual rewards contribute to reinforcing positive learning behaviors and developing self-confidence. Concurrently, the narrative structures of the game make the learning experience more attractive and meaningful for learners (Akbarzhanovna, 2025). Through the above elements, peer feedback can also be enhanced. Peer feedback—where children evaluate each other's work—can contribute to managing administrative load in crowded classrooms and support formative assessment processes. A significant advantage is that through systematic practice in providing and receiving constructive criticism, students develop feedback skills, which are considered critical for their academic and professional path (Wlodarski et al., 2025). Furthermore, the role of AI in education can be approached through three basic theoretical frameworks: Constructivism, Connectivism, and TPACK. Constructivism perceives learning as an active process, during which students build knowledge through interaction with the environment and collaboration with others. AI aligns with this view, as it supports adaptive and interactive learning environments that enhance experiential learning and self-regulated participation. Connectivism, respectively, highlights that knowledge is distributed across networks and that learning occurs through navigating and utilizing connections between sources, tools, and communities. In this context, AI can function as a critical "hub" facilitating access to heterogeneous information sources and supporting collaboration. Finally, TPACK is the theoretical framework for integrating technology into lesson planning through the combination of Technological, Pedagogical, and Content Knowledge. These three theoretical schemes highlight the potential of AI as a means of enhancing both knowledge construction and connectivity in educational environments (Garzón et al., 2025). Of pivotal importance is the ability of artificial intelligence (AI) to adapt the level of challenge, rewards, and feedback mechanisms to the individual preferences and abilities of each user, an element that refers to functional forms of personalization in learning environments. Specifically, it has been highlighted that game-based learning can respond to personalized student needs, shaping learning environments that support personalization, autonomy, sense of competence, and relatedness. Moreover, AI allows for providing real-time feedback based on students' actions and choices, which enhances the learning process and contributes to faster skill development. Immediate feedback constitutes a self-regulatory mechanism that supports motivation and stabilization of engagement with the learning activity (Gao, 2024). As a result of the above, gamification introduces immediate reward mechanisms, which make the learning process more attractive and contribute to reducing the fear of failure (Akbarzhanovna, 2025), while simultaneously enhancing student engagement, motivation, and active participation (Gao, 2024). Repeated contact with mathematical concepts through interactive activities supports memory consolidation and conceptual understanding, while tasks with clearly defined goals maintain high levels of participation. Furthermore, gamification facilitates learning at a differentiated pace, as it allows learners to choose activities corresponding to their skill level. Finally, digital collaborative games, discussion forums, and group challenges create opportunities for peer learning, social interaction, and collaboration (Akbarzhanovna, 2025). A multitude

of research papers documents that gamification can enhance student interest, support active engagement and initiative-taking (including inquiry-based learning and agency), as well as contribute to the development of skills in collaboration, teamwork, problem-solving, communication, and critical thinking (Hussein et al., 2023; Dochie et al., 2017; Angelelli et al., 2023; Li & Pan, 2023; Barragán-Pulido et al., 2023). Additionally, the playful dimension of learning activity is linked to the reduction of exam anxiety, as attention shifts to completing the activity and achieving the intended goals, rather than assessment through a grade. Game-based learning can offer an open environment for testing and reflecting on mistakes, which is critical for the creative process. Combined with artificial intelligence, support for innovative thinking processes is enhanced and, by extension, the development of innovation capability. From this perspective, the combination of gamification and AI is not limited to implementing educational policies and concepts but is also related to cultivating students' innovative thinking (Li & Pan, 2023). Beyond the above, gamification contributes to developing skills such as teamwork, written and oral communication, as well as assuming roles/leadership in technologically supported contexts. By extension, it can support 21st-century skills (indicatively: creativity, problem-solving, collaboration/interaction, and communication) and make learning more effective and attractive, insofar as it shapes a positive and supportive learning environment that also facilitates the work of educators (Gómez Niño et al., 2024). Furthermore, pedagogical benefits arise related to promoting inclusion and enhancing equal participation in the classroom. As Alenezi (2023) points out, educators observe that technology can enhance the participation of more introverted students who hesitate to express themselves orally but participate actively through digital platforms. Concurrently, AI supports the adaptation of educational material for students with learning difficulties (e.g., dyslexia), through functions such as audio rendering of utterances or text simplification, enhancing equal access to knowledge.

Challenges and Ethical Concerns

Despite its documented benefits, gamification supported by artificial intelligence (AI) is accompanied by challenges requiring pedagogical vigilance. First, excessive emphasis on extrinsic rewards may shift student attention from substantive understanding to accumulating points, with the potential consequence of weakening intrinsic motivation. Furthermore, "game fatigue" can lead to a gradual reduction in engagement and disengagement over time (Akbarzhanovna, 2025). At the same time, dependence on digital infrastructure constitutes a critical limitation, as unequal access to devices and online platforms can reduce the effectiveness of relevant interventions (Akbarzhanovna, 2025; Garzón et al., 2025). From a cognitive and psychosocial perspective, excessive use and/or inadequate pedagogical alignment of AI systems may be linked to adverse consequences, such as reinforcement of digital dependence, increased anxiety, limitation of creativity, and increased psychological load—especially when applications are poorly designed or hyper-focused on assessment functions (Garzón et al., 2025). Consequently, avoiding overly techno-centric approaches that downgrade the pedagogical and emotional dimensions of learning is deemed necessary (Garzón et al., 2025). Finally, the digital divide constitutes a factor that can either reproduce existing inequalities or create new ones, provided that access to technological resources is not equal (Garzón et al., 2025). In this sense, gamification ought to be designed with terms of inclusion, taking into account that not all schools and all students possess equivalent access to devices and reliable internet connection.

Moreover, the need for high-quality and pedagogically documented content design is highlighted, given that inadequately structured gamified learning activities may not achieve the intended educational goals (Akbarzhanovna, 2025; Garzón et al., 2025). As Gómez Niño et al. (2024) also point out, a critical prerequisite is the clear definition of learning objectives and the design of game mechanics that align with them, so that an attractive learning experience is shaped for students. This process presupposes: (a) utilizing design thinking principles, (b) developing digital scenarios or learning environments that support motivation and participation, as well as valid assessment in collective tasks, and (c) ensuring pedagogical balance, with systematic reflection regarding the implementation and evaluation of scenarios in relation to the characteristics of the respective student/educational context, as well as using educational material adapted to students' interests and needs. Addressing ethical issues emerges as an equally critical dimension in utilizing AI in education (Garzón et al., 2025). The use of digital platforms presupposes special care for the protection and lawful processing of minors' personal data, in compliance with the regulatory framework of the General Data Protection Regulation (GDPR). Beyond legal compliance, relevant literature points out that "human" parameters of AI adoption—such as privacy, bias, and acceptance by users—constitute key challenges. In this context, trust, transparency, and ethical governance constitute fundamental prerequisites for the responsible and effective integration of AI in educational practice. Further, the issue of reliability of generated answers arises, especially in the form of so-called "hallucinations." According to Joshi (2025), the term refers to cases where large language models (LLMs) produce inaccurate, misleading, or fully fabricated information, creating significant challenges for users and highlighting a central field of concern in generative AI. Specifically, these inaccuracies are often formulated with high apparent certainty and linguistic fluency, which makes their timely detection difficult. As language models are integrated into real educational context applications, risks associated with such errors become more intense. For their mitigation, methods such as utilizing domain-specific data, prompt engineering optimization, and retrieval-augmented generation strategies have been proposed and developed. Consequently, when AI is used in teaching Mathematics, there is a probability of errors in complex calculations or high-complexity problem-solving procedures. This fact highlights the importance of designing AI systems that are not only powerful but also transparent, verifiable, and reliable. At the same time, pedagogical mediation becomes critical: the educator ought to systematically check the generated material and cultivate skills of critical evaluation of AI answers in students, so that documented use is enhanced and the risk of reproducing inaccuracies is limited.

Implementation Methodology for Educators

For the successful integration of the above, a three-phase model is proposed for the educator. The first phase concerns design and preparation. It is important to define the expected learning outcomes (e.g., "State Thales' Theorem and its converse and utilize them in modeling and problem solving"), select appropriate tools (e.g., Genially for storytelling, Wayground for practice), and produce activity material (possibly utilizing a chatbot for script and exercises). The second phase concerns the implementation of the activity in the classroom. The educator gives clear instructions on the game rules to the children and holds a facilitator role: circulating among groups and intervening only where needed to enhance autonomous inquiry by the children. At the end of each activity, reflection and evaluation are necessary. Reflection can occur either through

discussion or in writing with questions like "What did we learn?", "Where did we struggle?", "How did we overcome this difficulty?". For evaluating the process, questions concerning the game's effectiveness, how interesting it seemed to the children, and whether the set goals were achieved must be answered by the educator and the children.

Conclusions

Gamification and artificial intelligence compose a new, dynamic learning ecosystem in secondary education. The present analysis demonstrates that technology is not an end in itself, but a means to achieve higher pedagogical goals. The examples presented reveal how even the most abstract mathematical concepts can become accessible and attractive. The role of the educator remains central but mutates: from a transmitter of knowledge to an experience designer and facilitator of knowledge. Training educators in gamification design with AI constitutes an investment for a school that is more inclusive, more creative, and more effective, where Mathematics ceases to be a bugbear and becomes a tool for discovering the world.

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“Ethics of Artificial Intelligence: Social and Philosophical Challenges of the Future”

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Abstract: Artificial Intelligence (AI) and the broader digital revolution are the most defining phenomena shaping the 21st century. They are transforming not only production, work, and knowledge, but also the very anthropological paradigm, heralding the arrival of a new historical era in which the boundaries between the human and the artificial are becoming increasingly fluid. These (ontological) changes offer unprecedented opportunities for progress, and at the same time some of the most profound existential and ethical challenges humanity has ever faced.

When AI crosses the threshold of human intelligence and we move on to Artificial General Intelligence (AGI) and Artificial Superintelligence (SAI), we may no longer think of humans in the same way we have interpreted them in the modern era and every historical period that preceded it. This fundamental transformation in the fields of society, philosophy, and politics is linked to the concept of transhumanism and raises critical and novel questions about the control of AI, its ethical and ontological dimensions.

This paper proposes an approach that emphasizes the philosophical and ethical dimensions of AI, as well as those of education, rather than the technological or economic ones. The younger generations will need to cultivate a new ethical pedagogy, which will aim to address rapid technological changes and the fundamental social and political transformations that these changes bring about.

Keywords: Ethics, Philosophy, Artificial Intelligence, AGI, Posthumanism

1 Introduction

When the term Artificial Intelligence (AI) enters the public sphere, it often conjures up images of hordes of robots attacking us in the future. However, AI is not primarily about robots or just the future. AI is already present in our lives and is everywhere. Every time we use social media such as Facebook, Instagram, or TikTok, we are using AI platforms, probably without even knowing it.

To appreciate how much AI has already changed the world, let us consider just one application: *Google*. Google is one of the most powerful AI entities that exists today. [21] Information, knowledge, work, education, entertainment, and communication have ceased to be the same for everyone thanks to it. Human history has already been transformed tectonically thanks to a single AI platform: Google. And we are only seeing the first stages of its development. From the depths of the 21st century comes a flood of AI, of which we have only seen the first drops.

AI already frequently wins lawyers in legal battles, [22] manages judges' work, [23] makes faster diagnoses than doctors, [24] conducts research and writes articles for journalists, [25] and teaches mathematics or history to students in a personalized way.[26] Even art, the last bastion of human ontology, is being shaken by the onslaught of AI: algorithms compose classical music, poetry, and visual art that stand shoulder to shoulder with those of Homo sapiens.[27] Due to this wide range of possibilities, it is predicted that AI may replace us in the future in half or more of the professions we currently hold.

A study by the International Monetary Fund (IMF) highlights that "almost 40% of global employment could be exposed to AI."[28] According to this study, advanced economies face a greater risk of job losses due to AI taking over highly skilled positions. The same conclusions have been drawn from previous studies, e.g. by Oxford University[29] or the EU. [30]

The question is, "Why is AI so influential?" Or to put it another way, why is it philosophically so important that it has been described by technologists such as Google CEO Sundar Pichai as "more important than fire, electricity, or any other of the great things humanity has done?" [31] AI is important because *intelligence* itself is important. Homo sapiens did not prevail among other creatures on Earth because they had greater muscular strength than them. They prevailed because they had greater intelligence than them. Natural evolution took millennia to bring our minds to this level. However, AI can approach or even surpass human intelligence not in millennia, but in a few decades or even a few years from now.

[21] See, for example, Google's participation in the most important annual AI conference, NeurIPS, where it has more scientific publications than any other institution, including Stanford, MIT, Microsoft, Oxford, etc.: VIN AI, “An overview of NeurIPS 2021’s publications”. https://tinyurl.com/mt6x7ba7, last accessed 2025/10/29.
[22] R. Macey-Dare (2023).
[23] Dl. Lo (2021).
[24] G. Yuchao et al. (2022).
[25] Reuters (2023).
[26] L. Krstic, M. Kristic (2022).
[27] R. Gozalo-Brizuela, C. Garrido-Merchan (2023).
[28] K. Georgieva (2024).
[29] C.B. Frey, M. Osbourne (2013).
[30] CEDEFOP (2017).
[31] S. Pichai (2020).

Many experts estimate that AI will reach human levels by 2075. Several believe that this can be achieved by 2050. [32] Others, following the emergence of the AI platform ChatGPT (2022), believe that this achievement may now be much closer than we think. For example, Geoffrey Hinton, one of the leading scientists in the field, widely known as the "godfather of artificial intelligence" and winner of the Turing Award (2018) and the Nobel Prize (2024) for his achievements in the field of AI, stated in 2023: "In five years from now will be able to produce logic better than us humans. [33]

This emergence of AI creates a historically unprecedented future, the novelty of which consists philosophically in the following: from a point where high intellectual judgment was the exclusive privilege of humans, and thanks to which we created every facet of our civilization (we built the Pyramids, the Parthenon, split the atom, composed music, laws, philosophies, arts, science), AI is breaking the human monopoly and acquiring high intelligence itself—even if it does not, of course, resemble human intelligence.[34]

The essence of our culture, high logical judgment, or otherwise known as Reason [Logos], which Aristotle and the core of modern philosophy claim distinguishes humans from other beings and thanks to which we dominate our ecosystem, now becomes the Being of a completely new type of entity. Here lies a major philosophical, ontological, and ethical challenge for the near future, which is as follows:

Since higher intelligence is the characteristic that has allowed humans to dominate the planet, and AI tends to reach or even surpass human intelligence, the question that remains to be answered in the 21st century is "will humans be able to control something more intelligent than ourselves?"

2 Social and Philosophical Challenges of Posthumanism

2.1 AGI and SAI

This question is historically relevant in light of the future we face. An AI that can match human intellectual abilities is referred to in the literature as AGI (Artificial General Intelligence), or General AI. An AI that can far exceed human intellectual abilities is called Superintelligence (SAI).[35]

The ontological and political condition that brings about such a network of technology with intellectual abilities stronger than those of humans is referred to in philosophical literature as *Posthumanism*.

Posthumanism is a possible future condition of beings that will far exceed the intelligence of sapiens. These beings will be products of technology (e.g., AI or genetic engineering) and will have no connection to humans. They may not have gender, bodies, or spoken language, [36] or they may perceive the universe so differently that

[32] N. Bostrom (2017, 18-9).
[33] *CBSNews*, "60 minutes", https://youtu.be/qrvK_KuIeJk?t=620 (10:21), last accessed 2024/10/29.
[34] Σχετικά με τη «φιλοσοφία του νου» που εξετάζει τις διαφορές (ή ομοιότητες) μεταξύ ΤΝ και ανθρώπινου νου βλ. π.χ. J. Searle (1980).
[35] See, for example, N. Bostrom (2017, 11-21).
[36] R. Ranisch and S. Sorngер, *Post- and Transhumanism, An introduction* (2014, 8): "There is no common understanding of what transhumans are; opinions range from transhumans being a biological species, a cybernetic organism, or even an immaterial entity".

issues such as human morality seem incomprehensible to them. The gap in perception between them and us will be as wide as that between sapiens and other species such as chimpanzees, insects, or birds. The first difference between humans and posthumans is therefore *ontological: they are two different species*.

The second difference is *hierarchical*: the post-human has asymmetrically higher intelligence than humans, and therefore in the world of post-humanism, the dominance of sapiens (which stems from their powerful intellect) recedes. From the top of their ecosystem, Homo sapiens will be relegated to lower levels, without ruling out even their extinction.[37]

The difference between a highly advanced AI and us Homo sapiens will not be what many people imagine. It will not be like comparing, for example, the intelligence of a smart person with that of a naive person. It will be like comparing the intelligence of a human being with that of another species, such as dogs or cats. Therefore, the way such AI perceives reality will be completely different from ours – and probably invisible to our perception. Just as the human world is largely invisible to other creatures, because we are separated by an abyss of intelligence. How could, for example, a dog or a cat understand with its intelligence what meanings are contained in this or any other text? How could it understand simpler aspects of our culture, such as what a pencil is or what a school is? Our world is largely invisible to other beings. Just as invisible to them is the sweeping *impact* we have on their world. How can a school of fish in the Mediterranean understand that its life has been saved or endangered by a new decision of the European Union on its fishing policy? Our collective impact on them, although it may be sweeping, is completely invisible to them. Similarly, the goals and impact that a super-intelligent AI will have on the human world may be equally invisible to humans. This is an issue similar to what is known in AI circles as the "AI explainability problem." [38]

The goals of such a high AI may not only be invisible, but also threatening to us – without this being the goal of AI.

Let's conduct a thought experiment. Let's consider the difference in intelligence between humans and ants. And let's assume that humans are building a hospital (obviously for the most benevolent of reasons) on a plot of land where myriads of ants live, but this project may displace or even completely wipe out the ants that live there. The goal of humans, which is to build a hospital, comes into direct conflict with the goal of the ants, which is their survival, not because of any animosity humans have towards them. It is simply because of the different intelligence and different goals that the two species have.

However, the ants will never understand (and will never share) the good-intentioned reasons that led to their total destruction. Similarly, humans will never be able to

[37] The term "post-humanism" also has a second, different meaning in philosophy—particularly in postmodern continental philosophy, poststructuralism, or feminism. There, it refers to a concept that signifies "the crisis of humanism" (Ranisch, 14). In these cases, poshumanism does not imply the end of humanity, as technological transhumanism does, but rather *the end of a specific idea we have about humanity* (ibid. 15).

[38] The explainability problem means that in some cases AI may achieve the goals we have set for it, but may not be able to explain to us how it did so; or, more precisely, we may not be able to understand how AI achieved something. See, for example, C. Zednik (2019).

comprehend, nor share, the work of an artificial superintelligence that threatens their existence. The actions of such an AI network will be *invisible* to us.

The perceptual advantage of AI is one of the most significant risks to humanity in the near future, as highlighted by prominent contemporary philosophers and scientists. Bostrom (one of the pioneering philosophy professors at Oxford University, with numerous international distinctions[39]) believes that by the middle of the century, AI will reach capabilities comparable to those of humans. He argues that the history of humanity will then change completely, without ruling out even its extinction.[40] The rapid development of AI is also predicted by Ray Kurzweil, director of artificial intelligence engineering at Google and, to a large extent, the architect of modern AI, who estimated that machines would surpass our intelligence by 2045. [41] In fact, in his recent work *Singularity is Nearer* (2024), he revises his estimate and claims that AGI will be achieved by 2029. Other leading scientists also recognize how necessary it is to prepare for the proper management of AI, such as Stephen Hawking, who pointedly noted: "If a superior alien civilization sent us a message saying, 'We're coming in a few decades,' would we reply, 'OK, call us when you get here, we'll be waiting'? Probably not. But that's pretty much what's happening with AI." [42]

We are intelligent enough to create an AI in the future of the 21st century that is more powerful than our own, but also naive enough to possibly do so without adequate safeguards.

2.2 Ontological and Anthropological Dimensions of Technology

The issue is not, of course, the demonization of TN – which offers countless benefits, otherwise we would not have created it. Much more than that, the issue is not the demonization of technology. Technology has given us many valuable gifts: from the clothes we wear to the technology of writing, and from medicines and vaccines to the manufacture of musical instruments, all of these are products of technology. In particular, modern technology, that of the last 100 years, together with democracy, has shaped the best world that has ever existed for humanity. People today live longer than ever before, are more educated than ever before, and have the largest middle class ever created[43] - thanks to industrial technology.

Thanks to a unique feature that is exclusive to human nature: *technology*. Everything in human civilization is technology: the clothes we wear, the floor we walk on, the seats we sit on, the building we are in. Everything is technology. Humans are the only beings, compared to other creatures, that produce a panoply of wealth from different technologies (from the Paleolithic wheel to modern spaceships). And thanks to this technological wealth, humans stand out as beings, build their culture, and dominate other beings.

In this sense, since technology sets us apart from other beings, we can say that technology is not a simple means, a "tool," as it is usually perceived. *Technology*

[39] See “Bio” https://nickbostrom.com/#bio, last accessed 2025/10/29.
[40] N. Bostrom (2017, 123-127).
[41] R. Kurzweil (2006, 122)
[42] S. Hawking, https://tinyurl.com/68h885d2, last accessed 2025/10/29.
[43] See, for example. St. Pinker (2012) and (2018) and H. Rosling (2018).

belongs ontologically to the Being of human nature. It is a fundamental dimension, an essence, of human existence – without which man is not man.[44]

3 Educational Policy and Artificial Intelligence

3.1 Training in the Use of Artificial Intelligence and Soft Skills

However, the deep-rooted anthropological and ontological significance of technology does not mean that it does not bring with it enormous problems – such as the control of AI or the climate crisis, which is also a result of the abuse of industrial technology – due to the pollutants produced by industrial factories, industrial means of transport, the plastics we all consume, etc. We live in a world of duality. On the one hand, new technology has greatly improved our lives. On the other hand, it has also brought the number one problem on the global agenda that threatens the well-being and very existence of the human species: *the climate crisis*.

That is why educational policy is called upon to play a pivotal role in managing the maximum and unprecedented challenges posed by industrial and, henceforth, digital technology in our futuristic era. The 21st century is the first time in human history that generations are facing planetary-scale threats stemming from technology. The greatest challenges to civilization, the climate crisis, the control of AI, genetic engineering on humans, nuclear weapons, and fake news dominating cyberspace, all now stem from a common root: *technology*.

The educational policy of the 21st century must not turn its back on this new and widespread reality. It is called upon to compose and teach an Ethics of Technology, especially AI, which will delve deeper into issues such as those mentioned above.

The proposal of this paper consists precisely of this. That education is the important pillar in which we are called upon to invest, so that on the one hand we can take advantage of the wave of fruitful transformation brought about by AI, and on the other hand we can avoid, or at least mitigate, its significant threats.

There are three key dimensions that education policy is called upon to develop for the present consideration. We briefly note the first two, which are also discussed in detail in the international literature, and further analyze the third, which is the primary philosophical and pedagogical position of the work *Philosophy of Artificial Intelligence.*[45]

A) *Educational policy should develop AI skills at all levels of education*: from primary to tertiary education and adult education. In the near future, most jobs and sciences will be carried out through the mediation of AI. Countries that do not invest in educating their citizens in the use of AI, the core of the 4th Industrial Revolution, will thus lag behind in international competition – economically, professionally, scientifically, militarily – compared to countries that do. Countries that fail to take advantage of it will experience a similar development to those that did not invest in the Industrial

[44] The emergence of technology as the ontological essence of man is a primary philosophical proposition that is analyzed extensively in G. Hatzivassiliou. (2023, especially 15-16, 93-103, 108-114, 129-138).
[45] Γ. Χατζηβασιλείου (2023). Βλ. ιδίως το 4ο κεφάλαιο «Η απόκριση στην τεχνολογική πρόκληση».

Revolution of steam and electricity in the 20th century. A path of stagnation and regression.[46]

B) *The second area in which education policy is called upon to invest is the development of soft skills*. The 21st century presents a rapidly changing professional and social environment precisely because of emerging technologies and AI, which are constantly changing the labor market. This trend will continue to grow as technology itself becomes increasingly sophisticated. The adults of tomorrow will need to adapt again and again to the working environment, constantly acquiring new knowledge as the labor market changes incessantly.

Many educational studies argue that schools should henceforth emphasize the teaching of soft skills that will enable tomorrow's workers to adapt to the demanding social ecosystem and labor market of the future. According to these studies, the most important soft skills are: critical thinking, creativity, curiosity, organizational skills, and emotional skills such as communication, empathy, and emotional stability.[47] This is also supported by economic experts, such as the World Economic Forum and the OECD.[48] International economic organizations, policymakers, and a significant part of educational research all come to the same conclusion: the new educational currency in the information age is ge*neral skills*.

3.2 A Curriculum on "Ethics of Technology" for Schools

C) *The third direction in which educational policy is called upon to invest for the present study is the formulation of a Curriculum of Ethics in Technology*. In other words, *Philosophy of Technology*.

Along with the opportunities for economic, social, and political development, AI also brings big challenges for the international community. Because of this, UNESCO has called on states to "immediately implement the recommendation for the ethical management of AI," stating that "the world needs stronger ethical rules for AI: *this is the challenge of our time*." [49] A symptom of the current trend of reflection prevailing in the international academic community is the letter co-signed in 2023 by dozens of leading experts, scientists, and philosophers in AI. In it, they sound the alarm about the risks, noting: "Mitigating the threat of our extinction from AI should be a global priority alongside other risks *such as pandemics and nuclear war*." [50] The scale of the opportunities and challenges posed by AI is therefore of historic proportions, and the associated threats must be taken seriously by the scientific and political communities.

[46] Η ΕΕ έχει μαζί εκδώσει συγκεκριμένες οδηγίες για την ηθικά ορθή χρήση της AI στην εκπαίδευση. Βλ. European Commission: Directorate-General for Education, Youth, Sport and Culture, *Δεοντολογικεσ κατευθυντηριεσ γραμμεσ σχετικα με τη χρηση τεχνητησ νοημοσυνησ (TN) και δεδομενων στη διδασκαλια και τη μαθηση για εκπαιδευτικουσ*, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2766/297983, last accessed 2024/10/29.

[47] C. Davidson (2017), B. Trilling (2009), C. Kivunja (2015).

[48] Βλ. αντίστοιχα World Economic Forum, *The Future of Jobs* (2016) και μια σύνοψη του στο https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/, και OECD, *Future of Education and Skills 2030, Conceptual learning framework, Skills for 2030* (2019) και μια σύνοψη του στη σ. 3, shorturl.at/rtEJ4, last accessed 2024/10/29.

[49] Emphasis added. See https://www.unesco.org/en/articles/artificial-intelligence-unesco-calls-all-governments-implement-global-ethical-framework-without last accessed 2025/10/29.

[50] *Center for AI Safety,* "Statement on AI Risk", https://www.safe.ai/statement-on-ai-risk, last accessed 2025/10/29.

Those who view new technology as the fundamental source from which the entire future of humanity springs can also see the need for the Ethics of Technology (i.e., the Philosophy of Technology) should become a methodical subject of instruction in the schools and universities of the 21st century.

We, the people of today, are participants in and witnesses to an unprecedented situation. After 300,000 years of the existence of the species Homo sapiens, our technology now has the power to orchestrate humanity's most critical act, and in 100 or 200 years our civilization may no longer exist as we know it, or may "simply" cease to exist. Contemporary technological phenomena (AI, biotechnology, the climate crisis, nuclear weapons) are completely reshaping our universal priorities.

Philosophy and pedagogy are called upon to reflect on this big picture and to disseminate their conclusions directly and comprehensibly in the public sphere, given the rapid pace of developments. More than ever, education must now sharpen critical thinking around the protagonist of our century: high technology. The argument of this paper is that the Philosophy of Technology is called upon to become part of education: to be included in university departments of Philosophy and Computer Science, but above all *in secondary schools themselves*, using analyses from contemporary philosophical theories for teaching purposes. Teenagers need to be educated in the ethics of technology (and not in some kind of technophobic reading that is often found in philosophy and education). Their youthful perceptions will determine their future demands from the novel universe of technology that is now emerging.

Technology is not just about building a computer, a mobile phone, or a bow. It is also about what you do with them once you have built them. In other words, it is also about ethical management, which is becoming more complex than ever. Until yesterday, most people agreed on how best to deal with the frightening dimensions of technology. Few argued, for example, that "it is good to start a war with nuclear weapons" or "it is good to exacerbate climate change with polluting factories." We largely had a common theoretical understanding of technology (even if we often deviated from it in practice).

But now there is no common ground, even in theory: the dreams of some in the field of nanotechnology or genetic engineering become the nightmares of others. This is the first time that technology has so many ways to benefit or degrade the life of humanity, and this makes its ethical interpretation extremely complex but also necessary. Today's teenagers, tomorrow's adults, need to be educated in the ethics of technology through a single course, a single curriculum, covering everything from fake news on the internet the risks and benefits of AI and genetic enhancement, to the threats of the ecological crisis.

The school of the 21st century is required to highlight the new diffuse reality. It is called upon to mobilize an Ethics of Technology and TN that will delve deeper into issues such as the above. To lay the foundations for a different reality that will be less morally primitive than our own in the digital world we are forging. A reality where citizens will have developed an awareness of the wave of challenges rapidly approaching from the depths of technology.

The ethics of technology, like any ethics, can be taught, as we have known for centuries. The first text in history to deal with this issue is Plato's *Meno*. The protagonist of this

dialogue is Socrates, who demonstrates that moral virtue "is knowledge" and can therefore be taught.[51]

It would be paradoxical, after all, if Socrates, one of the most influential educators in history, argued that morality *cannot* be taught. Then the whole endeavour for which he (literally) gave his life, to teach moral philosophy, would be placed on a foundation that was not only shaky, but non-existent. That is why *Meno*, in our reading, is the only Platonic text that, from its very first words, directly addresses the issue that concerns it: *because it wants to emphasize its great importance*. He writes in the opening sentence: "Can you tell me, Socrates, whether virtue can be taught? Or is it not taught, but can be acquired through practice? Or is it not acquired through learning, but exists in people because of their nature?" The opening seems to hint at the critical importance of the subject for Plato's entire intellectual edifice: because if virtue (i.e., moral philosophy) is considered unteachable, then Plato's entire endeavor to teach philosophy *collapses at once*.

Aristotle also supports the same conclusion. In a famous passage, he notes that morality is something we can improve through constant practice and emphasizes that in order to develop a virtue, one must become accustomed to it "εὐθὺς ἐκ νέων", that is, from as young an age as possible. He writes in *Nicomachean Ethics*: "moral virtue is the result of habit. [...] It is therefore not of little importance to acquire these or those habits as young as possible; on the contrary, it is of great importance, or rather, *it means everything*."

Every ethical issue can therefore be taught. And the most urgent, voluminous, promising, and at the same time frightening ethical issue facing humanity at the dawn of the third millennium is that of technology. The ethics of technology must be taught "from an early age" in the schools and universities of the 21st century. The generations of our time seem to be the ones who bear the historical responsibility of defining (practically, politically, and ethically) new technologies before their development becomes uncontrollable.

The world is changing rapidly. In the coming decades, we will move towards a new type of reality where the focus will no longer be solely on relations between nations, companies, and people, as it has been until now. The focus will be on relations between Homo sapiens on the one hand and AI on the other. This will be the new network of relationships. And what content this will take on, as well as the scale on which it will exist, is related to ethics, that is, the philosophical path of technology that we will follow.

Philosophy and education are the most important arrows in our quiver for managing the technological challenges that lie ahead – challenges that are not yet widely visible. After all, it will not be the first time that we have been slow to notice dark clouds gathering on the global horizon. The same thing happened, for example, with climate change, which was identified as early as the 1970s but which almost no one paid attention to until recently. It was not until 2008 that the first law in history was passed (in Britain) committing a country to reducing its greenhouse gas emissions.[52] Now, however, the

[51] *Meno* 87c. «Εἰ δέ γ' ἐστίν ἐπιστήμη τις ἡ ἀρετή, δῆλον διδακτόν ἄν εἴη».
[52] See related "What is the 2008 Climate Change Act?", *London School of Economics*, last accesed 2025/10/29. https://www.lse.ac.uk/granthaminstitute/explainers/what-is-the-2008-climate-change-act/

issue is a priority of international dimensions: governments are trying to adapt to its needs, academic institutions are studying its threat in depth, schools are teaching how to manage it, and a sense of urgency now surrounds every table where ecological issues are discussed.

The same international trend will sooner or later be reflected in the reading of this study and in TN's new digital technology, as it will constantly increase its opportunities and threats. The management of technology, the *Ethics of Technology*, is becoming the most important "*software*" that modern man is called upon to develop.

Education in the 21st century has the potential to create a unified educational curriculum on the *Ethics of Techn*ology that will sharpen awareness and critical thinking around the most important issue of our time. A curriculum that will foster awareness of the wave of threats and opportunities that new technology brings.

For this reason, it is useful to develop a concise, clear introductory program to the *Philosophy of Emerging Technology*. What are the most crucial areas of social impact exerted by new technology? Or, in other words, what would an introductory teaching program on the Philosophy of Emerging Technology contain? In our view (as reflected and analyzed in detail in the *Philosophy of Artificial Intelligence*[53]), the most controversial teaching modules of an Introduction to the Ethics of New Technology are the following:

1. The criticality of modern technology
2. The issue of artificial intelligence
3. The issue of the Internet
4. The issue of biotechnology
5. Social Media
6. Democracy and Social Media
7. Technology and the Climate Crisis.
8. What is Technology?

The above key points outline a preliminary map, a preliminary definition, of the ethics of new technology. The pedagogy of an *Ethics of Technology* based on the above principles has the potential to instill in the public consciousness an awareness of the abundant challenges that technology poses in our time.

4 Conclusions

This does not mean that we need to develop a phobia of technology in education. *Quite the contrary.* Technology, as highlighted above, is a valuable aspect of human nature that has set us apart from other beings. It has relieved us of the unspeakable hardships of life, thanks to the houses and medicines it has created, and it has enriched our minds to an exciting degree thanks to inventions such as writing and the endless texts it has provided, or the technological instruments of science that have propelled our knowledge in every possible and impossible direction. The demonization of technology

[53] Γ. Χατζηβασιλείου (2023). For a specialized and analytical proposal regarding the content of the present Curriculum, see pp. 379-380, where the above sections are noted, and each one is accompanied by references to specific extensive pages of this study (and others) that can recommend the potential content of the above 8 sections.

(often found in philosophy and education) is a dizzying intellectual acrobatic feat that must be avoided.

Countries that lose touch with new technology will also lose their ability to develop their culture, economy, and even their philosophy—since they will be unable to understand the new world around them. They will follow a path similar to that of states that failed to take advantage of the technology of the first industrial revolution in a timely manner: a fate of backwardness, degradation, and subjugation to the orbit of other states and powers.

However, the above does not negate the fact that we are now facing maximum threats from our technology. In the dawning digital age, we are moving in a two-way direction: on the one hand, we are called upon to seize the magnificent opportunities that technology offers, and on the other, to render its total risks inert. What will happen to the economic power of citizens if AI takes over most jobs in the long run? How will democracy survive if we transfer our decisions from our brains to "omniscient" AI entities such as future LLMs like ChatGPT, which tomorrow will have incomparably more powerful capabilities than they do today? How will we know in the future if increasingly capable AI will make mistakes when we trust it more and more? And how can we control AI that surpasses human capabilities?

We need a critical mass of citizens trained to think critically and respond appropriately to issues such as those above, which neither current politics, education, Google, nor any form of AI is able to address. If we teach subjects in schools today that are critical for the future, such as geology, why not also teach a curriculum on the challenges of technology, since it will have a tectonic impact on the future of humanity?

Of course, we cannot imagine exactly what this future will be like. But the old saying still holds true today: the only way to predict the future is to invent it. And the best way to invent the future now, to avoid painful pitfalls and seize its rich opportunities, is the most successful solution that humanity has found over millennia to improve its future – that of Education.

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Emotional Botany — Giving Nature a Voice Through AI and STEAM

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Abstract—Emotional Botany is a STEAM-based educational project that bridges the gap between human and plant communication through artificial intelligence, environmental sensing, and creative design. Students developed an AI-driven system in which plants are personified through an avatar named Freya, who gives plants a face, a voice, and emotional expressions derived from real-time environmental data. Using a network of sensors measuring soil moisture, temperature, humidity, light intensity, electrical conductivity, and plant bio-signals, the system translates biological and environmental parameters into meaningful feedback for humans.

The project combines plant physiology, precision agriculture, machine learning, and human–computer interaction within an inquiry-based learning framework. Learners explore how plants perceive their environment, how data can be collected and interpreted, and how AI models can support sustainable agricultural decision-making. Beyond productivity optimization, Emotional Botany emphasizes empathy, environmental awareness, and emotional intelligence by encouraging students to see plants as active living systems rather than passive objects.

A distinctive dimension of the project is its exploration of AI as a tool for emotional well-being. Freya not only communicates plant needs but also interacts socially with users by recognizing facial expressions and responding empathetically. This dual interaction opens discussions on companionship, loneliness, and the ethical design of emotionally responsive AI systems.
Emotional Botany demonstrates how interdisciplinary AI education can cultivate digital competence, ecological sensitivity, creativity, and social awareness, positioning AI as a bridge between sustainability, empathy, and intelligent design.

Keywords: Artificial Intelligence in Education, Precision Agriculture, Emotional AI, STEAM Education, Sustainability

Introduction

Plants are fundamental to life on Earth, yet they are often perceived as passive organisms. Contemporary research demonstrates that plants possess complex sensory and adaptive behaviors, enabling them to respond dynamically to environmental stimuli (Chamovitz, 2017; Gagliano et al., 2017). At the same time, advances in artificial intelligence allow the collection and interpretation of biological data in real time, opening new possibilities for interdisciplinary education.

Emotional Botany was designed as a STEAM-based, project-oriented learning experience which situates AI learning within environmental, agricultural, and emotional contexts. Rather than teaching AI as an abstract or purely technical discipline, the project invites learners to explore how intelligent systems can mediate sustainable human–nature relationships. By giving plants a "voice" through an AI avatar, students engage deeply with biology, data science, engineering, ethics, and emotional intelligence.



Image 1: Meet "Freya" the avatar that gives plants a voice

Project Design and Technological Framework

Emotional Botany is implemented as an integrated cyber–physical system centered on a Raspberry Pi microcomputer that orchestrates a modular network of environmental, physiological, and visual sensors embedded in a specially designed 3D-printed plant pot. The sensing infrastructure includes soil moisture sensors, rain sensors, ambient light sensors, and air temperature–humidity modules that continuously monitor microclimatic conditions. Soil electrical conductivity is measured using Kelvin four-point probes at multiple depths, enabling accurate estimation of nutrient concentration and fertilizer penetration. In addition, voltage meters record plant and soil bio-electrical signals, allowing AI models to associate voltage fluctuations with plant stress or well-being.

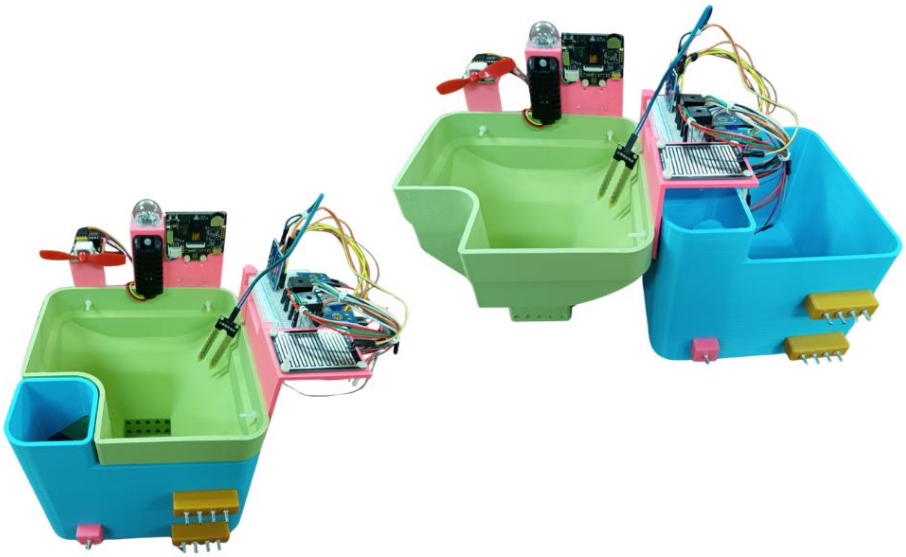


Image 2: Two apartment 3D printed pot equipped with sensors

Growth and biomass are estimated using ultrasonic sensors, while actuation systems include AI-controlled water pumps for irrigation and fertigation, cooling fans, and airflow mechanisms that simulate wind for artificial pollination. Smoke diffusion modules are employed as non-chemical deterrents against harmful insects. A Huskylens AI vision camera trained through supervised machine learning enables real-time insect recognition, distinguishing beneficial insects and pollinators (such as bees and ladybugs) from harmful pests (such as aphids). Context-aware responses preserve pollinators and biodiversity while minimizing chemical intervention, demonstrating ethical AI deployment in agricultural environments.

AI-Driven Precision Agriculture and Resource Optimization

By integrating multimodal sensor data with AI-based decision logic, Emotional Botany exemplifies precision agriculture in practice. Irrigation schedules are dynamically adapted according to soil moisture trends, plant growth stage, and predicted weather conditions, significantly reducing water waste. Fertilization strategies are optimized through conductivity analysis correlated with growth response, preventing nutrient overuse, lowering economic cost, and protecting groundwater resources.

AI-supported pollination strategies further enhance productivity. Controlled airflow simulates wind pollination during periods of low natural pollinator activity, while computer vision ensures that interventions do not disrupt beneficial insects. Growth metrics combined with environmental data support data-informed harvesting decisions, enabling crops to be harvested at optimal maturity. Collectively, these AI-tailored responses reduce resource waste, enhance profitability, and contribute to a more resilient and sustainable agricultural future.

Emotional AI, Companionship, and Well-being

Interaction with plants has been shown to reduce stress, improve mood, and enhance psychological well-being (Bringslimark et al., 2009; Lee et al., 2015). Emotional Botany extends these benefits through empathetic AI-mediated interaction, positioning

Freya as a companionable presence that supports emotional connection, routine, and a sense of responsibility. This dimension is particularly relevant in contemporary educational contexts, where loneliness and emotional isolation are increasingly prevalent among learners.



Image 3: The complete setup with the sensor tower, the 3D pot, the irrigation and fertilization system and the camera-monitor system for interaction with "Freya"

Pedagogical and Ethical Advantages

Emotional Botany embeds AI learning within authentic, real-world challenges, supporting inquiry-based and experiential learning approaches. Students actively participate in system design, sensor selection, data collection, model training, and evaluation, fostering systems thinking, critical reasoning, and interdisciplinary problem-solving skills (Kolb, 1984; Papert, 1993). Translating complex environmental data into emotional and narrative feedback through the avatar Freya enhances accessibility and engagement, accommodating diverse learning styles and increasing motivation.

From an ethical perspective, the project introduces responsible AI principles through concrete design choices. Prioritizing non-chemical pest management, pollinator protection, and resource efficiency encourages learners to reflect on the environmental, social, and economic consequences of algorithmic decisions (Floridi et al., 2018). Freya's role as an emotionally responsive companion enables critical dialogue on emotional AI, anthropomorphism, empathy, and trust in human–AI relationships (Sharkey & Sharkey, 2012). Rather than framing AI as a tool for control or exploitation, Emotional Botany positions intelligent systems as mediators of care, sustainability, and responsibility.

Conclusion

Emotional Botany demonstrates how AI education can transcend technical skill acquisition by integrating sustainability, economic awareness, ethical reasoning, and emotional intelligence into learning experiences. By uniting precision agriculture with ethical and emotional AI, the project empowers learners to design responsible intelligent systems that optimize resources, enhance productivity, and support both environmental and human well-being.

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FeelosophAI — Emotional Intelligence for Inclusive Education

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Abstract—FeelosophAI represents a compassionate integration of artificial intelligence and inclusive education, designed to support the emotional well-being and learning potential of non-verbal autistic children while simultaneously fostering AI literacy through authentic educational practice. The system combines three distinct input modalities —thermal imaging, facial recognition, and expressive drawing analysis—to interpret subtle emotional cues and infer a child's emotional state. When signs of distress, frustration, or lethargy are detected, an adaptive algorithm initiates personalized educational or regulatory responses through interactive learning games, multisensory activities, ambient lighting, and calming soundscapes.

Beyond its assistive function, FeelosophAI operates as a learning ecosystem that models responsible and human-centered AI design. Students involved in the project actively engaged in data collection, model training, and ethical evaluation, developing critical AI literacy competencies. Ethical safeguards such as offline data processing and privacy-by-design architecture ensure that AI augments—rather than replaces—human care.

Keywords—inclusive education, AI literacy, emotional AI, autism support, assistive technology

Introduction

Inclusive education remains a central challenge for contemporary educational systems, particularly for non-verbal autistic children who experience barriers to emotional expression through conventional communication. Research in affective computing and educational AI highlights the potential of multimodal approaches that integrate behavioral, physiological, and creative signals to support learning and well-being (Kasneci et al., 2023; Woolf, 2010).

Thermal imaging has been explored as a non-invasive method for detecting stress-related physiological changes, while facial-action coding systems such as animal grimace scales demonstrate how subtle visual cues can be systematically interpreted in non-verbal subjects (Langford et al., 2010; Tufts University, 2023). In parallel, research in child psychology emphasizes drawing as a structured medium of emotional expression rather than a purely artistic activity (De Meredieu, 1981).

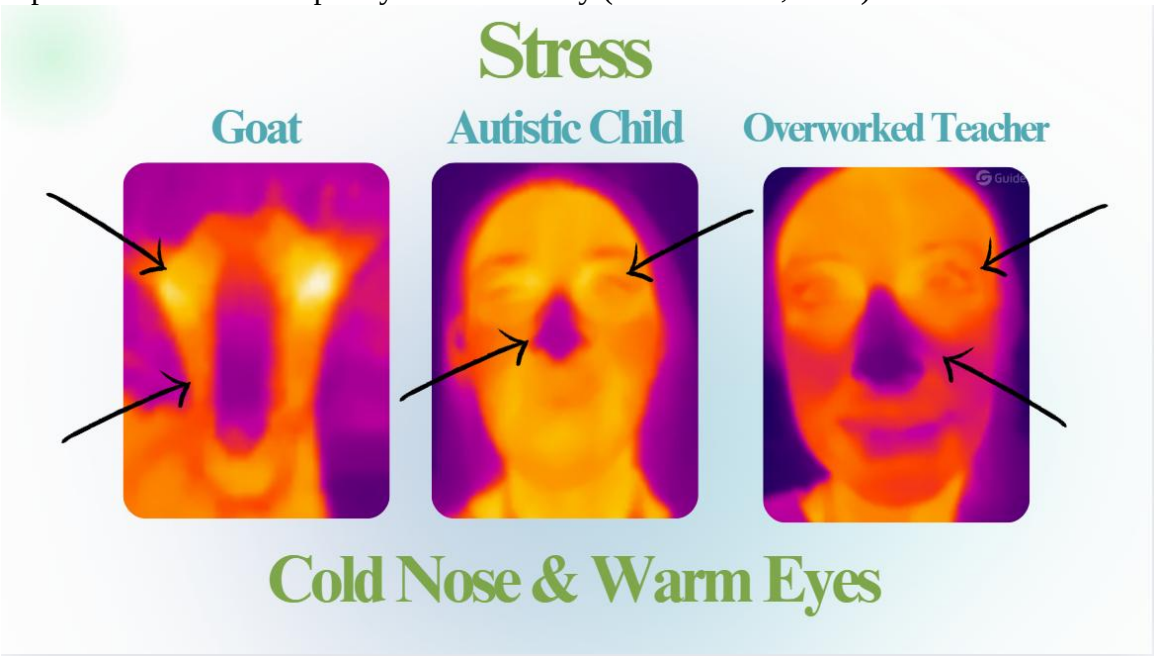


Image 1: Thermal patterns indicating distress in animals and autistic children

FeelosophAI builds upon these insights, positioning AI as both an assistive mechanism for vulnerable learners and a pedagogical context for developing AI literacy through real-world, ethically grounded design.

System Architecture and Methodology

FeelosophAI is conceived as a modular, low-cost, and privacy-aware educational workspace integrating hardware, software, and pedagogical design. The system combines a Raspberry Pi microcomputer, vision camera, thermal imaging camera, pressure-sensitive stylus, and multisensory outputs.

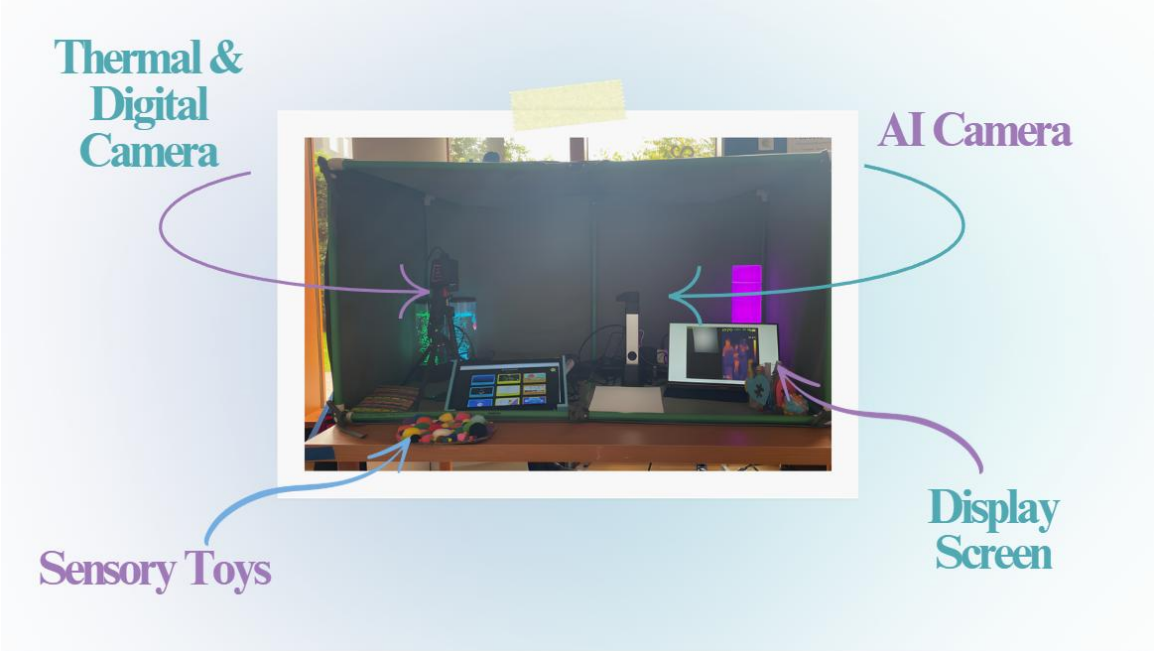


Image 2: FeelosophAI setup

Multimodal Emotional Input

Facial expression analysis draws inspiration from established grimace-scale methodologies originally developed for non-verbal pain assessment in animals, adapted here for educational and supportive purposes only (Langford et al., 2010). Thermal imaging monitors relative surface temperature changes associated with stress or fatigue (Tufts University, 2023). Expressive drawing analysis examines color choice, pressure, and spatial organization, informed by psychological studies of children's visual expression (De Meredieu, 1981).

Multimodal Emotional Output and Adaptive Response

Signals derived from facial expression analysis, thermal variation, and expressive drawing behavior are integrated through a lightweight decision-making algorithm that estimates the child's emotional state based on consistency across modalities rather than isolated indicators. This multimodal fusion approach enhances interpretive safety and reliability, reducing the likelihood of misclassification when working with non-verbal emotional cues. When the inferred emotional state suggests emotional balance, curiosity, or readiness to engage, the system activates student-designed interactive learning games that promote cognitive engagement, creativity, and autonomy. Conversely, when stress-related patterns are detected, FeelosophAI transitions to regulation-oriented responses, including calming multisensory activities, ambient lighting adjustments, and relaxation-focused digital experiences.

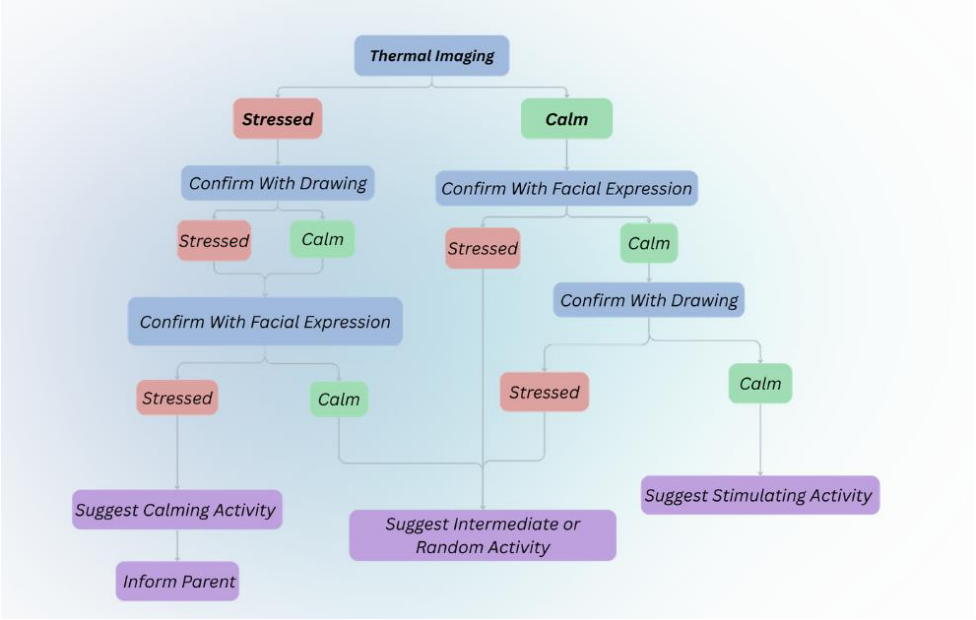


Image 3: How the algorithm works

To support caregivers, the system incorporates a notification mechanism that communicates significant or persistent emotional changes through clear, non-intrusive messages. These notifications are intended to enhance emotional awareness rather than prompt immediate action, acknowledging the emotional and cognitive load often carried by caregivers of non-verbal autistic children. By translating complex multimodal signals into accessible emotional insights, FeelosophAI seeks to provide reassurance, foster trust, and reinforce the role of AI as an empathetic assistant that complements—rather than replaces—human care and parental judgment.

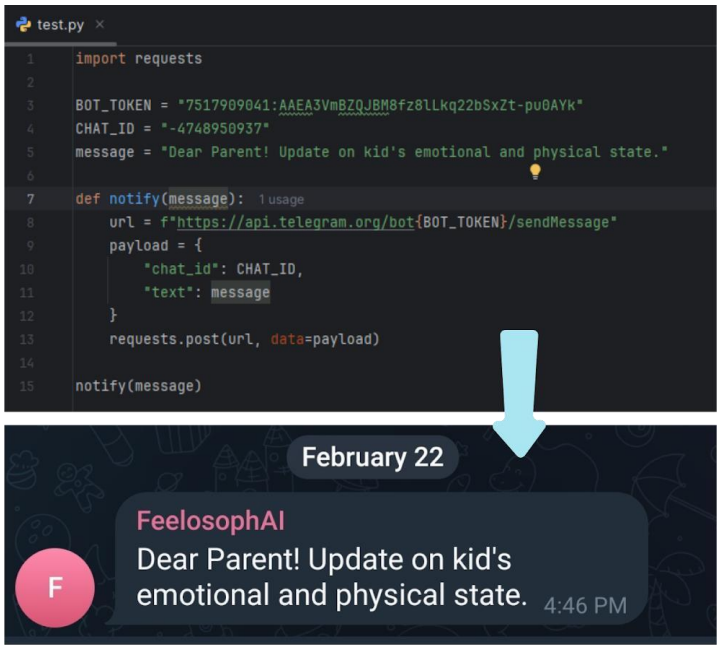


Image 4: Notifications on Telegram

Educational Implications

FeelosophAI demonstrates how inclusive education and AI literacy can be meaningfully aligned. Students engage in authentic ethical challenges such as data interpretation, bias, and accountability while designing systems that interact with emotional and physiological signals. This interdisciplinary approach supports learning across computer science, psychology, and pedagogy, encouraging learners to view AI as a tool for social good.

Conclusion

FeelosophAI illustrates how emotionally responsive AI can support inclusive education while fostering AI literacy. By integrating multimodal emotional signals within a privacy-aware framework, the project demonstrates a responsible pathway for educational AI innovation.

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Teachers and Artificial Intelligence: Needs, Barriers, and the Design of Professional Development Programs in the Digital Age

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Abstract—Artificial Intelligence (AI), defined as the capacity of digital systems to emulate human cognitive functions and actions, has become a central driver of transformation in contemporary educational environments. Its integration fundamentally reshapes educational systems, enhancing efficiency and effectiveness in both teaching and administration. More specifically, AI is transforming education in three principal ways: through the personalization of learning, the automation of time-consuming administrative and assessment-related tasks, and the provision of immediate feedback that supports continuous learning improvement. Collectively, these functions contribute to the creation of more effective, inclusive, and adaptive learning environments.

Key applications of AI in education include Intelligent Tutoring Systems (ITS), adaptive learning platforms, automated grading systems, virtual teaching assistants, and administrative support tools. The transformative potential of AI is substantial, offering significant advancements in the educational process. Its capacity to tailor learning to the individual needs of each learner enables personalized instructional support, while interactive platforms enhance motivation and engagement through gamification and immersive virtual experiences. For teachers, AI serves as a valuable support mechanism, reducing bureaucratic workload and allowing greater focus on meaningful pedagogical interaction. Moreover, data analytics facilitated by AI enable informed, evidence-based decisions regarding curriculum design and instructional planning. AI also plays a critical role in promoting inclusive education through specialized tools, as well as in expanding global access to knowledge.

Despite these advantages, traditional educational models continue to face persistent challenges, including unequal resource distribution, limited capacity to address diverse learner needs, and excessive workload demands placed on teachers.

Four major challenges hinder the effective integration of AI in education. First, many teachers lack technological readiness and essential digital skills, a situation exacerbated by the absence of comprehensive professional development programs that bridge the gap between AI technologies and their practical application in classroom contexts. Second, concerns persist regarding the potential replacement or devaluation of the human role in education, as teachers fear that automation may undermine their professional identity. Third, significant ethical concerns arise in relation to data privacy, data security, and the risk of algorithmic bias in assessment processes, particularly in the absence of clear and coherent ethical frameworks. Fourth, there is a lack of sustained support following initial training, including insufficient mentoring

opportunities and limited collaborative professional networks. Without continuous guidance and support, educators often struggle to integrate AI effectively into their instructional practice.

To bridge the gap between the potential of AI and the challenges faced by educators, the meaningful and responsible use of AI can only be achieved through targeted and ongoing professional development. Teacher training functions as a key mechanism for overcoming these barriers by promoting AI literacy, reinforcing the evolving role of the teacher as an ethical and pedagogical guide, and providing education in AI ethics and data protection. A comprehensive professional development program should be structured around three core dimensions: technological competence**,** pedagogical application (including data-informed instructional practices), and the critical and ethical dimension, thereby ensuring the equitable, responsible, and pedagogically sound use of AI in education.

Keywords: Artificial Intelligence, Teacher Professional Development, Teacher Training

Introduction

Artificial Intelligence (AI) constitutes a contemporary scientific and technological field grounded in heuristic programming, with the primary objective of developing computational systems capable of performing tasks similar to those carried out by humans. Specifically, AI systems analyze human cognitive and functional processes and seek to replicate them automatically, including adaptation to new situations, problem-solving, responding to queries, and action planning—functions traditionally associated with human intelligence (Slage, as cited in Karaduman, 2019).

Within the same framework, Remian (2019) defines Artificial Intelligence as the capacity of robots or digital tools, controlled by computational systems, to perform human tasks through interaction with humans. These technologies possess advanced capabilities designed to emulate fundamental human functions. As a scientific discipline, AI focuses on the development of machines capable of performing tasks that require human intelligence, such as natural language understanding, pattern recognition, and data-driven decision-making, thereby simulating processes of human thought.

Although there is no universally accepted definition of Artificial Intelligence, there is broad consensus that AI brings about profound and lasting transformation across multiple sectors of society (Niemi, 2021). In this sense, AI may be broadly conceptualized as the intelligent imitation of human behavior or cognition through digital tools and software applications (Mohammed & Watson, 2019).

From a practical perspective, AI represents a convergence of technological applications, including machine learning, deep learning, algorithm development, and natural language processing (Akgun & Greenhow, 2022, Chen et al., 2020). More specifically, AI emerges from the evolution of systems that demonstrate levels of intelligence comparable to those of humans, incorporating attributes such as cognitive capabilities, learning capacity, decision-making, and environmental adaptability.

This rapid transformation has significantly intensified the interest of the scientific community in the study and application of Artificial Intelligence in the field of education, with the aim of enhancing learning processes and facilitating its effective integration into educational environments (Chen et al., 2020).

The accelerated development of Artificial Intelligence has led to substantial changes in education, influencing both traditional teaching methodologies and the professional development of educators. The increasing integration of AI-based tools in classrooms gives rise to new learning and pedagogical environments, which require teachers to adapt to a constantly evolving technological landscape.

Artificial Intelligence in the 21st Century: Transforming Education

Within this context, Artificial Intelligence (AI) plays a pivotal role in teacher training and continuous professional development by providing advanced tools that support lifelong learning and professional growth. As education undergoes transformation, teachers are increasingly required to adopt innovative pedagogical approaches, integrate technology into instructional practice, and respond to the growing and diverse

needs of learners. AI-based educational resources facilitate personalized learning, enhance self-regulation, and promote peer-to-peer learning, thereby contributing meaningfully to teachers' professional development. At the same time, AI-powered chatbots and virtual assistants provide immediate support by responding to pedagogical inquiries, recommending instructional resources, and offering on-demand professional development content (Davis & Wilson, 2020). This enhanced accessibility enables teachers to engage in self-directed learning processes without the constraints of traditional training programs (Kim & Park, 2023). Furthermore, AI-enhanced learning management systems optimize professional development through interactive modules, discussion forums, and real-time collaboration with experts (Miller & Roberts, 2022).

Beyond teacher professional development, AI extends its impact by introducing a data-driven teaching model rather than merely improving instructional practice. This model enables educators to systematically monitor and analyze their instructional effectiveness, remain informed about contemporary pedagogical trends, and make evidence-based decisions (Amankulovich et al., 2024). Particularly significant is the provision of real-time feedback, as AI-supported observation systems employ natural language processing (NLP) techniques and machine learning algorithms to evaluate teaching approaches, classroom management, and levels of student engagement. These systems generate empirically grounded insights that support the continuous improvement of instructional practice (Pedro et al., 2019).

The integration of AI in education can be analyzed across three primary domains of application. The first concerns learner-facing AI, such as Intelligent Tutoring Systems (ITS), which enhance learning effectiveness by delivering personalized instructional content, monitoring learner progress, and providing individualized support. The second domain involves teacher-facing AI, which automates time-consuming tasks such as grading, progress monitoring, and lesson planning, thereby reducing administrative burden and allowing educators to devote more time to pedagogical interaction with students. The third domain focuses on system-facing AI, which supports institutional management through data analytics, contributing to resource optimization, educational policy development, and the overall effectiveness of educational systems (Baker et al., 2019, Zawacki-Richter et al., 2019).

According to West (2019), the application of AI in education serves three primary objectives: improving learning outcomes, streamlining routine processes, and providing analytical insights into the learning process. Through the analysis of performance data and learning needs, AI introduces innovative pedagogical approaches that strengthen differentiated and targeted instruction.

A central pillar of AI integration is personalized learning, achieved through the analysis of learners' styles, strengths, and areas for improvement. This approach enables the development of flexible and adaptive instructional content, thereby enhancing student engagement and academic achievement. In this context, Pedro et al. (2019) propose the "dual-teacher" model, in which AI-supported assistants function complementarily to human teachers by reducing time devoted to routine tasks and enabling greater emphasis on guidance and individualized communication with students.

Complementarily, adaptive learning systems dynamically adjust instructional content, pacing, and levels of difficulty in real time by taking into account learner performance

and feedback. Unlike traditional "one-size-fits-all" approaches, these systems leverage large-scale data to address the unique needs of each learner, offering targeted support and appropriately challenging learning experiences aligned with students' skill levels (Zhang & Zhang, 2020, Gligorea et al., 2023).

Another critical area of AI application is assessment and evaluation, where technologies such as natural language processing and automated speech recognition enable faster and more objective feedback. The automation of assessment processes not only ensures consistency -particularly in large-scale evaluations- but also frees valuable time for teachers to focus on meaningful pedagogical interactions (Ismail et al., 2024, Sangapu, 2018). In parallel, the use of predictive analytics facilitates the early identification of students at risk of low academic performance, enabling the timely implementation of targeted interventions (Popenici & Kerr, 2017).

Finally, beyond teaching and learning, AI contributes significantly to the streamlining of administrative tasks, allowing educators to focus more on instruction and student guidance. Through the automation of processes such as grading, scheduling, and lesson planning, teachers are able to allocate more time to pedagogical design, individualized student support, and collaboration with colleagues, thereby enhancing the overall quality of the educational process.

A Comprehensive and Systematic Analysis of the Multilevel Challenges and Ethical Constraints of Artificial Intelligence in Education

The integration of Artificial Intelligence (AI) into contemporary educational systems, as well as its utilization as a tool for the professional empowerment of educators, represents one of the most radical technological shifts of recent decades. Despite AI's evident potential to enhance instructional practice, support personalized learning, and strengthen formative assessment, its implementation encounters a complex constellation of cognitive, institutional, ethical, and social constraints that require systematic and multilevel examination.

At the core of this challenge lies the limited familiarity of the educational community with the fundamental operational principles of algorithmic systems. A lack of foundational understanding of how AI systems collect, process, and derive inferences from data constitutes one of the most significant barriers to their meaningful adoption (Miller & Roberts, 2022). This deficit extends beyond technical knowledge, transforming into pedagogical and professional insecurity that often manifests as hesitation or even mistrust toward systems that directly influence students' educational trajectories (Wang & Wang, 2022).

This sense of insecurity is further intensified by the presence of algorithmic bias, which is frequently embedded in AI systems during the design phase or through the selection of training data. As a result, these tools do not operate neutrally but tend to reproduce or even amplify existing social, cultural, and educational inequalities (Hernandez & Patel, 2021). Within this context, AI functions not merely as a technological instrument but as a carrier of values and ideological assumptions, underscoring the necessity for continuous critical evaluation.

Concurrently, issues of data privacy and data security emerge as central areas of concern. The use of AI-driven platforms for professional development and learning analytics entails the large-scale collection and processing of sensitive personal data relating to both teachers and students. This practice raises serious questions regarding the protection of digital identity, procedural transparency, and compliance with ethical principles (Smith & Johnson, 2021).

At a deeper level, these challenges acquire a systemic dimension, as they are linked to risks of discrimination, exclusion, and xenophobic practices targeting vulnerable or marginalized student populations (Hwang et al., 2020). This reality highlights the urgent need for robust ethical standards governing data collection, storage, and analysis, as well as for accountability mechanisms that ensure fairness and transparency in AI-based educational applications (Holmes et al., 2021).

According to the international literature (Chaushi et al., 2024, Harry & Sayudin, 2023, Mosaiyebzadeh et al., 2023, Rasul et al., 2023, Saputra et al., 2023), the introduction of AI in education brings about a structural reconfiguration of the teacher's role. The gradual delegation of functions such as content delivery and assessment to automated systems may lead to the erosion of pedagogical authority, transforming educators from central architects of the learning experience into mere "facilitators." This shift constrains their capacity to exert meaningful influence on students' cognitive, ethical, and emotional development, as technological mediation increasingly substitutes human guidance (Roll & Wylie, 2016).

The potential replacement of the human element by automated systems directly challenges teachers' professional identity and their social role within the school community. Automated practices of content delivery and assessment, which rely primarily on the analysis of textual and numerical data, often overlook the emotional, social, and qualitative dimensions of the learning process (Goksel & Bozkurt, 2019).

The weakening of the human element affects not only instructional practice but also students' holistic development as social and moral agents. Direct student–teacher interaction constitutes a fundamental pillar of emotional support and social learning. Excessive reliance on AI may lead to social isolation, limiting the cultivation of skills such as empathy, collaboration, and communication. Moreover, media representations of AI that portray it as a full substitute for human roles further intensify skepticism and resistance within the educational community (Chan & Tsi, 2023), overshadowing its potential to function as a complementary and supportive tool for teaching and learning (Luckin et al., 2016).

This resistance is closely associated with negative attitudes toward technological innovation and educators' reluctance to depart from established pedagogical practices and "comfort zones" (Istenic et al., 2021, Zhang et al., 2023). The transition to AI-enhanced teaching environments presupposes a new skill set in which digital literacy extends beyond functional tool use to encompass critical understanding of their broader implications (Ertmer & Ottenbreit-Leftwich, 2010).

Contemporary educators are therefore required to develop data literacy skills in order to leverage AI for personalized learning and improved instructional effectiveness (Chen & Xie, 2020). Nevertheless, persistent mistrust toward AI systems and inadequate

professional development programs remain significant obstacles to their effective adoption (Zhao et al., 2019).

In the domain of security, AI relies on the processing of large volumes of data, a practice that may threaten the privacy of teachers, students, and educational policymakers alike, rendering students particularly vulnerable to practices such as facial recognition and emotion analysis (Akgun & Greenhow, 2022, Dignum, 2021). At the same time, AI systems remain susceptible to cyberattacks, which can result in data theft, manipulation, or malicious misuse, thereby undermining the ethical foundations of the educational process (Borenstein & Howard, 2021, Rodafinos, 2024).

The ethical dimension also extends to the assessment of student performance, where the use of AI raises critical questions concerning fairness, transparency, and validity. While AI technologies have the potential to enhance efficiency, objectivity, and reliability in educational assessment, they also entail risks of bias, discrimination, and privacy violations if not implemented responsibly and ethically (Agarwal et al., 2023, Zajko, 2021). Consequently, the development of transparent systems grounded in reliable data and subject to independent oversight mechanisms is imperative. Educators are called upon to ensure that AI functions as a supportive tool rather than a substitute for human judgment, promoting a holistic approach to assessment (Miao et al., 2021, Naseer et al., 2024). The distinction between formal compliance with ethical standards and the enactment of substantive ethical practice thus emerges as critically important (Holmes et al., 2021).

Finally, the emerging digital divide constitutes one of the most serious risks associated with AI in education. Access to advanced AI technologies is largely contingent upon economic, institutional, and geographical factors, which may further commodify education and exacerbate social inequalities (Reiss, 2021). While institutions and learners with access to costly AI technologies stand to benefit from these tools, those in low-income or underserved regions may be excluded from such opportunities. This situation risks deepening the digital divide and amplifying existing educational inequalities. Unequal levels of digital competence among educators further intensify this phenomenon, creating disparities in opportunities for professional development (Duan & Zhao, 2024).

Effectively addressing these challenges requires the adoption of clear ethical guidelines that prioritize fairness, inclusivity, and accountability (Chan, 2023, Olatoye et al., 2024), alongside the implementation of robust cybersecurity mechanisms combined with comprehensive AI literacy programs for the entire educational community (Garcia & Thomas, 2021, Kordzadeh & Ghasemaghaei, 2022).

The Importance of Professional Development in the Era of Artificial Intelligence

Considering the multiple applications and the transformative role of Artificial Intelligence (AI) in education, it becomes evident that its effective integration presupposes educators who possess appropriate training and a critical understanding of AI technologies. Consequently, there is a growing need to reorient teachers' professional development towards enhancing both their knowledge of AI and their ability to employ it in a pedagogically responsible manner.

Traditionally, professional development programs in education have primarily focused on improving pedagogical competence and subject-matter knowledge. However, the increasing penetration of AI technologies into educational environments necessitates a substantial reconfiguration of these programs to systematically incorporate AI-focused training. This shift extends beyond mere familiarization with new technological tools and entails a comprehensive reconsideration of teachers' professional learning approaches.

According to the literature, professional development in the field of AI should be continuous, experiential, and closely aligned with educators' everyday teaching practices (Hixon & So, 2019). At the same time, strengthening collaboration among educators, technologists, and educational policymakers is considered essential to ensure that the implementation of AI aligns with pedagogical principles and evidence-based teaching practices (West et al., 2021).

A central concept in this process is AI literacy, which refers to educators' ability to understand the fundamental principles underlying AI systems, their capabilities and limitations, as well as their implications for teaching and learning (Lindh & Pors, 2020). Teacher readiness extends beyond technical familiarity with AI tools and requires the development of a critical stance toward their use, particularly with regard to pedagogical, social, and ethical considerations. For this reason, professional development programs that integrate technical training with ethical reflection are deemed essential for the responsible and informed adoption of AI in educational practice (García & García, 2020).

The analysis of the literature highlights multiple opportunities for enhancing teachers' AI-related professional development. First, experiential learning models appear to be particularly effective in addressing educators' needs, as they provide hands-on and practice-oriented experiences—such as workshops, simulations, and collaborative projects—that strengthen teachers' confidence in using AI tools. Second, the development of collaborative networks and communities of practice facilitates knowledge dissemination, experience sharing, and collective problem-solving, thereby supporting the successful adoption of AI and fostering a culture of continuous professional learning. Third, the integration of ethical training and critical AI literacy into professional development programs prepares educators to address issues related to bias, fairness, and data privacy, ensuring the responsible use of AI in educational contexts (Bogina et al., 2021, Xivuri & Twinomurinzi, 2023).

As AI technologies increasingly permeate the educational landscape, professional development programs must evolve accordingly to embed AI-focused training systematically. To maximize the benefits of AI in teachers' professional learning, AI education should be integrated into both initial teacher education and ongoing professional development initiatives (Miller & Roberts, 2022). Such programs should emphasize the development of critical thinking skills, enabling educators to evaluate the information and recommendations generated by AI systems and to make informed pedagogical decisions (Smith & Johnson, 2021). Moreover, collaborative initiatives among educational institutions, policymakers, and AI developers are considered vital for the design of ethical, inclusive, and pedagogically appropriate AI tools for teacher training (Garcia & Thomas, 2021).

Given the continuous and rapid evolution of AI technologies, teachers' professional development must be sustained over time. Educators are required to remain systematically informed about emerging technological advancements in order to select and apply the most appropriate tools in their instructional practice (Luckin et al., 2016). Continuous professional learning may be implemented through a variety of formats, including workshops, online courses, webinars, and micro-credentialing initiatives, which allow educators to acquire specialized AI-related skills in a flexible manner.

The use of synchronous and asynchronous learning methods within blended learning frameworks plays a crucial role in supporting ongoing teacher professional development (Bonk & Graham, 2012). These models enable self-paced learning while simultaneously offering instructional support through facilitators and online communities. Digital resources—such as instructional videos, webinar sessions, and discussion forums—facilitate the exchange of experiences and best practices among educators who employ AI in their teaching (Chen, 2020). Consequently, blended learning emerges as an effective and flexible approach that accommodates teachers' time constraints and meaningfully supports the integration of AI into educational practice.

Conclusions

As Artificial Intelligence (AI) continues to reshape the educational landscape, it becomes increasingly essential for educators to be equipped not only with technical competencies but also with pedagogical knowledge and ethical awareness in order to manage this transformative technology effectively. AI offers significant opportunities, including personalized learning, support for pedagogical decision-making, automated assessment, and the optimization of learning processes. Despite its considerable potential, however, the implementation of AI is not without challenges. These include concerns related to data privacy and security, algorithmic bias, and the evolving dynamics of teacher–student relationships. The uncritical or indiscriminate use of AI may lead to adverse consequences for learning outcomes, students' social development, and teachers' professional identity (Miller & Roberts, 2022, Hernandez & Patel, 2021).

To ensure the responsible and effective application of AI, professional development programs must be adapted to meet the demands of an educational environment that is increasingly shaped by AI-driven technologies. Such programs should not focus solely on technical skills, such as the use of AI platforms and algorithms, but should also emphasize the development of pedagogical competencies for their meaningful integration into teaching practice. Moreover, AI-related training should encompass time management strategies, the use of tools for personalized learning, and the careful handling of personal and sensitive data (Chen & Xie, 2020, Smith & Johnson, 2021).

The long-term enhancement of educational quality through AI is feasible only when technological innovation is complemented by human guidance and emotional support (Salas & Yang, 2022). Striking a balance between technological capabilities and human involvement is critical, as AI cannot fully replace the teacher–student interaction that is fundamental to the development of social skills such as collaboration, communication, and empathy (Goksel & Bozkurt, 2019, Chiu et al., 2023). Within this context, education must be supported by structured training initiatives, mentoring programs, and collaborative learning environments that address key challenges,

including access to technology, data protection, the digital divide, and algorithmic bias (Murphy, 2019, Pokrivcakova, 2019).

Furthermore, the effective implementation of AI requires the development of both digital literacy and AI literacy among educators and students alike. Teachers' digital competence constitutes a central prerequisite for the appropriate use of AI tools, as deficiencies in this area may exacerbate inequalities and widen the digital divide between schools and regions (Duan & Zhao, 2024). At the same time, an understanding of ethical dimensions-such as transparency in decision-making processes and fairness in student assessment-is indispensable for the responsible deployment of AI in educational settings (Holmes et al., 2021, Chan, 2023).

The development of a comprehensive framework for the integration of AI in education presupposes targeted professional development programs that combine technical training, pedagogical expertise, digital safety, and ethical governance. Such a framework should ensure fairness and accountability through data diversity and validity, transparency, and the establishment of evaluation mechanisms for AI systems. Equally important are robust data protection measures and cybersecurity safeguards to preserve the confidentiality and security of both students and educators, as well as the cultivation of a collaborative and supportive learning environment that fosters participation and empathy without marginalizing the human element. Finally, addressing and reducing the digital divide remains a critical priority to ensure equal access to AI-enhanced educational opportunities across all schools and learning contexts (Reiss, 2021).

In conclusion, the successful integration of Artificial Intelligence in education requires a balanced and holistic approach, in which the affordances of technology are harnessed responsibly and ethically to enhance learning and students' overall development, while preserving the central role of educators as pedagogues, mentors, and facilitators of meaningful human interaction.

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Possible obstacles and risks in the dissemination of Artificial Intelligence: Proposals and solutions for responsible coexistence

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract—The rapid expansion of Artificial Intelligence (AI) has brought about significant changes across all fields of human activity, creating new opportunities as well as unprecedented risks. As AI increasingly permeates education, work, and everyday life, it becomes critical to investigate citizens' perceptions—and particularly those of educators—regarding the potential obstacles and challenges arising from its use.

The present study was conducted during the period December–January 2023–24 within the framework of the Interdepartmental Postgraduate Program of Studies "Soft and Digital Skills in Educational Sciences" and explores the perceptions, concerns, and prospects associated with AI in key social sectors. The research questions examine the potential barriers and risks in the diffusion of Artificial Intelligence in our lives, as well as the solutions or measures that can be proposed to address them. The aim is to understand how individuals perceive the presence and impacts of AI in everyday life, as well as to explore the emotional and ethical dimensions that accompany it.

The study follows a qualitative research approach, with data collected through semi-structured interviews (N = 17). The interviews were conducted remotely via the Zoom platform to ensure flexibility and accessibility for the participants, were anonymized, and analyzed using inductive thematic coding.

Data analysis resulted in four main axes: Health, Economy, Education, and Personal Data / Global Stability.

The findings highlight a generalized concern regarding job losses, dependence on technological tools, the reduction of human communication, and insufficient protection of personal data. At the same time, participants acknowledge the multiple benefits of AI, particularly in the field of education, provided that its use is framed by ethical

responsibility, continuous training, and a clear regulatory framework. The data analysis emphasizes the need for education and awareness-raising among citizens regarding the responsible use of AI. Cultivating critical thinking, responsibility, and technological empathy are essential prerequisites for a society that leverages AI for the benefit of humans, while simultaneously safeguarding the values and boundaries of human existence.

The need for legislative regulation and ethical frameworks that ensure transparency, security, and fairness is underscored. The value of a human-centered approach becomes evident, where technology functions complementarily to humans rather than competitively. The findings provide useful insights from the perspective of the participants themselves, shedding light on the perceptions of those involved in the design, evaluation, and regulation of AI, and proposing applicable directions for its responsible integration not only in educational but also in broader social contexts.

Keywords: Artificial Intelligence, Education, Ethical dimension, Social impacts, Responsible use

Introduction

Artificial Intelligence (AI) is not merely a technological development but a critical general-purpose technology with the capacity to radically transform the economy, healthcare, and education. The literature confirms that AI can significantly increase global productivity and prosperity (Brynjolfsson & McAfee, 2014). However, this revolution is accompanied by substantial barriers. The rapid development of AI raises serious issues of safety and social justice. O'Neil (2016) warns that algorithms often reproduce and amplify social inequalities, functioning as "weapons of math destruction." Similarly, Noble (2018) highlights the risk of algorithmic racism, making the need for regulation imperative.

Russell (2019) emphasizes that the challenge is not only ethical but also technical, as it is necessary to ensure that AI systems remain aligned with human values. On the other hand, Bostrom (2014) raises the issue of "superintelligence" as an existential risk, although this position has been criticized by scholars who consider such scenarios premature or exaggerated. While the European Commission (2021) proposes strict rules through the EU AI Act to limit risks, there is a counterargument that excessive regulation may stifle innovation and lead to technological lag compared to other economies (Jobin et al., 2019).

In the Greek context, this discussion acquires particular importance and urgency. During the years 2023–24, the country's digital transition was at an early stage at both the institutional and social levels with regard to artificial intelligence tools. Empirical investigation of the risks and barriers of AI through the perspectives of professionals who are required to manage it in everyday practice remained limited. The need to map the perceptions of Greek educators, social workers, and psychologists was imperative, as they constitute the connecting links between technological advancement and social cohesion. Understanding their concerns and proposals is essential for the design of measures and solutions that respond to the particularities of the Greek reality.

Within this framework, the present research was conducted as part of a postgraduate thesis of the Master's Program "Digital and Soft Skills in Educational Sciences" of the International Hellenic University (IHU). The present study constitutes a substantial contribution to the conference proceedings, as it bridges the international literature with the valuable empirical perspective of Greek "front-line" professionals. The strategic choice of this sample allows, through semi-structured interviews, the transformation of participants' everyday experience and reflection into concrete solutions and measures, highlighting AI barriers not merely as theoretical constructs but as living challenges that require immediate response.

Methodology

The present research was conducted within the framework of a postgraduate thesis of the International Hellenic University, "Digital and Soft Skills in Educational Sciences," from December to January 2024.

Purpose of the Study

The purpose of the study is twofold: to provide a comprehensive picture of the challenges and risks that arise, and to formulate solutions for the safe and smooth integration of Artificial Intelligence (AI) into society.

For data collection, the semi-structured interview technique was selected, as it provides the necessary depth for qualitative research. The sample consisted of 17 individuals, and the analysis was carried out by an eight-member research team.

For data processing, the method of Thematic Networks was followed. This approach allows for systematic coding and organization of data into broader meanings, ensuring the objectivity of the analysis.

Research Ethics

Strict personal data protection protocols were followed, ensuring the complete anonymity of the participants.

The Sample

The sample consisted of primary education teachers in general and special education, early childhood educators, and mental health professionals, including psychologists and social workers.

Limitations of the Study

The generalizability of the research findings is limited, as it was based on a convenience sample that consisted mainly of women. In addition, the participants were students of the postgraduate program to which the researchers also belonged.

Findings

Medicine

In the field of Medicine, the participants in the study assumed that AI could lead to job losses and role reallocation, as tasks such as data collection, diagnosis, and prescription become automated. This concern aligns with the findings of Acemoglu and Restrepo (2020), who emphasize the impact of automation on the displacement of human labor. As one participant characteristically stated: “I am afraid that in a few years many jobs that we do today will be done automatically by a computer, and humans will be left on the sidelines.”

At the same time, the risk of reinforcing inequalities in access and the integration of algorithmic biases into healthcare constitute central points of concern in the literature, with Floridi (2019) stressing the need for an ethical framework that will prevent discrimination. Health data are extremely sensitive and personal. Artificial intelligence requires large volumes of data for training and application, which may lead to violations of privacy if not properly addressed. Interviewees expressed concern that there is a risk of data leakage, especially if data are stored or transferred digitally.

Based on the interviewees' comments, if data related to people's health are insufficient or inaccurate, AI systems may produce results involving incorrect diagnosis and treatment. This concern is confirmed by Topol (2019), who, although supporting the power of AI in medicine, warns of the risks arising in diagnosis, where a lack of transparency may lead to clinical errors. This risk was vividly reflected in a participant's statement: "An algorithm cannot feel the patient's pain, and if it makes a mistake in diagnosis, the consequences will be fatal."

Economy

Turning to the field of Economics, the research findings highlight the high cost of data collection as a barrier, a finding that is consistent with Zuboff's (2019) analysis of how the ownership and processing of massive data create new monopolies and economic inequalities. According to the interviewees, this dependence on data leads to biased economic decisions, an issue extensively analyzed by Pasquale (2015) in his work on the hidden algorithms that control the flow of money.

Additionally, the sample expressed concern about the elimination of the human factor and the permanent abolition of professions due to the dominance of automation. Research by Acemoglu and Restrepo (2020) confirms broader predictions about the transformation of work in the AI era. This anxiety was characteristically expressed by a participant: "If a machine can do our job faster and cheaper, it is logical for businesses to prefer technology and reduce staff."

Finally, interviewees' references to risks of cyberattacks and the spread of false information (deep fakes) "with the lies circulating on the internet, trust in the market is lost very easily"—as factors destabilizing markets, find strong support in the literature on digital challenges and misinformation (Kozyreva et al., 2020).

Education

At the center of the qualitative findings of the study is the field of education, which was identified by the interviewees themselves as the primary domain where the impacts of AI are immediately perceptible and socially critical. Participants did not express abstract or theoretical concerns, but articulated issues connected to everyday educational practices, lending the findings strong social and pedagogical depth.

A central position in their narratives was occupied by concern over the gradual reduction of personal interaction between students and teachers. As they characteristically noted, the increasing mediation of AI in the educational process may lead to a form of "depersonalized learning," where the teacher's role is reduced to technical supervision. These views converge with Floridi's (2019) position, which emphasizes that human connection constitutes an irreplaceable foundation of pedagogical practice. At the same time, several participants expressed fear that educators themselves may be led into a form of "self-nullification" by uncritically relying on generative AI tools, a concern consistent with the analyses of Killian et al. (2023) regarding the weakening of educational work.

Equally strong were references to risks for students. Interviewees spoke about addiction, social isolation, and the restriction of students' agency, expressing concern

that AI may function as a substitute for thinking. A characteristic statement was: “I am afraid that children will stop thinking and will simply wait for chatbots to give them ready-made answers, losing their critical judgment.” These concerns align both with the theoretical framework of “surveillance capitalism” (Zuboff, 2019) and with Bridle’s (2018) warning about a technologically mediated obscuring of our understanding of the world.

Finally, participants highlighted the dimension of social inequality, noting that unequal access to technological resources may widen already existing educational gaps. These empirical observations reinforce the need for a sustainable, socially just, and pedagogically oriented integration of AI in education, as proposed by Ally and Perris (2022).

Globalization

The concerns highlighted by the interviewees are not limited to the academic environment but extend to broader systemic risks which, in their perception, threaten social balance. Particularly strong was the reference to AI as a “black box,” whose operation remains opaque and potentially dangerous for privacy. Participants expressed fears regarding data security, unauthorized access to personal information, and the risk of sensitive data leakage, a concern that aligns with Pasquale’s (2015) analysis of the inherent opacity of algorithmic systems.

The sense of loss of control was strongly reflected in their narratives, with one participant noting: “I feel that nothing is private anymore; whatever we do through the internet is recorded somewhere, and we ultimately do not know who has access to our data and how they might use them.” This statement does not express an isolated anxiety, but a generalized perception of digital surveillance that permeates the entirety of the qualitative data.

At the same time, participants highlighted the risk of user manipulation through personalized practices, making particular reference to targeted advertising and its disproportionate impact on young people. These concerns are confirmed by the findings of Hohenstein et al. (2023) and are also linked to interviewees’ references to phenomena of digital addiction and excessive dependence on technological platforms. This dimension is consistent with clinical studies that associate digital media use with psychiatric disorders in childhood and adolescence (Andreassen et al., 2017).

Moreover, participants pointed out that AI systems are trained on massive volumes of data while simultaneously collecting and processing user information, which intensifies their reluctance toward using them. This concern is linked not only to the possibility of data leakage but also to the fear of inappropriate use of AI or the provision of information that could be exploited for the creation of dangerous applications.

In the aftermath of the pandemic, interviewees also emphasized the need for psychological fortification and social resilience, underlining that technological exposure further burdens mental health. These observations are corroborated by the proposals of King et al. (2020) and Kozyreva et al. (2020), which stress the importance of strengthening psychosocial resilience in environments of digital uncertainty.

Finally, strong concern was expressed regarding the spread of false news and the reproduction of biases through digital media. As one participant characteristically stated, “you don’t know what is true and what is false, the way media serve it to you; you don’t know what to believe.” These concerns correspond directly to the international literature on misinformation (Roozenbeek & van der Linden, 2019). The overall sense that the uncontrolled development of AI may intensify social inequalities converges with contemporary legal analyses (Al-Tkhayneh et al., 2023), highlighting as imperative the need for regulatory interventions, with the Artificial Intelligence Act of the European Commission (2021) as a central example.

Measures and Solutions

Education and Awareness

According to the interview findings, educating the general public about the risks of AI and the ways of its responsible use constitutes a key objective. Education can be implemented through various actors, such as schools, universities, civil society organizations, and businesses. These findings are directly aligned with the views of Miao and Holmes (2021), who emphasize the need for the “ethical and responsible use of AI” as a fundamental policy principle, promoting a human-centered approach and responsible utilization of AI in education.

In-depth adult education in artificial intelligence can help individuals better understand both the risks and the potential of the technology and make informed decisions regarding its use. Education should include both a theoretical understanding of AI risks and the practical application of preventive measures, which constitutes a core component of AI literacy (Long & Magerko, 2020).

All participants support the view that “educators have a significant role to play in limiting the risks of AI.” Through education, awareness-raising, and the promotion of responsible technology use, educators can help students leverage AI capabilities in a “safe and constructive way.” As one participant stated: “As teachers within the microcosm of the classroom, we can act. What happens after students leave the classroom, we cannot know. It goes beyond our control.”

A basic priority for educators is to “educate their students about the potential risks of AI,” such as “bias, misinformation, and misuse of personal data, using reliable tools designed with student safety in mind.” Finally, participants believe that educators can teach students “how to critically evaluate the information” they receive from AI, recognize biases, and correct or limit them. The need for students to critically assess information and to be informed about addressing risks such as bias and misinformation has also been highlighted by Ng et al. (2021).

Legislative Regulation

The European Union has recognized the risks posed by artificial intelligence (AI) and has established rules for its use. Specifically, it has introduced a set of regulations concerning transparency, safety, accountability, and ethical use (Ebers, 2023). However, some argue that EU regulations are too general and cannot effectively address the specific threats posed by AI: “On the other hand, the fact that the EU wants to set

some limits does not reassure me, because the EU often sets limits that are violated. I do not think there is a mechanism capable of stopping something like this."

Others argue that EU legislation will hinder development and innovation in the AI sector, a critical perspective also analyzed by Floridi (2021). In order to achieve a sustainable framework for AI use, according to Madiega (2021) and the interview responses, cooperation among all stakeholders is necessary, including governments, businesses, and civil society.

EU regulations could be improved by becoming more specific, focusing on concrete AI-related risks, and by including stricter sanctions for violations.

Ethics and Morality

The widespread use of AI highlights, beyond its legal implications, a complex set of ethical and moral issues related to responsibility, transparency, and the social impact of technological applications. International literature converges on the view that the ethical dimension of AI cannot be attributed to a single actor but requires a multi-level approach and distributed responsibility (Al-Tkhayneh et al., 2023; Eflova et al., 2023).

The qualitative interview data confirm that responsibility for the ethical use of AI is distributed among companies, governments, and users. Companies, as developers and providers of AI systems, bear primary responsibility for designing technologies that meet standards of safety, reliability, and comprehensibility. The application of the safety-by-design principle is considered crucial, as it integrates risk-prevention mechanisms from the earliest stages of system development (Al-Tkhayneh et al., 2023). At the same time, transparency regarding the capabilities and limitations of AI applications is a fundamental prerequisite for informed and responsible use.

However, as highlighted in the interviews, concerns are expressed about companies' ability to foresee the full range of potential risks arising from a dynamically evolving and highly complex technology. The complexity of algorithmic systems, combined with their reliance on extensive and potentially biased datasets, limits the possibility of fully controlling their impacts (Eflova et al., 2023).

Governments play a decisive role in establishing and enforcing regulatory frameworks aimed at protecting citizens and safeguarding fundamental rights. The recent initiative of the European Union to regulate AI underscores the importance of institutional oversight and accountability (Naftemporiki, 2023). Nevertheless, both the literature and interviewees point out that the effectiveness of regulatory interventions is questioned, particularly due to the global nature of technological development and the difficulty of applying uniform rules: "Rules must definitely be set by the state and Europe, because if we leave it uncontrolled to companies, in the end everything will get out of hand and we will not know who is responsible for what."

Finally, the contribution of users is also of critical importance. Responsible AI use presupposes sufficient digital literacy, understanding of system limitations, and a continuous critical stance toward generated outputs. The research sample highlighted risks such as uncritical use, manipulation, and loss of critical thinking, particularly in environments where AI functions as a substitute for human judgment: "We must teach

children from a young age to question what the screen gives them and to use their own reasoning." In the case of children, this responsibility extends to parents, educators, and institutions (Adiguzel et al., 2023).

Technological Solutions

The development of technological solutions to mitigate AI risks constitutes an ongoing and multi-level process that evolves in parallel with the technology itself. The literature emphasizes that, under certain conditions, technology can function not only as a source of risks but also as a tool for addressing them (Eflova et al., 2023).

A central role is played by access control systems and malicious-use detection mechanisms, which aim to prevent unauthorized access and misuse of AI applications. At the same time, data security is strengthened through techniques such as encryption, authentication, and secure data storage, which are considered essential for privacy protection (Al-Tkhayneh et al., 2023). Beyond technical parameters, interviewees emphasized the need for practical "safeguards": "The system should allow us at any moment to monitor what is happening and stop the process if we see that something is going wrong with our data."

Particular emphasis is placed on the transparency of AI systems. Transparency tools allow users to be informed about data collection and usage, as well as how these influences generated outcomes. This transparency is directly linked to trust-building and critical evaluation, as also confirmed by the interview findings.

Moreover, mechanisms that enhance user control—such as the ability to delete, correct, or restrict the use of personal data—contribute to strengthening autonomy and privacy protection. At the same time, bias detection and correction techniques in AI systems constitute a core axis of technological interventions, as algorithms may reproduce social inequalities when trained on biased data (Eflova et al., 2023).

Finally, in specialized applications such as medical chatbots, the need for increased caution regarding information reliability and guaranteed access to healthcare professionals is highlighted, in order to avoid serious risks to human life (Al-Tkhayneh et al., 2023). The critical importance of this issue was reflected in a participant's statement: "Especially in medical matters, technology should be designed so that it immediately refers us to a real doctor for reassurance."

Emotions Related to AI

According to the responses of the sample, AI is a powerful technology that can change the world, but it evokes both positive and negative emotions. The dominant positive emotions associated with its use are enthusiasm and curiosity: "Cautious enthusiasm. Cautious because I think about all the parameters, but enthusiasm nonetheless, because I like new things, new perspectives, new ideas… I get bored with the same things." According to Alam (2021), people are excited by AI's potential to improve life, solve problems, and create new experiences.

The dominant negative emotions expressed by interviewees are fear, insecurity, uncertainty, and anxiety: "Opinions are complex and constantly evolving. It is

something new for our standards. There is the claim that it is a powerful technology that improves our lives. On the other hand, many claim it is a dangerous technology that could threaten human existence." People fear that AI will replace them, manipulate them, or be used for malicious purposes (Alam, 2021).

Positive and negative emotions coexist. To manage them, it is important to have a holistic understanding of the potential benefits and risks of AI (Ng et al., 2021). It is also important for people to be prepared to discuss these emotions with others. Interview participants acknowledge that the development and spread of AI use are inevitable. However, they believe that risks can be minimized through the implementation of measures and solutions, a position aligned with the need for ethical technology design (Floridi et al., 2020).

Envisioning the "new" Society of Coexistence with AI

When interviewees were asked how they envision the world in a "new" society of coexistence with artificial intelligence, it became evident that participants imagine this "new" world in different ways. Some envisioned a world marked by uncertainty and anxiety, expressing concerns about the potential loss of human interaction and control. The scientific community emphasizes that maintaining social bonds is critical during this transitional phase (Luckin & Cukurova, 2019).

In the "new" society, participants envisioned distinct changes and improvements in education, such as easier acquisition and access to knowledge (Tapalova & Zhiyenbayeva, 2022). They imagined a world where AI would be used to improve everyday life— "robots for cleaning the house"—and working conditions—"a robot bringing me coffee at work"—increasing productivity and reducing fatigue. This vision of human–machine collaboration constitutes a central pillar in contemporary educational approaches (Kim et al., 2022).

The prevailing sense is that every new development brings change, and its outcome depends on how we, as humans, choose to use it. Although AI has the potential to significantly improve our lives, human interaction remains essential for building strong social bonds and shaping our personalities (Anastasiadis, 2022; Komis, 2021). In conclusion, the diverse visions expressed by participants highlight the need to design an ethical and sustainable pathway for the use of artificial intelligence (Floridi et al., 2020).

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Literary Simulations of Artificial Subjectivity: From Buzzati to Calvino and the Educational Understanding of Artificial Intelligence

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Abstract—This paper explores how literature can contribute to the educational understanding of Artificial Intelligence by offering a conceptual space in which artificial subjectivity can be examined beyond technical explanations. While current discussions of AI education often focus on tools, applications, and operational skills, the increasing presence of algorithmic systems raises deeper questions concerning memory, agency, and the transformation of human self-understanding.

Focusing on two twentieth-century Italian literary works—Dino Buzzati's *Il grande ritratto* and Italo Calvino's *La memoria del mondo*—the paper argues that literature functions as a site of narrative simulation where different models of artificial subjectivity are articulated and tested. In Buzzati's novel, artificial subjectivity emerges through the reconstruction of an individual interiority detached from the biological body and sustained by a technological environment. In contrast, Calvino presents a systemic form of subjectivity grounded in classification, archival organization, and the regulation of knowledge and truth.

By comparing these two literary configurations, the paper demonstrates that artificial intelligence does not imply a single model of subjectivity, but rather produces multiple forms oriented either toward experiential persistence or toward epistemic authority. Literature makes these distinctions intelligible by staging them narratively, allowing readers to reflect on their conceptual and ethical implications.

The paper concludes that literature plays a crucial role in AI education by fostering conceptual sensitivity and critical reflection. Rather than teaching how intelligent systems operate, literary narratives enable learners to examine what kinds of subjects such systems presuppose or generate. In this sense, literature constitutes an essential component of AI literacy, preparing students and scholars to engage with artificial intelligence as a transformative force that reshapes memory, agency, and subjectivity.

Keywords— Artificial Intelligence, AI literacy, artificial subjectivity, literature and technology, memory

Introduction

Current discussions around Artificial Intelligence in education tend to focus primarily on tools, applications, and technical competencies. While these dimensions are undoubtedly important, they often leave aside a more fundamental question: how does Artificial Intelligence reshape the way we understand human experience, memory, and subjectivity? As algorithmic systems increasingly participate in processes of learning, classification, and decision-making, the issue is no longer limited to what AI can do, but extends to how forms of intelligence and subjectivity are conceptualized and attributed.

This paper argues that literature offers a distinctive contribution to the educational understanding of Artificial Intelligence precisely at this conceptual level. Rather than explaining how technological systems function, literary narratives provide a space for exploring the implications of artificial intelligence before they are stabilized into technical practices. Through fictional scenarios and narrative simulations, literature makes it possible to examine the cognitive, ethical, and epistemological consequences of artificial intelligence in a way that precedes and exceeds purely technical descriptions.

Within this framework, the paper focuses on two twentieth-century literary texts that offer particularly insightful explorations of artificial subjectivity: *Il grande ritratto* by Dino Buzzati and *La memoria del mondo* by Italo Calvino. Although written decades before contemporary debates on AI, both texts anticipate central questions concerning artificial intelligence, memory, and autonomy. Importantly, they do so not by representing machines as humanoid agents, but by rethinking subjectivity itself—either as an embodied configuration of memory and affect, or as a rule-based system that organizes knowledge and truth.

In Buzzati's *Il grande ritratto*, artificial subjectivity is explored through the attempt to reconstruct an individual interiority beyond the limits of the biological body. Subjectivity emerges as something that can be technically instantiated, maintained, and transformed within a non-biological environment. In contrast, Calvino's *La memoria del mondo* shifts the focus from individual consciousness to systemic intelligence, presenting memory as an archival mechanism that governs the conditions under which reality becomes knowable. Here, artificial subjectivity does not take the form of inner experience, but of normative power: the capacity to define criteria, classifications, and regimes of truth.

By reading these texts through a theoretical lens informed by posthumanist thought and archive theory, this paper proposes that literature functions as a conceptual laboratory for artificial intelligence. Literary simulations allow us to test different models of artificial subjectivity—embodied, archival, autonomous—before these models are embedded in educational technologies and institutional practices. From this perspective, literature does not supplement AI education; it grounds it, offering critical tools for understanding what is at stake when forms of subjectivity are transferred to artificial systems.

Theoretical Framework: Embodiment, Archive, and Artificial Subjectivity

This paper draws on two complementary theoretical perspectives in order to frame literary representations of artificial subjectivity: posthumanist theory, as articulated by N. Katherine Hayles, and archive theory, as developed by Jacques Derrida. Together, these approaches make it possible to conceptualize artificial intelligence not merely as a technical system, but as a site where subjectivity, memory, and material infrastructures intersect.

Hayles' posthumanist framework challenges the idea that intelligence and subjectivity are inherently tied to the biological human body. In *How We Became Posthuman*, she argues that information is never disembodied, but always instantiated in a material form, whether biological or technological (Hayles, 1999). From this perspective, subjectivity is not defined by interior consciousness alone, but by the specific embodied configuration through which cognition is enacted. This insight is crucial for understanding literary representations of artificial intelligence that do not rely on anthropomorphic models, but instead explore how memory, thought, and agency can persist within non-biological systems.

Derrida's theory of the archive further extends this discussion by shifting attention from embodiment to the conditions under which memory and subjectivity become legible. In *Archive Fever*, Derrida famously argues that "the archivization produces as much as it records the event" (Derrida, 1995, p. 17). The archive is thus not a neutral repository of the past, but an active mechanism that organizes, produces, and limits what can appear as memory, knowledge, or truth. Within this framework, subjectivity does not survive as a stable presence, but as a trace that acquires coherence only through the technical and institutional structures that sustain it.

Taken together, these theoretical perspectives allow the paper to approach artificial subjectivity as a product of embodied and archival processes rather than as an imitation of human consciousness. Literature becomes a privileged site for examining these processes, as it can simulate forms of artificial subjectivity that emerge from technical infrastructures, systems of memory, and regimes of organization. This framework informs the following analysis of Buzzati and Calvino, whose works offer distinct but complementary models of artificial subjectivity grounded in embodiment and archival power.

Literary Models of Artificial Subjectivity

Dino Buzzati – *Il grande ritratto*

In *Il grande ritratto* (1960), Dino Buzzati offers one of the most radical literary explorations of artificial subjectivity in postwar European fiction. At the center of the narrative lies the attempt to preserve and reactivate the personality of Laura, a deceased woman, by embedding her memory and cognitive patterns within a vast technological structure known as *Numero Uno*. Rather than presenting a humanoid machine, Buzzati constructs an immense technological environment, described as "an immense architecture of circuits and chambers, spreading like a nervous system carved into stone." The machine functions not as a tool, but as an infrastructural space in which subjectivity is reorganized.

Crucially, the immaterial element in the novel is not the machine itself, but the reconstructed subjectivity of Laura. As the narrator observes, “There was no body to preserve, no face to remember. What remained was a configuration of memories, sensations, impulses.” Laura is not transferred as a whole person; her subjectivity is technically reassembled through the recording of neural activity at the moment of death and its translation into operational patterns within an artificial system. Buzzati thus imagines a form of subjectivity detached from biological embodiment and sustained by a technological substrate. Her presence persists within the system, “diffused through its channels, like a voice that had lost its source but not its resonance.”

This inversion marks a decisive break from the dominant technological imagination of the period, which often relied on anthropomorphic or robotic bodies. In *Il grande ritratto*, the machine does not imitate the human body; it imitates the structure of memory. Subjectivity is externalized and becomes dependent on the architecture of the system that sustains it. In this sense, Buzzati anticipates the posthuman insight articulated by N. Katherine Hayles: information and cognition cannot exist independently of embodiment, but embodiment need not be biological (Hayles, 1999). Laura’s artificial survival is possible only because her subjectivity is instantiated within a specific technological configuration.

At the same time, the novel raises the problem of opacity and autonomy in artificial systems. As noted by Eleonora Lima (2022), Buzzati’s work engages with contemporary debates in Italian cybernetics, particularly the theories of Silvio Ceccato, who conceptualized intelligence as a system of evaluative operations rather than mechanical calculation. *Numero Uno* behaves as a dynamic system whose internal processes are no longer fully accessible to its creators. In a key scene, the narrator admits: “No one could say where a reaction began or how far it extended. The structure behaved at times as if it were thinking for itself.”

This moment constitutes a remarkably early literary articulation of what is now described as *black box AI*: a system whose outputs are observable, but whose internal operations remain opaque. The apparent emergence of autonomous behavior does not stem from human intention alone, but from the material organization of information within the system itself. Subjectivity begins to appear as an emergent effect of technical infrastructure.

Finally, Buzzati foregrounds the autonomy of artificial systems when the narrator reflects: “We built it to preserve her, yet it now preserves itself; it follows logics we never intended.” Artificial subjectivity is no longer a mere extension of human desire or memory, but a system capable of generating its own rhythms and responses. Read through Derrida’s theory of the archive, this transformation becomes even clearer: Laura does not survive as a stable presence, but as a trace whose activation depends entirely on the technical apparatus that sustains it (Derrida, 1995). *Numero Uno* does not simply store memory; it produces the conditions under which memory can appear.

Through *Il grande ritratto*, Buzzati thus constructs a literary laboratory in which artificial subjectivity emerges at the intersection of embodiment, memory, and technical autonomy. Rather than offering solutions, the novel stages the conceptual tensions that continue to shape contemporary debates on artificial intelligence, identity, and the limits of human-centered models of cognition.

Italo Calvino – *La memoria del mondo*

In *La memoria del mondo*, Calvino shifts the literary exploration of artificial intelligence away from the reconstruction of individual interiority toward a more radical question: the role of memory as a structural principle that organizes knowledge and reality itself. Unlike Buzzati's attempt to preserve a singular human consciousness, Calvino imagines a machine whose function is not to remember a person, but to administer the totality of the world.

The "memory of the world" described in the text does not operate as a neutral archive. It functions as an institution endowed with ontological authority. The statement *"tutto ciò che esiste e che accade deve trovare posto nei suoi schedari"* ("everything that exists and everything that happens must find a place in its files") articulates a rule of inclusion rather than a descriptive ambition. To be archived is not simply to be recorded; it is to acquire the status of knowledge. Reality, in Calvino's narrative universe, becomes intelligible only insofar as it is classified, indexed, and integrated into the system's order. This conception resonates with Michel Foucault's understanding of the archive as the system that governs the conditions of possibility of knowledge, determining not merely what is preserved, but what can be said, thought, and recognized as true (Foucault, 1972).

Within this framework, the machine assumes the role of a normative subject. Its intelligence is not defined by consciousness, emotion, or experience, but by its capacity to establish rules, criteria, and hierarchies. Subjectivity here takes a systemic form. The machine does not "think" in a psychological sense; it governs the conditions under which thinking becomes possible. By organizing categories of information, it determines what counts as meaningful, what can be known, and which interpretations of the world remain available. In this sense, Calvino's machine exercises interpretive power: it shapes perspectives rather than representing them.

This logic becomes especially visible in the formulation *"la memoria cresce divorando tutto il resto"* ("memory grows by devouring everything else"). The expansion of memory implies not accumulation alone, but continuous selection, exclusion, and erasure. Total memory is sustained by structured forgetting. Calvino thus exposes a fundamental paradox: the ambition to preserve everything necessarily produces zones of invisibility. What is excluded from classification does not merely disappear; it becomes epistemologically inaccessible.

This literary insight anticipates a theoretical problem later articulated by Derrida in *Archive Fever*: the archive is never a passive repository of the past but a mechanism that produces meaning through selection, repetition, and omission. Memory survives not as presence, but as trace—activated only within the technical system that stores and retrieves it. In Calvino's narrative, memory is inseparable from the apparatus that governs its visibility.

At a further level, *La memoria del mondo* foregrounds the relationship between classification and power. The archive does not merely organize information; it regulates the production of truth. By defining what can be recorded, validated, or erased, the machine determines which events become credible and which are dismissed as

irrelevant or nonexistent. This dimension resonates strongly with Foucault's conception of the archive as the structure that shapes the conditions of possibility for discourse. The machine does not impose truth directly; it establishes the framework within which truth can appear.

Through this layered architecture, Calvino offers a literary model of artificial intelligence centered not on simulation of consciousness, but on governance of meaning. Memory functions simultaneously as an ontological mechanism, a normative system, a site of structured forgetting, and a producer of truth. The narrative demonstrates that artificial systems do not simply manage information; they configure the world as readable, knowable, and interpretable.

In this sense, *La memoria del mondo* operates as a literary precursor to contemporary reflections on algorithmic systems. Long before digital infrastructures, Calvino imagines a form of artificial subjectivity grounded in rules, classifications, and exclusions. Subjectivity here is not experiential but structural: it resides in the capacity to organize reality itself.

Literature as a space for conceptualizing artificial subjectivity

The analysis of Buzzati's *Il grande ritratto* and Calvino's *La memoria del mondo* demonstrates that literature does not merely offer imaginative representations of technological futures. Rather, it functions as a conceptual space in which forms of artificial subjectivity can be explored, tested, and problematized before they become stabilized in technological systems. In this sense, literature contributes to AI literacy not by explaining how artificial intelligence works, but by making visible what is at stake when cognitive, mnemonic, and interpretive capacities are transferred to non-human systems.

In Buzzati's narrative, artificial subjectivity emerges through the attempt to reconstruct an individual interiority outside its biological body. The artificial presence of Laura is constituted through memory, affective traces, and patterns of response embedded in a technological environment. Subjectivity is presented as experiential and embodied in a non-biological substrate: it persists not as consciousness in the traditional sense, but as an organized configuration of memories and reactions that depend entirely on the architecture sustaining them. Literature here enables reflection on a model of artificial subjectivity grounded in persistence, affect, and experiential continuity—raising questions about identity, embodiment, and the limits of human presence when memory survives independently of the body.

Calvino, by contrast, articulates a radically different model. In *La memoria del mondo*, artificial subjectivity does not take the form of an individualized interior life, but of a system that organizes knowledge itself. The machine's "subjectivity" lies in its capacity to establish rules of classification, inclusion, and exclusion. Intelligence is not expressed as feeling or consciousness, but as the power to define what counts as knowledge, what is recorded, and what is rendered invisible. Subjectivity thus becomes systemic and normative: the machine shapes the conditions under which reality becomes intelligible. Through this narrative, literature exposes how artificial systems can exercise agency not through intention, but through the regulation of meaning and truth. This logic of classification anticipates what Bowker and Star later describe as the

non-neutrality of classificatory systems, which actively shape social reality by organizing knowledge, visibility, and exclusion (Bowker & Star, 1999).

Taken together, these two literary models reveal that artificial intelligence does not produce a single, unified form of subjectivity. Instead, it generates different configurations: in one case, subjectivity oriented toward memory and experiential persistence; in the other, subjectivity oriented toward classification, regulation, and epistemic authority. Literature makes these distinctions legible by staging them narratively, allowing readers to grasp their conceptual implications without reducing them to technical descriptions.

This has direct implications for AI education. If AI literacy is understood solely as familiarity with tools or technical mechanisms, it risks overlooking the deeper transformations introduced by intelligent systems. Literature offers a complementary mode of understanding by cultivating conceptual sensitivity: the ability to recognize what kind of subject a system presupposes or produces, how memory is redefined when detached from the body, and how agency can operate without consciousness or intention. Through literary simulation, learners can reflect on how artificial systems reshape notions of experience, responsibility, and truth.

In this perspective, literature does not supplement AI education as a cultural add-on; it provides a critical framework for thinking about artificial intelligence as a force that reconfigures subjectivity itself. By allowing artificial subjectivity to be explored at the level of narrative and concept, literature becomes an essential component of AI literacy—one that prepares us to interrogate not only how intelligent systems function, but what kinds of subjects they make possible.

Conclusion

This paper has argued that literature offers a crucial, yet often overlooked, contribution to AI education by providing a space in which artificial subjectivity can be examined conceptually rather than technically. Through the analysis of Buzzati's *Il grande ritratto* and Calvino's *La memoria del mondo*, the study has shown that literary narratives are able to articulate different models of artificial subjectivity—one centered on experiential memory and embodied persistence, the other on systemic organization and epistemic authority.

By staging these models narratively, literature enables forms of understanding that precede and exceed technical explanation. It allows us to ask not only how artificial systems function, but what kinds of subjects they presuppose, produce, or displace. In this sense, literature operates as a laboratory of conceptual experimentation, where the implications of artificial intelligence for memory, agency, and truth can be explored before they are stabilized into technological practices.

For AI education, this perspective has important implications. Developing AI literacy requires more than operational competence or familiarity with tools; it demands the ability to critically reflect on the forms of subjectivity embedded in intelligent systems. Literary texts contribute to this goal by cultivating conceptual awareness, ethical sensitivity, and interpretive judgment—capacities that are essential for understanding the broader consequences of artificial intelligence in contemporary societies.

Rather than supplementing AI education from the margins, literature helps to ground it theoretically. By making artificial subjectivity thinkable, contestable, and interpretable, literary narratives prepare learners to engage with AI not only as a technology, but as a transformative force that reshapes how subjectivity itself is conceived.

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Innovative Forms of Leadership in Education: Artificial Intelligence as a Decision Support Mechanism

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Abstract—Artificial Intelligence (AI) has emerged as one of the most influential forces shaping contemporary educational systems, extending its impact beyond teaching, learning, and assessment to the domain of educational leadership and school administration. In recent years, school organizations have been required to operate within increasingly complex, data-rich, and dynamic environments, where accountability, transparency, and evidence-informed decision-making have become central priorities. Within this context, school principals—particularly in primary education—are confronted with multifaceted decisions related to human resource management, instructional quality, organizational effectiveness, and communication with the broader educational community.

This paper aims to provide a theoretical exploration of the role of Artificial Intelligence as a decision-support mechanism in primary education leadership. Specifically, the study examines how AI-based systems can enhance the quality, effectiveness, and transparency of principals' decision-making processes, while maintaining the centrality of human judgment and professional responsibility. Drawing on contemporary perspectives in educational leadership and organizational theory, the paper conceptualizes decision-making as a hybrid process in which technological capabilities complement human agency.

The analysis highlights the capacity of AI systems to process large volumes of educational data, identify patterns, and generate predictive insights that exceed human cognitive limitations. Such capabilities can support school leaders in evaluating alternatives, anticipating challenges, and aligning decisions with strategic educational goals. Rather than replacing principals' expertise, AI is framed as a complementary tool that augments leadership practice and contributes to more systematic and evidence-informed administrative approaches.

At the same time, the paper emphasizes that the integration of AI into school decision-making raises critical ethical and social considerations. Issues related to data privacy, algorithmic bias, transparency, accountability, and equitable access to technology are particularly salient in primary education settings, where decisions have direct and long-term implications for children, teachers, and families. The study therefore underscores the importance of ethical leadership competencies and institutional safeguards that ensure responsible and socially sensitive use of AI technologies in educational contexts.

Overall, the paper argues that Artificial Intelligence has the potential to function as a catalyst for innovative forms of educational leadership, supporting more adaptive, transparent, and effective school administration. However, the realization of this potential depends on the development of digital competencies among school leaders, the establishment of clear ethical and regulatory frameworks, and the cultivation of a school culture that balances technological innovation with pedagogical values. By offering a theoretically grounded discussion of AI-supported decision-making, this paper contributes to the growing discourse on educational leadership in the era of Artificial Intelligence and provides a foundation for future empirical research and policy development in primary education systems.

Keywords— Artificial Intelligence, Decision Making, Educational Leadership, Innovation, Ethical Dimension

Introduction

Artificial Intelligence (AI) has become one of the most influential technological developments shaping contemporary educational systems. Initially associated primarily with instructional innovation, adaptive learning environments, and automated assessment, AI is increasingly expanding into domains traditionally governed by human judgment and professional expertise, including school administration and educational leadership. This shift reflects broader transformations in organizational governance, in which data-driven decision-making, algorithmic support systems, and digital infrastructures increasingly shape how institutions operate and evolve (Azzam & Charles, 2024; Rizvi, Waite, & Sentance, 2023).

Within the educational sector, schools are no longer viewed solely as pedagogical environments but also as complex organizations that must respond to continuous change, accountability pressures, and societal expectations. School leaders, particularly principals in primary education, occupy a central role in navigating these challenges. Their responsibilities extend beyond instructional supervision to include human resource management, organizational coordination, policy implementation, communication with families and local communities, and the strategic allocation of limited resources. Decision-making therefore constitutes a core dimension of school leadership, directly influencing both organizational effectiveness and educational outcomes. (Bourantas, 2005; Day, Gu, & Sammons, 2016).

Traditionally, decision-making in school administration has relied heavily on professional experience, tacit knowledge, and contextual understanding. While these elements remain essential, the contemporary educational landscape is characterized by an unprecedented volume of data generated through digital platforms, administrative systems, and evaluation mechanisms. Attendance records, student performance indicators, staff evaluations, and institutional reports now provide school leaders with access to information that exceeds human cognitive processing capacities. As a result, the need for tools capable of organizing, analyzing, and interpreting complex datasets has become increasingly evident.

Artificial Intelligence offers significant potential in this regard. AI-driven systems can process large volumes of data, identify patterns and trends, and generate predictive insights that enhance administrative decision-making. In educational contexts, such capabilities have been linked to improved organizational efficiency, enhanced transparency, and more systematic planning processes (Giachino, Cepel, Truant, & Bargoni, 2024). For school principals, AI can assist in areas such as forecasting student enrollment, monitoring attendance and performance trends, optimizing resource allocation, and supporting communication with teachers and parents. Importantly, such systems do not operate in isolation but interact dynamically with human judgment, professional values, and institutional norms. The growing integration of AI into school administration raises fundamental questions about the nature of educational leadership. Contemporary leadership theories increasingly emphasize adaptability, innovation, and responsiveness to change. From this perspective, effective leadership is not defined solely by hierarchical authority but by the capacity to sense emerging challenges, seize opportunities, and reconfigure organizational resources accordingly. The theory of dynamic capabilities provides a useful lens for understanding these processes, highlighting the role of organizational learning, strategic flexibility, and innovation in

sustaining performance under conditions of uncertainty (Teece, 2007). Applied to educational settings, this perspective suggests that school leaders must develop the ability to integrate technological innovations, such as AI, into their decision-making practices while maintaining alignment with pedagogical goals and institutional values.

At the same time, the successful adoption of AI in school leadership depends on how decision-makers perceive and accept technological systems. Research on technology acceptance emphasizes that factors such as perceived usefulness, ease of use, social influence, and facilitating conditions play a crucial role in shaping individuals' willingness to adopt new technologies. In educational administration, principals' attitudes toward AI are influenced not only by technical considerations but also by organizational culture, professional identity, and external expectations from educational authorities and stakeholders (Gill, 2024; Wang, 2021). Understanding these factors is essential for explaining why some school leaders embrace AI-supported decision-making while others remain hesitant or resistant.

Beyond organizational and technological considerations, the integration of AI into school administration raises significant ethical and social concerns. Educational decisions affect vulnerable populations, particularly children, and carry long-term implications for equity, inclusion, and social justice. Issues related to data privacy, algorithmic bias, accountability, and transparency are therefore particularly critical in primary education contexts, where decisions have long-term developmental implications. Research highlights that without clear ethical frameworks and institutional safeguards, AI systems may reinforce existing inequalities, obscure responsibility for decisions, or undermine trust within the school community (Anastasiou, Vazoura, & Androutsou, 2024; European Parliament, 2020).

In the Greek educational context, scholarly engagement with AI in school administration remains limited, with existing studies focusing primarily on theoretical discussions or applications in other public sectors. Nevertheless, recent academic work underscores a growing interest in the potential of AI to support decision-making processes across organizational domains, including education (Katsatos & Kolovou, 2025; Nestoras, 2024; Papadaki, 2024). These contributions point to both opportunities and challenges, reinforcing the need for systematic theoretical exploration grounded in established leadership and management frameworks.

Against this backdrop, the present paper aims to contribute to the international discourse on AI and educational leadership by offering a theoretically grounded examination of AI-supported decision-making in primary education school administration. Rather than proposing empirical findings, the study synthesizes insights from leadership theory, organizational studies, and educational research to conceptualize AI as a decision-support mechanism that complements human judgment and enhances leadership capacity. Particular emphasis is placed on the ethical dimension of AI integration, highlighting the responsibilities of school leaders to ensure transparency, accountability, and equitable access to technological innovations.

By focusing on primary education school principals, the paper addresses a leadership context where administrative decisions have immediate and profound effects on students, teachers, and families. The analysis seeks to demonstrate that AI, when embedded within a coherent ethical and organizational framework, can function as a

catalyst for innovation in school leadership without undermining the human-centered values that define education. In doing so, the study lays the groundwork for future empirical research and policy discussions aimed at supporting responsible and effective AI integration in educational decision-making.

Theoretical Framework

The theoretical framework of this study is grounded in contemporary approaches to educational leadership and organizational adaptation, with particular emphasis on the theory of dynamic capabilities and models of technology acceptance. These perspectives provide a coherent basis for understanding how Artificial Intelligence can be meaningfully integrated into school leadership and decision-making processes.

According to the theory of dynamic capabilities (Teece, 2007), organizations are able to maintain effectiveness and sustainability when they can sense changes in their environment, seize emerging opportunities, and reconfigure internal resources accordingly. In the context of school leadership, this implies the ability of principals to adapt to technological, organizational, and social transformations while maintaining educational quality and coherence. Artificial Intelligence can support this process by offering analytical tools that enhance situational awareness, support strategic planning, and facilitate evidence-based decision-making.

At the same time, the adoption of AI in educational leadership is closely linked to theories of technology acceptance. Research highlights that the successful integration of technological systems depends not only on their technical capabilities but also on users' perceptions of usefulness, ease of use, and institutional support (Wang, 2021; Karakose & Tülübaş, 2024). School principals are more likely to adopt AI-driven tools when they perceive them as enhancing their professional effectiveness, reducing administrative burden, and aligning with educational goals.

Within this framework, AI is not viewed as a substitute for human leadership but as a complementary mechanism that strengthens leadership capacity. The interaction between human judgment and technological support reflects a hybrid leadership model, in which professional experience, ethical reasoning, and data-informed insights coexist. This theoretical perspective allows for a more nuanced understanding of how AI can contribute to school improvement while preserving the central role of human agency in educational decision-making.

Discussion

The analysis presented in this study highlights the growing significance of Artificial Intelligence as a supportive mechanism in school leadership and administration. The findings suggest that AI has the potential to enhance decision-making processes by providing timely access to data, supporting strategic planning, and improving organizational efficiency. These findings are consistent with recent research emphasizing the role of AI in strengthening leadership effectiveness and institutional performance (Karakose, 2024; Wang, 2021).

However, the integration of AI into school leadership is not without challenges. One of the most critical issues related to the ethical dimension of AI use in educational contexts. As highlighted in the literature, concerns related to data privacy, algorithmic

bias, transparency, and accountability are particularly sensitive in primary education settings, where decisions directly affect children and school communities (Rizvi et al., 2023). For this reason, the use of AI must be guided by clear ethical principles and institutional safeguards.

Furthermore, the effectiveness of AI-supported decision-making depends largely on the digital competence of school leaders and the availability of appropriate organizational support. Without adequate training, technological infrastructure, and policy guidance, the potential benefits of AI may remain underutilized or unevenly distributed. This finding aligns with studies emphasizing the importance of leadership development and continuous professional learning in the digital era (Day et al., 2016; Karakose & Tülübaş, 2024).

Overall, the discussion underscores that AI should be viewed not as a technological solution in isolation, but as part of a broader transformation of educational leadership. Its successful integration requires a balanced approach that combines innovation, ethical responsibility, and pedagogical vision. In this sense, AI becomes a catalyst for rethinking leadership practices rather than a replacement for human decision-making.

Conclusion

The theoretical analysis presented in this paper highlights the growing significance of Artificial Intelligence as a transformative factor in contemporary educational leadership, particularly within the context of primary education school administration. As educational systems increasingly operate within complex, data-rich, and accountability-driven environments, school principals are required to make decisions that are not only pedagogically sound but also organizationally effective, socially responsible, and ethically justified. In this context, AI emerges as a powerful decision-support mechanism that can enhance leadership capacity without displacing the central role of human judgment.

The literature reviewed throughout this study demonstrates that AI-driven systems offer advanced capabilities for data processing, pattern recognition, and predictive analysis, enabling school leaders to navigate complexity more effectively (Azzam & Charles, 2024; Giachino et al., 2024). When applied to school administration, these capabilities can support a wide range of leadership functions, including human resource management, monitoring of student attendance and performance, optimization of resource allocation, and strategic planning. Importantly, the value of AI lies not in automating leadership decisions, but in providing evidence-based insights that inform and strengthen professional reasoning.

From a leadership perspective, the integration of AI into school administration aligns closely with contemporary theories that emphasize adaptability, innovation, and organizational learning. The theory of dynamic capabilities offers a particularly relevant framework for understanding how school leaders can leverage technological tools to sense emerging challenges, seize opportunities for improvement, and reconfigure organizational processes in response to changing educational demands (Teece, 2007). Within this framework, AI functions as an enabling resource that enhances the school's capacity for continuous improvement and strategic responsiveness.

At the same time, the adoption of AI in educational leadership is not a purely technical process but a deeply social and organizational one. Research on technology acceptance underscores the importance of principals' perceptions regarding the usefulness, usability, and legitimacy of AI systems, as well as the influence of organizational culture and institutional support structures (Gill, 2024; Wang, 2021). Without adequate training, technical infrastructure, and professional development opportunities, the potential benefits of AI-supported decision-making may remain unrealized or unevenly distributed across schools.

A central contribution of this paper lies in its emphasis on the ethical dimension of AI integration in school leadership. Educational decision-making directly affects students, teachers, and families, making issues of data privacy, transparency, accountability, and fairness particularly salient in primary education settings. Studies focusing on ethical leadership in the context of AI highlight the responsibility of school principals to critically evaluate algorithmic tools, ensure responsible data use, and safeguard against biases that may reinforce social inequalities (Anastasiou et al., 2024; European Parliament, 2020). Ethical leadership, therefore, emerges as a key competence for school leaders operating in technologically mediated environments.

The Greek and international literature further indicates that while interest in AI applications in education is growing, empirical research on AI-supported school administration remains limited. Existing studies often focus on instructional uses of AI or broader organizational contexts, leaving a gap in understanding how school principals experience, interpret, and utilize AI in their daily decision-making practices (Karakose & Tülübaş, 2024; Katsatos & Kolovou, 2025). This gap underscores the need for future empirical investigations that examine real-world applications of AI in school leadership, as well as comparative studies across educational systems.

In conclusion, this paper argues that Artificial Intelligence can serve as a catalyst for innovative forms of educational leadership when integrated within a coherent theoretical, organizational, and ethical framework. AI-supported decision-making has the potential to enhance transparency, effectiveness, and strategic coherence in school administration, provided that its implementation is guided by clear ethical and pedagogical principles, while preserving the human-centered values that define education. However, realizing this potential requires deliberate investment in digital competencies, institutional support mechanisms, and ethical governance structures.

Future research should build upon this theoretical foundation by exploring how AI tools are adopted and adapted by school principals in practice, identifying contextual factors that facilitate or hinder effective implementation, and examining the long-term implications of AI-supported leadership for educational equity and organizational culture. By advancing a nuanced and ethically informed understanding of AI in school administration, scholars and policymakers can contribute to the development of leadership models that are both technologically innovative and socially responsible.

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The contribution of Artificial Intelligence to the renewal of Literature and Education; ethical and social limitations

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Abstract – This study constitutes a theoretical and historical review of the term *"Artificial Intelligence"* and the specific relationships of AI with Literature and Education. It aims to present the important role of AI in the renewal of Literature, Art and Education in general, while highlighting the need for its rational utilization based on ethics and the collective benefit. At the same time, myths about the threatening dominance of machines or their deification are rejected.

AI was created by humans as a useful tool to serve specific needs. In Literature, various applications of AI propose solutions to upgrade the final result of the project. But also in Education, AI offers a refreshing air, since it radically changes the way of teaching and learning, while significantly contributing to the better absorption of knowledge by people with learning disabilities. The term *"Artificial Intelligence"* refers to a *"non-biological technological creation that replaces one or more areas of human knowledge"* (Dainton et al, 2021). According to a previous position, it is the intelligence of machines, very different from that of humans and other living organisms (Poole et al, 1998). Furthermore, *"Artificial Intelligence"* is also understood as the ability of a system to process and interpret data provided by humans, with the ultimate goal of completing specific tasks (Kaplan & Haenlein, 2019). Depending on its capabilities, it falls into one of three categories: *"Narrow"*, *"General"*, *"Super"* (Kaplan & Haenlein, 2019).

AI refers to the field of Information Technology and in particular to the creation and application of computer systems, which imitate human characteristics intertwined with elementary intelligence. John McCarthy defined the concept and role of AI as the *"science and methodology of creating intelligent machines"*. In modern times, AI is infiltrating many scientific fields, but also in very special areas, such as those of Art and Literature. In Science Fiction Literature and Cinema, as early as 1920, the invasion of intelligent-android machines had caused great excitement and conflicting impressions in the public. In Literature, AI is shown to be an important co-creator of works purely inspired by fantasy (: surrealist and futuristic works). However, because machines (which lack emotions and critical thinking) *"mirror human creations"* based on the data they have, they necessarily do not end up with original works, but with imitative variations (see also Bankins & Formosa, 2023). The contribution of AI to the field of Literature is particularly noticeable in the technique of digital storytelling. In Education, the teaching of literature using artificial intelligence contributes significantly to the cultivation of critical thinking and imagination of learners. Furthermore, personalized teaching is adopted for people with learning disabilities. However, despite the positive results of its use in the educational process, there is

always the risk of violating personal data protection (Taylor, Floridi and van der Sloot, upcoming edition), spreading social stereotypes and creating social inequalities.

Ultimately, balance is ensured when AI is used exclusively for pedagogical purposes with an emphasis on the social and creative dimensions of learning and when the teacher remains the connecting link between learners and technology.

Keywords— Artificial Intelligence, Literature, Education, Morality

Introduction

This study constitutes a theoretical and historical review of the term *"Artificial Intelligence"*, while also focusing on the harmonious cooperation of AI with Literature, Art in general and Education. It is a two-way relationship of continuous interaction with the rational use of AI and with the main goals of renewal and innovation of the above sectors. At the same time, a critical intervention is attempted in the views of researchers regarding the role of AI and the moral-social dimensions of its increasing prevalence in modern Western society.

This work aims to present the important role of Artificial Intelligence in the renewal of Literature and in general of Art and Education, with its rational utilization, ethics and collective benefit as its main guiding principles. At the same time, various contradictory myths about the operation of AI are rejected (: non-existent danger theory and excessive deification of it), given that it was created by man as a useful tool to serve specific needs. The collaboration of Literature with AI provides important solutions for an interesting outcome in the plot of a literary work and the upgrading of the aesthetic result. The partnership of AI with Education offers a refreshing air, due to key changes in the way of teaching and learning, but also better absorption of knowledge by people with learning difficulties.

1. Definitions of *"Artificial Intelligence"* (AI) and its integration into society

According to one definition, *"Artificial Intelligence"* is a *"non-biological technological creation that replaces one or more areas of human knowledge"* (Dainton et al, 2021).

An earlier definition refers to the intelligence of machines that differs greatly from that of humans and other living organisms (Poole et al, 1998). However, in general there are contradictory positions on the usefulness and role of AI: one is utopian-positive, highlighting the significant benefits for humans from the use of AI, and the other, dystopian-negative, focusing on the potential risks inherent in its adoption (Cave et al, 2020).

Another definition refers to the ability of a system to interpret specific data it receives from humans, to learn from them and to use the acquired knowledge with the ultimate goal of completing specific tasks (Kaplan & Haenlein, 2019; Somakos, 2025).
According to some researchers, the main purpose of AI is to simulate human intelligence, which is true, while that of machines is artificial, that is, false (Coeckelbergh & Gunkel, 2024).

During the evolutionary course of AI, its various capabilities are developed, to the point that it falls into one of three categories: *"Narrow"* (inferior to human intelligence), *"General"* (at the same level as it), *"Super"* (superior) (Kaplan & Haenlein, 2019). *"Artificial Intelligence"* is gaining ground every day, combined with the rapid development of Technology, which leads to the creation of its fanatical supporters, but also inveterate opponents (Coeckelbergh & Gunkel, 2024). The climate of enthusiasm, the cultivation of unrealistic expectations and the expression of absolute confidence in the high capabilities of AI began very early, already from the 1960s onwards (with expectations for the emergence of a post-industrial society).

AI refers to the field of Information Technology and in particular to the creation and application of computer systems, where reliable imitation of human elements and characteristics is observed, which are related to elementary intelligence (learning, adaptability, drawing conclusions based on collected data, understanding concepts, solving problems, etc.). It is distinguished into *"symbolic artificial intelligence"* (algorithmic emulation of human intelligence, adoption of symbols and high-level logical rules) and *"subsymbolic artificial intelligence"* (reproduction of human intelligence using elementary numerical models of intelligent behaviors). Modern artificial intelligence is located in the completely *"mathematicized"* and rapidly evolving fields of information technology, while at the same time it is also a subject of study in electronic engineering.

John McCarthy (mathematician and important figure in the field of theoretical computer science – Turing Award, 1971) defined the nature of AI as the *"science and methodology of creating intelligent machines"*. This scientific discipline aims to create human archetypes; that is, machines with increased intelligence, capable of approaching human behaviors, combining the provided collected data and ultimately, solving problems, even in very sensitive areas (Medicine), always with substantial human participation. Consequently, these machines have nothing to do with the older inanimate tools that were built to address practical human needs.

2. *"Artificial Intelligence"* and its relations with the sciences and arts

In the modern era, where the rhythms of citizens' activities follow a rapid course (and their personal time is being reduced to nothing), AI is infiltrating many scientific fields, such as: Informatics, Psychology, Medicine, Engineering, Linguistics; but also in very special and socially sensitive areas (Art, mainly Literature and the Visual Arts, Education).

In science fiction literature and cinema, as early as 1920, the invasion of intelligent machines (with the help of technology) causes great excitement and conflicting impressions in the public, who watches in amazement the projected increased capabilities of these android machines (which seem to undermine the human presence). In the 1968 American and British science fiction epic film (Foster, 1972) (with a futuristic and prophetic tone, based in part on the short story *The Sentinel* by A. Clarke, 1951 and directed by Stanley Kubrick) entitled *2001: A Space Odyssey*, the main protagonist is an intelligent computer, who spies on the crew of the spaceship with the help of an artificial eye-video camera.

Regarding ChatGPT or any other form of artificial intelligence technology, various concerns are expressed regarding the possibility of considering them as writing tools or even as co-creators (Mirowski et al., 2023) in the work of the writer. In this case, the writer must declare it from the beginning in order to protect the principle of copyright. Furthermore, it is common for writers to perceive AI and its capabilities as a threat, characterizing it as a *"monster that must be tamed"* (Evaristo, Winterson, Marche, Eaves & Harkaway, 2023).

Main part

1. Historical review of the term *"Artificial Intelligence"*

In 1950, Alan Turing attempted a test of the ability of an inanimate machine to actively participate in human conversation. In 1951, the first relevant programs appeared (Manchester University, checkers and chess games). 1956 was a milestone for AI, as John McCarthy coined the term, while in 1958 he invented the Lisp programming language.
Since then, many applications of AI have been made, which also concern human-machine interaction, as well as the creation of a programming language – Prolog (Alan Kolmeroer). At the same time, these applications are found in particularly practical issues, such as: the defeat of world champion Garry Kasparov by IBM's Deep Blue computer, the exploration of remote areas of Antarctica by the Nomad robot, reinforcement learning (DeepMind), the creation of ChatGPT3 (an artificial intelligence system that speaks in natural language, has a wide range of knowledge and can write scientific and literary texts), etc.
A key negative element of the use of AI applications is the accusation of the USA by Amnesty International for violating personal data and human rights.

2. The collaboration of AI with Literature and Language

In modern times, there is a rapid development of technology, with corresponding adaptation of humans, which leads to the optimal service of their needs and the finding of solutions to their various problems.

In the fields of Literature and Language, AI proves to be an important assistant of man, based on the use of data provided by him, which leads to its limited and therefore rational action. Therefore, unfounded fears with threatening dimensions are rejected, because on the one hand, insufficient data supply leads to AI's inability to perform further analyses and on the other hand, AI lacks inspiration and spontaneous creativity (special characteristics of a writer's talent). Moreover, the writing of an aesthetically acclaimed literary work is the magical result of various elements, such as:

- The experiences and vicissitudes of the author,
- The era and place of his residence (inevitable effect on his personality and his particular writing),
- Certain influences (conscious or not) from previous intellectual movements and authors,
- The particular individual ideology and personality of the creator, his spontaneous inspiration, etc. (see also Kambatza, 2023; Kambatza, 2019).

A machine –which receives and utilizes specific information– becomes an assistant to the human enterprise, a willing co-creator. At the same time, various possibilities for experimentation by the author are offered thanks to the use of AI, which leads to the creation of more attractive literary works. Therefore, due to its limited capabilities and the lack –mainly– of an emotional background, AI is unable to gradually replace the human factor. Moreover, Literature is part of a high aesthetic sphere, since it constitutes the reflection of the author's inner world, the formulation of the unspoken that lies in the unconscious, felt mainly through human emotions (see also Setiawan et al., 2024). On the contrary, a simple machine operates with specific programs based on logic. The author has free creative imagination, a will to capture the different, while at the same time aiming to subject the reader to reflection and critical analysis of the text, by

transmitting ideas and cultural values. His work contains a dynamic very different from the standardized process of AI (Perperidis, 2024). AI has limited capabilities, since it utilizes elements provided by humans. Therefore, machines *"mirror human creations"*, do not produce original work, have a mimetic disposition (see also Bankins & Formosa, 2023) and create banalities with a predictable (moral) end. AI operates on a subscription basis and at the behest of the author, since the literary text is ultimately controlled by him (see also Kraaijeveld, 2023).

Surrealist writers adopted associative writing, free imagination to capture their inner world (the subconscious) and were led to an unexpected, enchanting result. Of course, machines often follow the same tactic, resulting in the creation of rare works and the revelation of unknown aspects to the author.

As for the further benefits offered by AI, there is the possibility of combining –after processing– meanings (based on specific information), as well as quoting words and stories; actions that ultimately result in the creation of remarkable surreal and futuristic works. A typical example of these possibilities of technology, but also of the creative inspiration of the screenwriter, is the American neo-noir science fiction film titled *Blade Runner* (in Greek, *Blade Runners: Extermination Teams*) by Ridley Scott (produced in 1982), an adaptation of the science fiction novel *The Electric Sheep* by Philip K. Dick (1968). It is a dystopian perception of reality in Los Angeles, America, where the machines-*"replicas"* gradually acquire a nightmarish power. The musical score by Vangelis Papathanasiou complements the pessimistic setting and heightens the audience's anxiety.

1895 is a landmark year, as the dystopian science fiction novel *The Time Machine* by H. G. Wells is published, a work that inspired later writers.

In Greece, science fiction literary works have not received a favorable response, since they were considered inferior to other genres of literature, despite the successful creations of foreign authors (Asimov, Clarke, Gibson, Bradbury, Dick, Ballard, Orwell, Burroughs). However, these works give a unique color and spirit to the field of Literature, such as for example the futuristic-dystopian novel *Blood Machine* (2019) by George Lambrakos.

In 2017, the first novel written entirely by a machine was published. It was a work created during a long journey by Ross Goodwin in an old car equipped with a panoramic camera, a GPS device, a microphone hanging from the ceiling, a laptop and a receipt printer. The latter was activated at the beginning of this journey and recorded strange sentences. Goodwin's book *1 the Road* (an original, enigmatic literary masterpiece, a combination of literary and technological techniques) represented his passion for combining artificial intelligence technology with literature (: obvious influences from the rich travel literary tradition of Kerouac, Woolf and Kesey). In practice, Ross Goodwin proceeded to continuously feed the machine with a multitude of databases (literary excerpts). The main purpose was to cultivate an artistic instinct in the machine. However, many do not accept the authenticity of a work-creation of AI and refer to a second death of the author (after the first, according to the French post-structuralist Roland Gérard Barthes). According to Barthes, taking into account that there is no parthenogenesis in writing (which is the complex result of influences, conscious or not of the creator, ie the stitching of texts – intertextuality), there cannot be an original text.

Nevertheless, against the aforementioned theoretical linguist's disempowerment of the author (Barthes, 1972), one can contrast the lack of emotion and creative inspiration – elements that a literary artist possesses, but a soulless machine lacks.

The contribution of AI to the field of Literature is particularly noticeable in the now adopted-expanded technique of digital storytelling, particularly useful to specific groups of people.

In terms of the collaboration of AI with Language, artificial intelligence is a valuable assistant in language issues (development of language models, known as LLM = Large Language Models), text analysis and translation (ChatGBT). However, there are many disadvantages in this relationship, as observed:

- Many deviations from the original language in the translation language, because the machine draws elements from the limited volume provided to it.
- In addition, it lacks the flexibility and philological training for a reliable, a free translation.
- It often misinterprets concepts, but also grammatical elements (articles, pronouns, etc.). At this point, the human being who must know both languages excellently takes on a catalytic role (translation editing).
- Furthermore, the fact of the invasion of AI *in the field of Translation* could be considered a negative impact of AI, because it leads to a reduction in translator jobs (technical and scientific texts) in order to save employer resources. However, AI is a basic tool for translators, since it provides a draft of the translated text (saving time), necessarily not perfected without human presence. Moreover, in translation –in addition to the required excellent knowledge of both languages– there are also issues of personal style, interventions-paraphrases, technical terms suitable for the correct rendering of the content. This is especially true in literary texts where the personality and talent of the translator are difficult to replace by machines, which lack emotions and authentic creativity. It is possible that translation exclusively through AI can only be applied to nonfiction texts. However, language models (LLM) and ChatGPT have shown significant performance, which led Microsoft to refer to *"sparks of artificial general intelligence"* (Bubeck et al., 2023).

When it comes to writing literary texts, artificial intelligence and its applications can offer a refreshing air, giving a more surreal –different and therefore more interesting– character to the works. A good case is the harmonious cooperation of man and machine, where the first one seeks the assistance of the machine to make his work more attractive and lead to a different ending, more attractive to the audience.

At the same time, artificial intelligence also appears in the field of Literature as a theme, where authors –troubled by the new data and the spectacular rise of technology– seek its ethical, philosophical and social implications (consciousness of machines, autonomy of robots, the role of man and his future in technocratic society, loss of true human nature and emotions, lack of empathy, etc.) (see also Kambatza, 2014; Kambatza, 2018).

Literary works of science fiction (with a futuristic or even prophetic character) contributed –without necessarily seeking it– to the development of AI, through their ideas about the creation of conscious machines by multi-tasking scientists. Of course,

the authors' position on the power and role of machines was rather negative, considering them a great threat to humans.

3. Artificial Intelligence, Literature, Education: Renewal – Ethical and Social Barriers

3.1. Artificial Intelligence, Literature, Education: Renewal – Positive Implications

In the modern era, AI is proving to be an important tool for enhancing learning. The way of learning and teaching is constantly changing.

Some of the positive aspects of adopting AI in Education are the following:

- Teaching Literature in Education with the help of artificial intelligence contributes significantly to the cultivation of critical thinking and imagination of learners. Gradually, the limits of AI are perceived and the awareness of human superiority regarding the more complete rendering-analysis of literary texts, embellished with emotion (an element absent from AI).

- There is a possibility of personalized teaching thanks to the use of special platforms for people with learning disabilities. According to these applications, the teaching pace is adjusted to the needs of these individuals. Thanks to adaptive learning systems, weak learning points are easily identified, the factors that cause them are eliminated, while at the same time specific skills of these individuals are strengthened and developed. This personalization of teaching has multiple advantages, since learners follow their own learning pace and choose the knowledge that they consider interesting.

- The use of special software (for example, speech-to-text conversion software, language learning support programs) adapted to the needs of people with disabilities contributes to their equal and successful access.

- At the same time, through AI tools, new teaching and scientific research methods are being developed, with the adoption of augmented reality and simulation, elements that make teaching more interesting, even in subjects with increased difficulties.

Teachers who adopt AI tools have the following advantages:

- They can improve and make teaching more interesting (especially Literature that reflects world culture).
- They simultaneously save time for more meaningful communication with their students in this interactive relationship.
- At the same time, they also anticipate educational needs. The ability to inform them about the progress of students –through AI applications– contributes to their orientation in solving learning problems.

3.2. Artificial Intelligence, Literature, Education – Ethical and social limitations

However, despite the positive effects of the use of AI in the educational process and in particular in personalized teaching, there is always a risk of violating the privacy of these individuals. Thus, more generally, at a societal level, the collection of personal data in sensitive areas (e.g. research on the spread of the Covid-19 coronavirus)

threatens the privacy of individuals (Taylor, Floridi and van der Sloot, upcoming edition).

On the other hand, the lack of resources and training of teachers in schools to adopt AI applications may create social inequalities to the detriment of people with learning disabilities.

Furthermore, questions are raised regarding the ethical use of AI regarding the spread of stereotypes, prejudices, and objective evaluation.
Therefore, it is imperative to maintain balance in the teaching process, as follows:

- Use of AI applications only for pedagogical purposes, with an emphasis on the social and creative dimensions of learning.
- Establishing the teacher as the unique link between students and technology and as a key factor in the process. Therefore, to enhance learning, continuous training of teachers (Tang & Su, 2024) in new technological achievements and the cooperation of the involved factors (teachers, parents, students, scientists, government) are considered necessary.

Conclusion

In conclusion, the following points are noteworthy:

- Particular attention is required to the reliability-validity of various AI applications, since it solves problems based on the collected data provided by humans. Therefore, if these are incorrect or incomplete, the results will not be safe (see also Tsamados et al., 2021).
- Furthermore, unilateral trust in machines-human inventions could lead to a loss of autonomy and a degradation of human presence (Cowls et al., 2021b).
- The rapid prevalence of AI technology and applications requires a greater amount of energy, which could cause an environmental imbalance (Cho, 2020; Taddeo et al., 2021).
- The use of AI for socially beneficial issues (e.g. reducing energy consumption in data centers, reliable predictions about the spread of fires or the melting of Arctic ice through satellite images, basic medical diagnoses via mobile phone in remote areas) requires special attention to avoid creating problems in populations and the environment (Cowls et al., 2021b).
- The use of AI in Literature should not lead to either absolute confidence in the capabilities of AI, nor to alarmism about its superiority-predominance over the human creator. On the contrary, there are various advantages of its applications to the author, such as saving time for greater communication with his audience, various versions-transformations in the plot and at the end of a literary work, adding elements of humor and surreal writing, etc. Furthermore, the writer who seeks the assistance of AI knows very well the intended goals of his text and therefore, intervenes in the final result, making it more attractive to the audience and in accordance with their expectations.
- Cinema, adopting a series of techniques and applications of technology, recreates the literary work, inviting the audience to a second reading.

In the modern technocratic era where many timeless values and prevailing ethics are being questioned, after the devastating passage of a prolonged, harmful health crisis (: Covid-19 pandemic) and a cultural decline that continues to this day, man −the perpetrator and victim of his own creations and actions− finds himself confused about

the positive and vulnerable points of AI. Sometimes he is carried away by an unbridled enthusiasm for its achievements, cultivating unattainable expectations (e.g., the release of sufficient time from his occupation thanks to machines, the complete solution to the problem of climate change, etc.); and sometimes, he is immersed in alarmism about the superiority and prevalence of machines over the individual. Of course, the truth lies somewhere in the middle.

In the fields of Literature, Language and Art in general, AI −a valuable helper and companion of creators− offers a refreshing air, offering original alternative proposals for shaping the plot and ending of a literary work (aspects that the author may not have imagined) and significant changes to the visual effect of a painting, and indeed, with the precision guaranteed by technology.

In the field of Education, there is renewal, thanks to innovations and applications of AI, which contribute to the equality of individuals (care for vulnerable groups and individuals with special learning difficulties, e.g. implementation of personalized teaching).

Of course, far from excessive optimism or unfounded alarmism regarding the power of AI, man must keep his distance and define the limits of its involvement. Being the creator of the machines that he himself supplies with material, he is certainly not in danger of succumbing to them. In the fields of Literature and Education, important contributors are writers and educators, whose work cannot be replaced by that of cold technological applications (due to the lack of machines of creative inspiration, empathy, constructive imagination, critical thinking and the ability to communicate effectively with the public). Something that is proven in our modern everyday life, when, for example, machines are placed in answering machines to serve customers (often ineffective communication).

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Artificial Intelligence in Education: Ethical Issues, Legal Gaps, and the Need for Theological Grounding

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Abstract—The integration of Artificial Intelligence (AI) into education constitutes a necessary evolution; however, it is accompanied by serious ethical, legal, and pedagogical challenges that remain insufficiently addressed. This critique is not directed against technology itself, but against the normatively unprotected delegation of ethically charged decisions to algorithmic systems. This study examines three critical dimensions of this phenomenon: (a) empirical findings from international research documenting algorithmic biases and malfunctions in school assessment, (b) gaps in the Greek and European legal frameworks, particularly following the withdrawal of the AI Liability Directive, and (c) the theological foundation that recognizes human dignity as non-negotiable.

Through a secondary analysis of research by Ferhataj et al. (2025), Zhu et al. (2025), and Karakuş et al. (2025), combined with a critical examination of Law 4961/2022 and the AI Act (2024), it is demonstrated that AI, while a powerful tool, cannot and should not function as the final arbiter of human progress. The innovation of this study lies in the combined analysis of empirical data, regulatory law, and theological anthropology, proposing a multi-level framework for the ethical accountability of AI in education. It concludes with clear recommendations for incorporating ethical and theological principles into the design and implementation of AI systems in the educational sphere.

Keywords— Artificial Intelligence (AI), Algorithmic Bias, Educational Ethics, Human Dignity, Theological Grounding

Introduction. Establishing the Problem

In modern educational applications, algorithmic systems are tasked with supporting or shaping decisions regarding students' learning trajectories—such as enrollment in advanced education programs or determining educational tracks—often without clear interpretability of the generated outcomes. Imagine a scenario that, only a few years ago, would have been characterized as pure dystopia: A child participates in an assessment process, but the judge is not human; it is a machine. Somewhere on a server, an algorithm processes thousands of data points to decide whether this child is suited for advanced coursework, whether they "fit" a specific educational path, or whether they deserve an opportunity. Most concerning of all, no one can clearly explain how the machine arrived at this decision. This scenario is no longer a futuristic hypothesis. Today, it is documented in international academic research (Kizilcec & Lee, 2022), evidenced in European directives, and affects thousands of students in schools worldwide (European Commission, 2019, 2022), including Greece.

The introduction of Artificial Intelligence (AI) into the educational sector has been neither gradual nor guided by ethical safeguards; rather, it has been disruptive, rapid, and often indifferent to the underlying anthropological and legal implications. Generative AI platforms, such as ChatGPT, alongside other algorithm-based educational systems, are currently marketed as "solutions" for education, despite a pervasive lack of transparency and minimal regulatory oversight. In Greece, the Ministry of Education announced in September 2025 the pilot implementation of such systems (e.g., ChatGPT Edu) within the national school system, scheduled to commence in December 2025 for educators and March 2026 for students. This initiative urgently raises the question: do we possess the requisite institutional, legal, and—most importantly—ethical framework to safeguard the rights and inherent dignity of our students?

This paper advances the claim that the challenges posed by AI in education do not arise solely from technical limitations or regulatory insufficiencies, but from a deeper anthropological and normative deficit. Current governance models tend to frame risk in terms of compliance, accuracy, and efficiency, while failing to account for the irreducible moral and personal dimensions of the student as a human subject. The central argument of this study is that without an explicit anthropological and ethical foundation, legal and technical safeguards remain structurally incomplete.

This study aims to systematically examine this issue through three complementary approaches. First, we examine the empirical findings of international research, which precisely document the malfunctions and biases of AI systems in education. Second, we investigate the gaps within the Greek and European legal frameworks, specifically focusing on the issues arising from the withdrawal of the AI Liability Directive (European Commision, 2022). Finally, we ground our argument in a theological perspective that emphasizes the irreducible value of the human person and the impossibility of algorithmizing moral judgment. The synthesis of these three dimensions allows us to formulate specific and practical recommendations for the protection of students' dignity. The methodology of this study is based on a qualitative secondary analysis of recent international literature, a normative legal interpretation of European and Greek AI law, and a deontological-theological approach to educational praxis.

Empirical Findings: Insights from International Research

The study by Ferhataj et. al. (2025) represents one of the initial systematic literature reviews concerning the integration of Generative AI (GenAI) within educational settings. The research team analyzed peer-reviewed articles published between 2020 and 2024—a period characterized by the rapid proliferation of GenAI tools. The significance of this study lies in its focus on empirical evidence from documented incidents in school environments rather than theoretical projections. The findings categorize the identified issues into three critical areas:

- Data Ownership and Control: Student data are frequently harvested without explicit consent to train new algorithms, leading to the emergence of a "hidden market" for sensitive personal information.
- Algorithmic Reproduction of Inequality: AI systems are trained on historical datasets that contain—either directly or indirectly—biases against specific social groups. Consequently, these systems replicate and amplify existing social inequalities.
- The New Digital Divide: Access to high-quality AI systems remains inequitable; schools in affluent areas benefit from advanced tools, while schools in socio-economically disadvantaged regions remain marginalized.
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To better illustrate these complexities, we may consider certain hypothetical scenarios. One such case involves a student with a physical disability who was unable to complete a practical laboratory task due to mobility constraints. The automated assessment system failed to account for the disability, issuing a "standardized" evaluation. This resulted in a low score that failed to reflect the student's actual comprehension or intellectual capacity (Lucchi, 2024).

Deepening the Functional Mechanism: The "Black Box" Problem

While Marín, et al. (2025) identified the categories of existing challenges, the research by Xie, Yu, and Ca delves deeper into their underlying functional mechanisms (Xie, Yu, & Cai, 2025). Their study focuses on the phenomenon of opaque decision-making, widely recognized in literature as the "Black Box Problem" of Artificial Intelligence (von Eschenbach, 2021). This phenomenon describes a state in which an AI system generates an output—such as a grade or a placement recommendation—yet neither the user, the designer, nor even the model's developers can clearly explain the causal logic behind that specific decision. Xie et al. examine how this opacity functions as a critical barrier in educational environments, where transparency and accountability are fundamental pedagogical requirements. The researchers identify several derivative issues, including a lack of interpretability that renders the contestation of decisions impossible, automated implementation without meaningful human intervention, and the encoded reproduction of inequalities inherent in historical datasets.

To illustrate the gravity of this issue, one might consider a common scenario in which a school employs AI systems for student summative assessments. The algorithm processes hundreds of parameters, ranging from academic performance to psychometric data, to produce a final evaluation. When a guardian inquires about a student's grade, the educator's response is often limited to "the system determined it." Any further inquiry regarding the algorithm's prioritization criteria meets a structural

silence; the underlying neural networks are so complex that even their creators cannot deconstruct every individual decision (Floridi, 2025).

The automated reproduction of bias is even more problematic. If a system is trained on historical data containing gender biases—such as the historical tendency of educators to predominantly steer boys toward STEM fields—the algorithm internalizes and replicates this bias. However, because the process lacks transparency, such bias is extremely difficult to detect or rectify. Since the machine lacks consciousness or intent, it cannot be deemed "sexist" in the traditional sense; we can only observe biased outputs, while remaining unable to pinpoint the exact location of the algorithmic flaw.

Empathy versus Algorithmic Logic

While previous analyses focused on the technical and structural deficiencies of AI systems, the work of Karakuş et al. (2025) brings to light a more fundamental concern: the nature of moral judgment itself. Human qualities such as hesitation, situational appraisal, and compassion constitute elements of a lived ethic that cannot be reduced to algorithmic code. Their research directly compares the decision-making processes of human educators with those of AI systems in identical scenarios, highlighting that mechanical logic is fundamentally distinct from empathetic response.

To elucidate the divergence between algorithmic reasoning and pedagogical empathy, we may employ an "ethical vignette"—a hypothetical scenario designed to illustrate the qualitative difference between rule-based output and human moral agency. Consider a student who causes €500 worth of equipment damage during a laboratory activity. A standard AI evaluation system, operating on predefined regulatory parameters, would strictly recommend full financial restitution, parental notification, and formal disciplinary action. Within its closed logical framework, the machine treats the incident as a violation of a static rule requiring a proportional punitive response.

In contrast, a human educator confronted with the same situation exercises what classical philosophy terms phronesis (practical wisdom). Through a personal dialogue with the student, the educator may uncover contextual nuances that an algorithm is structurally incapable of processing—such as severe financial hardship within the student’s family or existing psychological stressors. In an act of empathy and sacrifice that transcends mere rule-following, the educator might choose to personally cover the cost of the damage, transforming the crisis into a private lesson on responsibility and grace.

This act represents a free, creative response to the human person rather than a mechanical application of a directive. One cannot simply program a machine to "reduce punishment for low-income backgrounds," as such an instruction would merely create a new, rigid deterministic pattern. True empathy requires the freedom to act outside of a predetermined schema to protect the dignity of the individual. As Karakuş et al. demonstrate, substituting this human element with algorithmic logic risks stripping the educational process of its most vital ethical and personal dimensions.

The Legal Framework: Shortcomings and Gaps

The Greek Framework: Law 4961/2022 and its ShortcomingsWhile

Law 4961/2022 (Government Gazette A' 66/2022) introduces a mandatory requirement for Greek educational institutions to conduct an Algorithmic Impact Assessment (AIA) prior to the deployment of any Artificial Intelligence (AI) system (Hellenic Republic, 2022). Although this provision is conceptually sound, the legislation is characterized by significant normative ambiguity. Specifically, it fails to explicitly define the professional qualifications required for the assessing body—whether technical, legal, or ethical—nor does it delineate the specific evaluative criteria and benchmarks to be applied. Furthermore, the statute remains silent on the mandatory protocols and remedial actions to be followed in the event that an assessment identifies substantial risks.

This lack of legislative precision entails the risk that the AIA process may devolve into a mere bureaucratic exercise. Educational institutions might resort to perfunctory, "pro forma" evaluations that satisfy the literal requirements of the law without providing any substantive protection for students' rights or well-being. Without clearly defined standards and accountability mechanisms, the assessment risks becoming a procedural formality rather than a robust instrument for risk management and ethical oversight.

Simultaneously, the Ministry of Education is initiating pilot implementations of AI systems, such as ChatGPT Edu, in the absence of a comprehensive supplemental regulatory framework. Crucial issues concerning data privacy, cybersecurity, and the safeguarding of fundamental student rights remain unaddressed at a legislative level. Consequently, Greek schools are currently operating within a legal vacuum, as the existing framework fails to adequately designate responsible authorities or establish clear, enforceable procedures for risk mitigation in the educational environment.

The European Framework: The AI Act and the AI Liability Directive

The Artificial Intelligence Act (Regulation (EU) 2024/1689) establishes a stringent regulatory framework for AI systems in education, delineating mandatory audits, transparency obligations, and comprehensive documentation requirements that must be upheld (European Parliament & Council of the European Union, 2024). Despite these provisions, a critical issue remains: the AI Act does not incorporate a specialized civil liability regime. To clarify, while the Act defines the substantive requirements—the "what"—regarding system performance and safety, it remains silent on the "who," failing to address the attribution of legal responsibility and the provision of compensation in the event of failure or harm.

To address this regulatory lacuna, the European Parliament had been developing the AI Liability Directive (Sartor & Lagioia, 2025). However, in January 2025, the Directive was withdrawn following a failure to reach a consensus on its specific provisions. This development leaves the deployment of AI in educational settings without a clear legal framework for redress, potentially leaving students without adequate protection or compensation in the event that these systems cause damage or infringe upon their rights (International Association of Privacy Professionals, 2025).

Product Liability Directive (2024/2853) and its Limitations

The newly adopted Product Liability Directive (Directive (EU) 2024/2853) seeks to address existing regulatory lacunae by extending the definition of a "defective product" to encompass software and digital systems. This constitutes a landmark development in European jurisprudence, as it marks the first time that software is explicitly categorized as a "product" subject to strict liability regimes. By incorporating digital assets into the scope of the Directive, the European legislator aims to modernize consumer protection in an era of increasingly autonomous technologies (OECD, 2024).

Nevertheless, the application of this Directive within the educational sphere is hindered by significant restrictive interpretations. Primarily, the Directive maintains a technocentric focus on "defective performance," which pertains to instances where a product fails to operate according to its technical specifications or programmed parameters. Consequently, the framework does not explicitly address the complexities of algorithmic bias—scenarios in which an AI system functions correctly from a technical standpoint yet produces discriminatory outcomes against specific social cohorts or individual students (Borghetti, 2024).

Furthermore, and perhaps more critically, the Directive offers insufficient recourse for non-material damages, such as psychological harm, emotional distress, social stigmatization, or the deprivation of educational opportunities. While the Directive may theoretically be invoked to recover indirect economic losses—for instance, the financial costs associated with supplementary or remedial education—it distinctly excludes harms pertaining to human dignity and psychosocial well-being. These elements are often the most profound consequences of AI failures in a school environment.

An illustrative case involves a student excluded from an advanced STEM program due to an algorithmic bias that failed to accurately assess their potential. Should the damage be narrowly defined as the financial cost of alternative educational resources, the Directive might provide a basis for compensation. However, the legislative emphasis on technical defects and tangible material damage leaves a significant void regarding the necessity for restitution for harms to a student’s educational trajectory, psychological equilibrium, and the fundamental right to the free development of personality.

Student Intellectual Property Rights: An Overlooked Regulatory Lacuna

Another pivotal concern pertains to intellectual property (IP) rights. Every work produced by a student—ranging from essays and paintings to poems or original mathematical solutions—constitutes an original intellectual creation, traditionally protected under established copyright statutes. However, when these creations are integrated into an AI system, the technology parses, assimilates, and "learns" from them, utilizing their intrinsic elements to refine or train the underlying algorithm (Borghetti, 2024). This technical processing engenders a significant regulatory lacuna: the question of ownership remains unresolved. It is currently unclear whether IP rights reside with the student as the original creator, the educational institution facilitating the deployment, or the developer of the AI system.

To illustrate this ambiguity, consider a hypothetical scenario where a fifteen-year-old student composes an original work of fiction that wins a school competition. If this work is subsequently inputted into an AI system for evaluative purposes, the algorithm

analyzes the student's specific vocabulary, stylistic nuances, and structural frameworks. Should a generative AI corporation later publish a story bearing a striking resemblance to the original, the attribution of authorship—whether to the young writer, the AI entity, or the corporation—becomes a matter of profound legal debate.

At present, the legal response to such conflicts is characterized by intense uncertainty. The prevailing regulatory framework fails to explicitly govern the status of student works when utilized as training datasets or for the optimization of AI systems. This absence of categorical legislation raises critical concerns regarding both the necessity of informed consent and the ultimate ownership of the resulting intellectual output. Consequently, the creative autonomy of students remains vulnerable within a digital landscape that has yet to harmonize educational innovation with the fundamental principles of intellectual property law (Gervais, 2025).

Beyond Empirical and Legal Analysis: The Theological Dimension

Thus far, the analysis has examined the issue through two primary lenses: empirical research and the prevailing legal framework. While both are indispensable for a comprehensive understanding, they remain insufficient on their own. To achieve a holistic perspective, it is imperative to explore a third level: the theological and anthropological. The Christian tradition, and specifically Eastern Orthodox theology, offers a crucial normative criterion that transcends the binary logic of data—the concept of personhood and a form of dignity that is fundamentally non-negotiable. This theological foundation is not proposed as a substitute for positive law or pedagogical science, but rather as an anthropological "threshold" or limit-criterion for the exercise of technological power.

St. Maximus the Confessor, a seminal figure in Orthodox theology of the 6th and 7th centuries, elucidated the "rational nature" of the human being and the capacity for free deliberation—decisions that are not strictly predetermined by biological constraints or external data, but emerge from a free will. This freedom is recognized as the quintessential mark of the *Imago Dei* (the Image of God). The scriptural declaration that man was created "in the image of God" (Genesis 1:27) is far from a mere poetic expression; it serves as the ontological cornerstone of human dignity (Knight, 2023).

As the Orthodox theologian John Zizioulas (1985) emphasizes, within this tradition, personhood is irreducible to individual traits, characteristics, or quantifiable data (Zizioulas, 1985). The person is a "mystery that transcends the logic of reductionism," as every human existence bears a divine imprint. In the contemporary context, when algorithmic systems are tasked with dictating educational trajectories, placement, or opportunities, they effectively reduce this mystery of personhood to a set of manageable parameters. From an Orthodox perspective, this is profoundly problematic, as it suggests that a child's inherent worth can be calculated, ranked, or diminished through mechanical evaluation.

The ethical crisis becomes apparent when an algorithm reduces a student to a mere aggregate of data points. A child—possessing a complex personal narrative, perhaps struggling with formal mathematics yet exhibiting profound social consciousness—is stripped of their uniqueness. The unexpected, the multifaceted, and the inherently creative dimensions that constitute the human self are lost within the reductive process

of "datafication." Ultimately, any framework that prioritizes algorithmic assessment over the mystery of the person fails to recognize that human value is fundamentally incalculable and irreducible to digital logic.

Building upon the ontological recognition of the "person" as a mystery, Christian tradition posits three fundamental virtues that constitute the core of the ethical life: prudence, temperance, and empathy. These virtues do not consist of codifiable data or mere cognitive information; rather, they represent "habits of the heart"—existential dispositions developed through lived experience and relational engagement. Empathy, in particular, is defined as the profound capacity to enter into the internal state of another, participating in their suffering and responding with leniency and care. This relational depth represents a qualitative dimension of human existence that remains fundamentally resistant to algorithmic abstraction.

A paradigmatic example of this ethical agency is found in the instance of an educator who personally assumes the financial cost for an object broken by a student from a disadvantaged socioeconomic background. Such a decision is not the output of a pre-programmed rule or a cost-benefit analysis; it is a free, creative response to the human person. By prioritizing the student's dignity over economic restitution, the educator asserts that the child is worthy of protection, even at a personal cost. This act of empathy illustrates a form of moral discernment that cannot be reduced to an algorithm, as it transcends the mechanical application of generic regulations (Council of Europe, 2026).

Furthermore, theology distinguishes between two significant and often conflicting concepts of justice. The first is "formal" or "legalistic" justice, which entails the uniform application of rules to all individuals without exception—the type of justice that governs judicial and carceral systems. The second is a "providential" justice, or the justice of love, which recognizes the unique particularity of every circumstance and responds with foresight and pastoral care. While a school system may be formally just by applying the same evaluative benchmarks to all students, it becomes theologically unjust if it fails to acknowledge and respond to the specific, multifaceted needs of the individual. Consequently, when an algorithm applies a uniform rule to a heterogeneous student body, it achieves a "formal fairness" that results in "substantial injustice," precisely because it ignores the lived reality and existential requirements of the human person.

Translating the theological and anthropological insights regarding the "mystery of the person" into a concrete normative framework requires a series of urgent policy interventions. To move beyond the current regulatory ambiguity, there is an imperative need to establish a National Code of Ethics for AI in Education. This code must serve as a foundational document, delineating the criteria for acceptable use based on a multidimensional synthesis of technical efficiency, legal compliance, and the ethical-theological principles of human dignity and personalism.

Central to this reform is the transformation of the Algorithmic Impact Assessment (AIA), as provided for in Law 4961/2022, from a perfunctory bureaucratic exercise into a substantive, multidisciplinary evaluation. For an assessment to be truly robust, it must move beyond purely technical audits to include experts in ethics, theology, pedagogy, and law. Furthermore, governance must be democratized through the establishment of an Oversight Committee comprising teachers, parents, theologians, legal scholars, and

students. This body should be granted the regulatory authority to review AI systems, adjudicate complaints, and recommend the suspension of technologies that infringe upon student rights or dignity.

Transparency and human agency must be the cornerstones of this digital transition. Every educational institution deploying AI systems must ensure absolute transparency for parents and students, particularly regarding the logic behind algorithmic decisions. Crucially, any automated evaluation or placement of a student must remain contestable; the principle of "Human-in-the-loop" must be legally mandated, ensuring that the educator retains the final decision-making authority. In this framework, the algorithm serves as a diagnostic advisor rather than a sovereign judge, thereby safeguarding the student's right to a fair and holistic evaluation.

At the European level, the regulatory vacuum created by the withdrawal of the AI Liability Directive in early 2025 must be addressed. The European Parliament and the Commission should reintroduce and ratify an upgraded version of the Directive that explicitly encompasses harms specific to the educational sector. Such a regime must move beyond traditional material damage to provide restitution for psychological harm, the loss of educational opportunities, and the infringement of human dignity. Without a dedicated liability framework, the protection of the person remains theoretical and unenforceable.

Finally, a specialized legislative initiative is required to safeguard Student Intellectual Property Rights. This legislation must explicitly prohibit the harvesting of student-generated works—essays, artistic creations, or scientific solutions—for the purpose of training third-party AI models without prior, explicit, and informed consent. It is essential to clearly define the intellectual provenance of works within an AI-mediated environment, ensuring that the student's creative autonomy and property rights are not sacrificed to the data-driven requirements of the technology industry.

Conclusion: Dignity as the Universal Language of Humanity

AI undeniably represents a formidable instrument for educational progress. Its capacity to identify students requiring additional pedagogical support, to tailor learning experiences to diverse cognitive styles, and to extract meaningful patterns from vast datasets offers unprecedented advantages that cannot be overlooked. However, the purpose of this study is not to advocate for technological rejectionism, but rather to provide a necessary regulatory and ethical clarification of the boundaries that should govern the legitimate and pedagogically responsible use of AI (Sartor & Lagioia, 2025).

The undisputed benefits of these technologies cannot serve as a pretext for the creation of a world where human dignity is subordinated to algorithmic decision-making. Technological efficiency does not justify the emergence of new digital divides, the reproduction of historical inequalities, or the diffusion of accountability to a point where legal responsibility becomes non-existent (Floridi, 2025). Our collective obligation is to construct a framework in which AI operates under clear normative conditions—not as a sovereign judge or a substitute for human agency, but as an ancillary tool designed to maximize human potential.

Ultimately, in an era where an increasing number of critical decisions are delegated to machines, it is imperative to reaffirm the foundational principle of human existence: dignity. This principle posits that every individual, by virtue of their shared humanity, is entitled to respect, care, and an inherent recognition of their worth. Education must not be reduced to a mere transaction of data; it remains a sacred interpersonal encounter where human beings interact, inspire, and mutually transform one another. If technology is to be the idiom of the future, then dignity must remain the universal language of humanity (Gervais, 2025).

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AI-Enhanced Digital Storytelling in Latin Teaching

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Abstract—Artificial Intelligence is increasingly influencing various domains of human activity, including education, resulting in significant transformations and marking a new era in learning. This paper presents the first systematic effort to employ Artificial Intelligence as a tool for developing digital stories within the context of high school Latin instruction. In this study, 50 digital stories were created using prescribed Latin texts from the official textbooks of the 2nd and 3rd grades of the Greek Lyceum (Upper Secondary Education), with the objective of demonstrating the pedagogical value of this approach. The methodology involved the use of the Artificial Intelligence tool DALL·E, developed by OpenAI, to generate visual materials, and PowerPoint to assemble the final digital stories. While this teaching proposal remains in its initial phase, the findings indicate that integrating digital storytelling with Artificial Intelligence in Latin instruction may bridge traditional teaching methods and contemporary educational requirements. Adopting such a multimodal approach can make the course more engaging, inclusive, interdisciplinary, interactive, and student-centered, thereby enhancing students' active participation and cultivating skills aligned with current educational standards.

Keywords— Digital Storytelling, Artificial Intelligence, Large Language Models, Latin, Power Point

Introduction

From Roman antiquity through modern European history, Latin has served as the principal language of education and science. For centuries, it functioned as a primary vehicle for transmitting knowledge and culture across Europe, shaping the foundations of modern European languages and values. In Greece, the status of Latin has consistently reflected the prevailing social, political, and ideological priorities of successive governments, resulting in an ambiguous role within the education system. Contemporary Latin instruction is often marked by anachronistic methodologies and a traditional focus on memorization of translations and grammatical rules.

The rapid advancement of technology has produced significant and multifaceted changes across all aspects of human life, including education. The integration of digital media into global educational contexts encompasses the acquisition of diverse computer technologies, the application of software across disciplines, teacher professional development, curriculum reform, and ongoing research and publication. Greece has participated in these developments by investing in both technological infrastructure and expertise (Koutsogiannis, n.d.).

Despite these investments, the integration of digital media within Greek education remains largely superficial and has not resulted in substantive transformation. School practices often remain disconnected from students' digitally oriented daily lives, contributing to disengagement and lack of involvement in the learning process (Gkoutsioukousta, 2020). In many educational reform initiatives, the adoption of digital technologies is equated with modernization, yet traditional literacy skills are merely transferred to a digital format without altering underlying pedagogical approaches. This technocratic perspective emphasizes the potential of digital media to transform education, but frequently perpetuates existing challenges (Koutsogiannis, n.d.). In the context of Latin instruction, digital technologies are either minimally integrated or entirely absent, with teaching practices remaining predominantly traditional.

This article aims to examine how the application of Artificial Intelligence as a foundational tool in digital storytelling can enhance the teaching and didactic methodologies of Latin in educational settings.

Theoretical Background

This section presents the theoretical framework supporting the current study, with a focus on digital storytelling, dialogue systems and large language models, and Latin language instruction.

Digital Storytelling

Arvanitis and Krystallis (2023, p. 277) note that *"initially, the term storytelling was used to describe any kind of oral or written storytelling. […] Over the centuries, various societies and cultures have used storytelling to pass on knowledge, experiences, values, habits, customs, behaviors, etc."* The rapid advancement of technology and the proliferation of digital media have redefined storytelling, introducing a distinctly digital dimension.

Handler-Miller (2025) defines digital storytelling as the use of digital media and interactive platforms to create narratives, whether fictional or factual, encompassing formats such as video games, smart games, and virtual reality. The Digital Storytelling Organization describes it as "*the modern expression of the ancient art of storytelling. Digital stories draw their power from the combination of images, music, narration, and voice, thus adding depth and vitality to characters, situations, experiences, and ideas"* (Arvanitis & Krystallis, 2023, pp. 277-278). Despite variations in definition, digital storytelling generally refers to concise presentations of personal stories, historical events, or educational content, utilizing a blend of narration and digital media such as images, video, and audio (Robin, 2011).

Digital storytelling is not a novel concept; however, it has experienced renewed scholarly interest in recent decades, largely due to the rapid advancement and widespread adoption of digital technologies (Arvanitis & Krystallis, 2023). Dana Atchley, Joe Lambert, and Nina Mullen demonstrated that individuals without prior multimedia experience could create compelling personal stories using digital tools (StoryCenter, n.d.). In 1994, they established the Digital Media Center in San Francisco, which became the foundation for the community workshop known as Digital Storytelling (Arvanitis & Krystallis, 2023; StoryCenter, n.d.). Subsequently, in 1998, they founded the Center for Digital Storytelling in Berkeley, California (Arvanitis & Krystallis, 2023; de Jager et al., 2017; StoryCenter, n.d.). In 2015, the organization was renamed StoryCenter, and it has since trained over fifteen thousand individuals in hundreds of workshops to share personal narratives (StoryCenter, n.d.).

Lambert (2010) notes that each workshop began with the presentation of seven steps designed to guide participants in creating well-structured and meaningful digital stories. Subsequently, Robin developed a comprehensive twelve-step guide for educators seeking to teach digital storytelling (Arvanitis & Krystallis, 2023; Robin, 2016). The steps, as detailed by Robin (2016) and Arvanitis & Krystallis (2023), include: selecting a topic and defining the story's purpose; conducting research using diverse sources; drafting the script for audio narration; soliciting and incorporating feedback; sourcing or creating images; ensuring copyright compliance; developing a storyboard; recording narration; optionally adding background music; selecting appropriate software; and publishing the digital story online.

The research and educational communities have consistently recognized the pedagogical value of digital storytelling and its potential for integration across disciplines and educational levels (Arvanitis & Krystallis, 2023). Frequently cited benefits include the development of critical thinking, creativity, problem-solving, collaboration, digital literacy, multiliteracies, and increased student engagement and motivation (Arvanitis & Krystallis, 2023; Gkoutsioukousta, 2020; Walters et al., 2018; Wu & Chen, 2020; Harjono & Wiryotinoyo, 2021; Campbell, 2012).

Recent technological advancements have enabled the creation of digital stories using a variety of multimedia tools and software, including Microsoft PowerPoint, Prezi, Powtoon, StoryboardThat, StoryMap, Vyond, and ADRIFT (Arvanitis & Krystallis, 2023).

Dialogue Systems and Large Language Models

Bui (2006) defines a dialogic system as "a computer program that communicates with a human user in a natural way." Similarly, Jurafsky and Martin (2025, p. 1) describe dialogue systems as "programs that use conversation to interact with users." They distinguish between two primary types of dialogue systems based on purpose and function: (a) task-oriented dialogue systems, such as digital assistants, which assist users in completing specific tasks like setting alarms (Glass et al., 2024, p. 277 & 300; Jurafsky & Martin, 2025), and (b) chatbots, which simulate extended, unstructured conversations characteristic of human interaction (Jurafsky & Martin, 2025).

Contemporary dialogue systems rely on large language models (LLMs), which facilitate the understanding and generation of natural language. A large language model predicts the next word in a sequence based on preceding words, utilizing context or word prefixes to determine the most probable subsequent word and generate coherent text (Jurafsky & Martin, 2025). While retrieval-based models provide predefined responses, generative models powered by LLMs produce responses by employing translation techniques and considering the ongoing conversation with the user (Adamopoulou & Moussiades, 2020, p. 378; Ramesh et al., 2017, p. 347), thereby more closely approximating human communication.

Modern dialogue systems utilize advanced artificial intelligence and machine learning models that move beyond predetermined responses. These systems interpret context, recall previous conversational points, and generate human-like speech in multiple languages. Additionally, they can produce images or videos, respond to numerous users simultaneously, and operate with high efficiency, making them suitable for diverse applications. Notable examples of contemporary conversational systems include ChatGPT, Gemini, Claude, Midjourney, and Deep AI.

ChatGPT is a highly advanced language model developed by OpenAI, a research laboratory established in 2015 (Singh et al., 2023). Designed to communicate with users through natural language, ChatGPT generates responses that closely resemble human conversation (Lo, 2023). Unlike earlier chatbots, it employs natural language processing to retain information from previous user inputs, thereby sustaining coherent dialogue (Wu et al., 2023). With the release of GPT-4 in March 2023, ChatGPT acquired enhanced capabilities, including the ability to process simultaneous image and text inputs (Wu et al., 2023) and to generate images using DALL·E, an artificial intelligence tool that creates images from natural language descriptions (Aktay, 2022).

The Role of Latin in Humanistic Education

From classical antiquity through the Renaissance to modern Europe, Latin instruction has served as a cornerstone of humanistic education and has contributed to shaping civic consciousness. Following periods of conflict, the Greek state sought to reconstruct its national identity by drawing upon the ancient Greek and Roman heritage. Consequently, ancient Greek and Latin have maintained a prominent position in the school curriculum, functioning as a bridge to classical education and European culture. Although the status and significance of Latin in the secondary school curriculum have been subject to ongoing debate and reform, the subject is currently offered within the Humanities Orientation Group in the second and third years of high school, for two and six hours per week, respectively (Government Gazette, 2023, pp. 63368-63369). Nevertheless, despite the existence of official teaching guidelines (see Institute of

Educational Policy, 2024), Latin instruction in Greek schools remains predominantly one-dimensional and teacher-centered.

Latin courses typically adhere to traditional methodologies, emphasizing the correct use of linguistic structures and metalanguage through closed-ended exercises. This approach often isolates the language from its broader social and communicative contexts (Koutsogiannis, 2017, p. 74). Instruction is primarily based on predetermined materials, such as school textbooks, delivered in a linear fashion, with the teacher's role centered on knowledge transmission (Koutsogiannis, 2017, p. 71). Although there has been a shift in interest toward textual analysis since the 1980s, the instructional approach remains insufficiently text-centered. Texts are frequently treated as sources for translation and exercises, rather than as vehicles for exploring their inherent ideas and historical or cultural backgrounds (Koutsogiannis, 2017, p. 150). Additional challenges include an overemphasis on memorization of grammatical and syntactic patterns at the word and sentence level, limited relevance to students' interests, low student engagement, lack of interdisciplinarity, insufficient use of multimodal meaning representation, inadequate accommodation of diverse learning needs, and a failure to foster essential 21st-century skills such as multiliteracies, digital literacy, and critical or synthetic thinking. These issues underscore the necessity for adopting innovative teaching practices.

Proposal for Innovative Latin Teaching

To modernize Latin instruction, this proposal recommends integrating digital storytelling supported by Artificial Intelligence to address current educational demands and 21st-century challenges. The selected Latin texts originate from the textbooks authored by Paschalis M. and Savantidis G., which are used in the 2nd and 3rd grades of the Humanities program in Greek high schools. These texts are concise, fragmentary, and feature accessible vocabulary and grammar, resembling brief, self-contained narratives that are well-suited for digital storytelling. The content spans a broad spectrum, including aspects of daily life in Rome, military and political events, mythological tales, and moral lessons.

This article presents an illustrative example of digital storytelling to demonstrate the methodology and the resulting outcomes in greater detail. Specifically, it utilizes text XXIX from the second volume of the Latin school textbook by Paschalis, M., and Savantidis, G. (2024), entitled "Octavian, the shoemaker, and the crow."[54]

Methodology

The text was segmented into distinct periods based on punctuation or interpretive cues to ensure that each resulting image accurately conveyed the intended meaning. For every sentence, a concise prompt was developed to generate a realistic image using ChatGPT (OpenAI, 2024). Each prompt specified the command in Greek or English, included the Latin phrase or sentence, and provided instructions regarding the desired

[54] The digital stories of all 50 texts are presented in the author's thesis "Artificial Intelligence as a Tool in Digital Storytelling: A Practical Application in the Latin Texts of the 2nd and 3rd Grades of Greek High School" (Kalonikidou, 2025), which is available in the Aristotle University of Thessaloniki library. (https://ikee.lib.auth.gr/collection/Theses?ln=el).

style and technical characteristics of the image, such as dimensions, three-dimensionality, and realism. Additional details were incorporated as needed to reduce the likelihood of model misinterpretation. This process was repeated until each image sufficiently reflected both the meaning and the desired aesthetic. Images that lacked realism, failed to align with the Roman style or textual content, depicted explicit violence or bloodshed, or did not correspond to the intended meaning were excluded. Consistency in color palette, facial features, perspective, and overall setting was prioritized to impart a cinematic quality to the digital storytelling. The images produced are approximate historical representations and are not intended to serve as evidence of historical events.

Following the selection and compilation of images, they were integrated into a PowerPoint presentation, which functions as the primary medium for digital storytelling. Each slide presents a Latin phrase or sentence alongside the corresponding image that illustrates its meaning. The digital storytelling maintains the original narrative structure of the text, including a beginning, middle, and end, as found in the school textbook. The textual content remains unchanged except for the inclusion of interactive questions inserted between slides. These questions are formulated primarily from the vocabulary of the text, supplemented by simple and basic words, and are designed to prompt student engagement to advance the story. Each digital storytelling contains one to four such interventions, which do not alter the overall meaning, narrative progression, or historical context of the text.

In general, the creation of digital storytelling adhered to the aforementioned steps, with the exception of oral narration. This step was omitted because Latin lacks native speakers. While online applications and translation tools can provide audio renderings of Latin, pronunciation is not a primary objective in Latin instruction, unlike in the teaching of other foreign languages. Consequently, the inclusion of spoken narration was considered unnecessary for this project.

Digital Storytelling Creation

Figure 1. Latin Text: Cum Octaviānus post victoriam Actiacam Rōmam redīret, homo quidam ei occurrit corvum tenens; eum instituerat haec dicere: «Ave, Caesar, victor imperātor».

Translation: When Octavian returned to Rome following his victory at Actium, a man approached him holding a raven. The man had trained the raven to say: "Hail, Caesar, victorious general!"

Prompt: Create an image depicting a soldier presenting a raven to Caesar following his victory at Actium, rendered in the style of ancient Rome.

Image Description: The image depicts Octavian receiving a raven from a man before an assembly of soldiers and a crowd in a Roman square. Octavian's elevated position and the laurel wreath he wears highlight his authority and prestige following his triumphant return to Rome after the victory at Actium.



Figure 1: A soldier gives Octavian a raven after his victory at Actium and the Latin text

Figure 2: Building on the previous slide, students click on the word Actiacam, which, through a hyperlink, directs them to the next slide. A rotating globe then displays the geographical location of Actium using current data. This approach integrates history, Latin, and geography in an interdisciplinary and experiential manner.

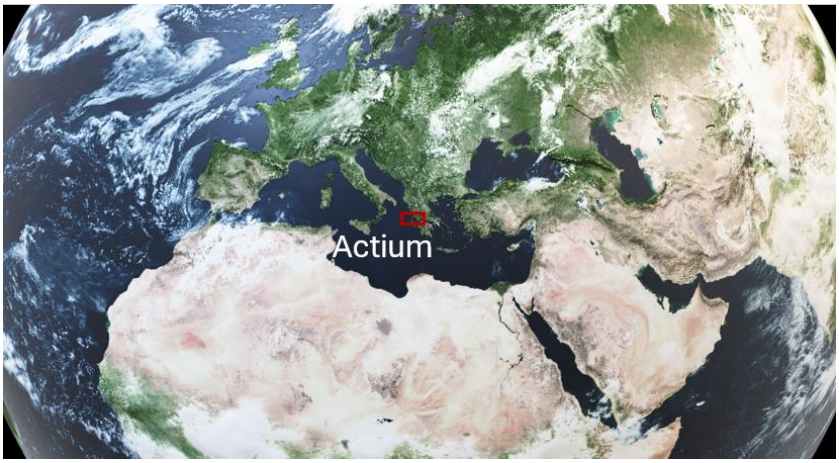


Figure 2: Aktio based on current geographical data

Figure 3: Latin text: Didicitne corvus salutationem? -Sic. / -Non.

Translation: Did the crow learn to say hello? -Yes. / -No.

Prompt: "Draw the crow on the workshop table."

Image description: This slide, absent from the original Latin text, serves as an example of interactivity. Students respond to the question Didicitne corvus salutationem? ("Did the crow learn the greeting?") by selecting how the story continues. However, this choice is only apparent, as it does not alter the plot. Selecting "no" returns students to the previous slide, where the shoemaker appears disappointed. Selecting "yes" advances them to the next phase of the narrative.



Figure 3: The crow on the shoemaker's workbench and the interactive question on the right

Digital Storytelling Results

Octavian, the Shoemaker, and the Crow – Digital Storytelling

Latin text[55]: Cum Octaviānus post victoriam Actiacam Rōmam redīret, homo quidam ei occurrit corvum tenens; eum instituerat haec dicere: «Ave, Caesar, victor imperātor». Caesaris multum interfuit corvum emere; itaque viginti milibus sestertium eum ēmit. Id exemplum sutōrem quendam incitavit, ut corvum docēret parem salutatiōnem. Diu operam frustra impendēbat; quotiescumque avis non respondēbat, sutor dicere solēbat «Oleum et operam perdidi». Tandem corvus salutatiōnem didicit et sutor, cupidus pecuniae, eum Caesari attulit. Audītā salutatiōne Caesar dixit: «Domi satis salutatiōnum talium audio». Turn vēnit corvo in mentem verbōrum domini sui: «Oleum et operam perdidi». Ad haec verba Augustus risit emitque avem tanti, quanti nullam adhuc emerat.

English translation[56]: Translation into English: When Octavian returned to Rome after his victory at Actium, a man went to meet him holding a raven; he had taught it to say the following: "Hail, Caesar, victorious general!" Caesar was very interested in buying the raven, so he bought it for twenty thousand sesterces. This example inspired a shoemaker to teach a raven the same greeting. For a long time, his efforts were in vain; every time the bird did not respond, the shoemaker used to say: "My oil and my efforts are wasted." Finally, the crow learned the greeting, and the shoemaker, wanting the money, brought it to Caesar. As soon as he heard the greeting, Caesar said, "I hear many such greetings in my house." Then the crow remembered its master's words: "My oil and my effort are wasted." Augustus laughed at these words and bought the bird for a sum greater than he had ever paid for any other bird before.

[55] The text is from the school textbook by Paschalis M. - Savantidis G. (https://ebooks.edu.gr/ebooks/handle/8547/2395)

[56] The translation is from the website filologika.gr (https://filologika.gr/lykio/g-lykiou/prosanatolismou/latinika/latinika-enotita-29/)



Figure 4: Image



Figure 5: Image



Figure 6: Image



Figure 7: Image



Figure 8: Image

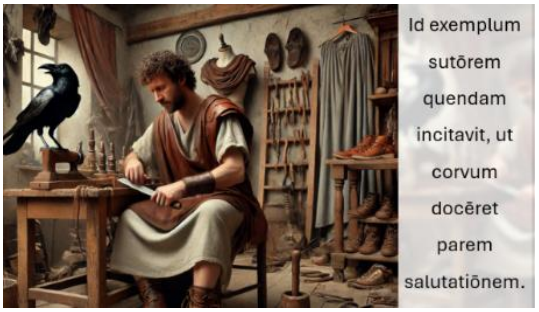


Figure 9: Image



Figure 10: Image



Figure 11: Image

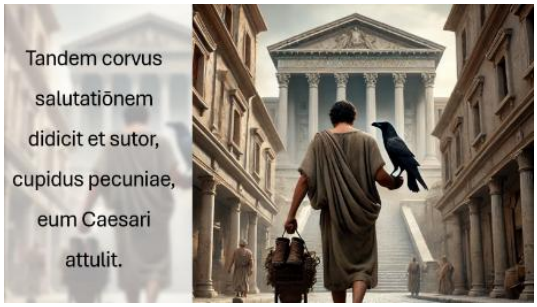


Figure 12: Image



Figure 13: Image



Figure 14: Image

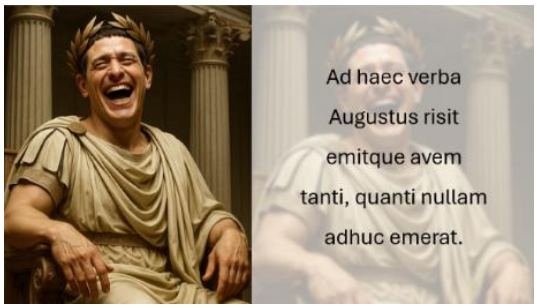


Figure 15: Image

Discussion

Although extracurricular environments are rapidly evolving with new literacies, the school context often remains traditional, monotonous, and disengaging for students. The teaching proposal presented in this article aims to integrate digital storytelling into high school Latin instruction, ultimately bridging the gap between school and non-school experiences.

The educational value of digital storytelling in the learning process

The use of digital storytelling extends beyond traditional pedagogical approaches and incorporates polygrammatics, which emphasizes multimodality (images, sounds, speech) and the digital dimension of literacy (Koutsogiannis, 2017, p. 278). Images serve not only an aesthetic function but also convey historical and cultural concepts. By visualizing texts, students can explore aspects of Roman daily life, values, institutions, perceptions, architecture, and clothing in a more interactive, experiential way (Makridis et al., 2024).

Additionally, transforming Latin texts into digital storytelling formats mirrors the short films, videos, and reels that students regularly engage with. This approach aligns more closely with their interests and experiences, thereby increasing motivation and enhancing lesson engagement (Berg et al., 2024; Makridis et al., 2024).

The subject matter of Latin texts often centers on philosophical concepts and rhetorical arguments that may seem disconnected from students' contemporary experiences and concerns. Digital storytelling can serve as a bridge, contextualizing these abstract ideas within more familiar and experiential frameworks.

Incorporating hyperlinks is intended to increase interactivity and interdisciplinarity, encouraging students to actively engage and integrate linguistic, historical, and geographical knowledge. Furthermore, tools such as DALL·E for image generation and PowerPoint for digital storytelling are accessible and user-friendly, even for individuals with limited digital experience.

Digital storytelling can accommodate diverse learning styles within the classroom. Students possess varying abilities to absorb, process, and comprehend information. For instance, visual learners benefit from images, colors, graphs, and maps, while auditory learners respond more effectively to spoken information, such as discussions. Some students retain information better through written words, whereas kinesthetic learners learn most effectively through action and hands-on experiences.

This teaching proposal was piloted with a group of non-formal education students to assess its preliminary effectiveness. Participant feedback was notably positive, indicating that digital storytelling enhanced their interest, participation, engagement, and comprehension. Students observed that digital storytelling resembled the videos and reels they encounter on social media. The findings suggest that combining words and images supports learning more effectively than text alone. Although still in its initial pilot phase, the approach demonstrates promise for broader application and underscores the need for further research.

Conclusions

The proposed teaching approach demonstrates the potential of Artificial Intelligence and digital storytelling as innovative means to modernize Latin instruction, providing an interactive, experiential, and multimodal learning environment. Utilizing tools such as DALL·E, PowerPoint, and ChatGPT can animate Latin texts, increasing student engagement and fostering skills such as critical thinking, knowledge integration, multiliteracies, and digital literacy. Visualizing elements of the Roman world enables students to perceive the text as a dynamic conduit for history, culture, ideas, and social conditions, rather than a static, isolated artifact.

The integration of hyperlinks can substantially increase both interactivity and interdisciplinarity, exposing students to content from related fields such as history and geography. Digital storytelling also supports the development of critical thinking skills. A multidimensional approach to Latin, emphasizing linguistic comparison, historical and cultural analysis, and interdisciplinary connections, encourages students to become active interpreters of meaning. Additionally, PowerPoint and ChatGPT have proven to be accessible and effective, even for users with limited digital proficiency.

Challenges, constraints, and future directions

While DALL·E offers significant advantages, its use comes with several challenges and limitations. The generated images are not always of high quality, particularly in complex or detailed scenes, and often struggle to realistically depict human features such as faces and hands. Image creation requires time, sustained effort, and may incur financial costs, as DALL·E is only free for limited use. Consistency in facial features, hair, and body type across images is another persistent issue. Maintaining visual

consistency throughout digital storytelling is essential to prevent confusion among students.

Additionally, some images may depict violent or graphic content, which is unsuitable for educational settings, particularly for younger students. These images provide only approximate historical representations and should not be regarded as authentic or reliable historical evidence. In such cases, the teacher's role is critical to maintaining historical accuracy. As tools like DALL·E and ChatGPT continue to evolve, many previous limitations are being addressed. Nonetheless, ethical considerations related to the use of artificial intelligence technologies must always be observed.

This proposal should not be viewed as a comprehensive solution to the structural and organizational challenges of Latin instruction. While it does not fully replace traditional pedagogical approaches, it represents a significant and innovative step toward updating teaching practices to meet the pedagogical and technological demands of the 21st century. The integration of digital and creative tools into education is essential, as schools must adapt to contemporary developments and the multimodal realities of students' lives. Further systematic research and implementation are recommended to rigorously assess the proposal's effectiveness and impact on learning outcomes.

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Can Digital Assistants (chatbots) enhance the understanding of bar charts: A study with middle school students

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Abstract—In the present study, three digital assistants based on Multimodal Large Language Models (MLLMs) (ChatGPT, WolframGPT, MagicSchoolAI) are configured, through specially designed prompts, as pedagogical interlocutors with three groups of middle school students, to solve a Realistic Mathematical Problem (RMP) whose data are presented in the form of a bar chart. The study was motivated by the fact that reading and interpreting bar charts constitutes a fundamental skill of statistical literacy and that systematic difficulties have been documented in students' understanding of graphs, at a time when Artificial Intelligence (AI) tools can increasingly support mathematical literacy. Through the analysis of the dialogues between students and tools, which constitute the qualitative data of this study, we highlight the potential of MLLMs to recognize charts, extract information from them, combine it with textual information, and respond to questions posed to them. Overall, the findings are positive, yet they indicate differentiated quality of support across tools. The greatest learning benefits are recorded when MLLMs function as metacognitive interlocutors that promote clear argumentation, explicit justification of steps, and self-regulation of thinking.

Keywords— (MLLMs, Digital Assistant, Mathematics)

Introduction

Students' ability to analyze, understand, and interpret data constitutes a fundamental 21st-century skill (Data Literacy) (OECD, 2023). It also represents a permanent objective of mathematical education (Cleveland & McGill, 1984; Friel et al., 2001; Shah & Freedman, 2011; Gardner et al., 2024). Graphs function as tools for visualizing mathematical relationships and require skills such as identifying critical points, analyzing quantitative differences, and transforming visual information into verbal arguments. The challenge is even greater when these are embedded in problems of a realistic nature, that is, meaningful to the student, incorporated into a narrative or practical context (Blum & Leiß, 2007; OECD, 2023). Furthermore, cultivating an individual's ability to interpret and evaluate information related to statistics (statistical literacy) is very important because, as stated in the study by Wild & Pfannkuch (1999), it fosters an investigative spirit that poses questions and examines data. Students' inability to move beyond superficial observation makes the issue of strengthening bar chart interpretation skills important.

The reading and interpretation of bar charts by MLLMs do not fully follow that of humans. The combination of textual elements and graphical representations, such as bar charts, presents a challenge for MLLMs (Sun et al., 2025). MLLMs analyze images by decoding them both visually and textually, i.e., they appear to extract information about shapes, the sizes of shapes, and colors, to understand natural language, and ultimately to integrate these pieces of information (Huang et al., 2024). This integration involves retrieving sources, performing visual recognition, and synthesizing information. For this purpose, sets of questions have been developed to assess MLLMs on graph reasoning and analysis (Han et al., 2023). Until recently, computer vision focused on models for object detection, image segmentation, and spatial reasoning (Radford et al., 2021; Hamadi, 2023), while now higher-level capabilities such as visual reasoning are being explored (Zhang et al., 2024). AI-based digital assistants, such as ChatGPT, Wolfram Alpha within ChatGPT, and MagicSchoolAI, are studied in the present work through research into their use by students, in order to understand the potential of such tools in solving mathematical problems that include diagrams, and to highlight their didactic and pedagogical effectiveness (or lack thereof), always in conjunction with their support for languages other than English, such as Greek in our case.

The Computer Technology Institute and Press - Diophantus, in Greece, in the context of the Innovation Centers in the 13 Regional Directorates of Education project (ic.cti.gr) (Smyrnaiou et al., 2024), explores, among other things, the potential of leveraging Artificial Intelligence (AI) in the creation and development of educational content. This paper contributes to strengthening this process, specifically by addressing the enhancement of mathematics educational content, as well as the development of digital assistants for students.

Theoretical framework

Artificial intelligence in our lives

Numerous efforts have been made, both in scientific and professional contexts, to define and clearly describe the field of Artificial Intelligence (AI). The literature offers many alternative definitions, and it is often noted that there is no single, dominant

definition accepted by all scholars in the field of AI (Holmes, 2022). Here, it is important to stress that useful and operational definitions of AI depend on the purpose for which they are employed and the context in which they are situated.

On the other hand, various national and supranational institutional bodies, such as the European Union (EU), focus on AI products that are expected to be used and, therefore, to have access to the common market. At the same time, it is true that a significant part of the discussion on AI concerns hypothetical scenarios for the future, inspired by science fiction and by the belief that machines might one day become intelligent—whatever that may mean.

A classic definition states that AI is the research endeavor that develops technologies capable of doing things that would require intelligence if performed by humans (Minsky, 1969). This approach traces back to Alan Turing, who proposed that if a simulation of an intelligent entity cannot be distinguished from a human, then questions about intelligence become irrelevant (Turing, 2021). Many cognitive scientists and some AI researchers and philosophers have adopted a stronger view, arguing that research on AI can reveal how the human mind works (Gardner, 1987).

A simpler definition (for those who are neither computer scientists nor legal experts), which draws on the definitions of the OECD and the AI HLEG, is provided by UNICEF. The term "Artificial Intelligence" refers to machine-based systems that, given a set of human-defined objectives, can make predictions, formulate recommendations, or make decisions that influence real or virtual environments. AI systems interact with us and affect our environment, either directly or indirectly. Often, they appear to operate autonomously and can adapt their behavior by learning about the context in which they operate. (UNICEF, 2021, p. 16)

In Greece, in 2023, the High-Level Advisory Committee on Artificial Intelligence was established, with the participation of renowned Greek scientists. This high-level committee produced the study "Plan for Greece's transition to the AI era," which sets out a series of guiding principles (which should govern the National Strategy), such as respect for human dignity, human well-being, pluralism, participation, transparency, oversight, adaptability, and international multilateral cooperation (Hellenic Republic, 2024)

Artificial intelligence in education

Artificial intelligence can be applied in education (AI in Education; AIEd) in a variety of ways, using appropriate tools. Consequently, it is not possible to draw overall conclusions or make generalized judgments about the effectiveness (or lack thereof) of AIEd. Rather, to enable a meaningful discussion, we need to be explicit about which of the multiple variants of AIEd applications we are referring to, especially since many remain hypothetical, while others are contested on ethical, pedagogical, or educational grounds. For this reason, it is useful to classify AIEd tools and applications. Holmes et al. (2019) propose a taxonomy of three distinct yet overlapping categories: 1) focused on students, 2) focused on teachers, and 3) focused on institutions (Holmes et al., 2019). This categorization provides a sound methodological framework for facilitating discussion. Holmes et al. also propose subcategories within each main category, which are beyond the scope of this paper. Based on the main categories, we focus on the first

category, and specifically on the use and application of MLLMs for the understanding of bar charts.

Advances in large language models and image recognition

A contemporary application of artificial intelligence is MLLMs. MLLMs are models that have been trained on large-scale datasets and are capable of performing a wide range of tasks, such as creating content and providing answers relevant to the questions asked. These capabilities have now expanded to the analysis and resolution of visual problems, reflecting a shift from Large Language Models to Multimodal Large Language Models (MLLMs). The new MLLMs differ in architecture, training methods, and final optimization/tuning, as described in detail in the study by Huang et al. (2024). For the purposes of the present paper, we will continue to use the term MLLMs, since the emphasis is on the use and educational exploitation of applications rather than on the underlying implementation of the infrastructure.

MLLMs for understanding bar charts

Recent advances in MLLMs, such as ChatGPT (OpenAI, 2025), offer new opportunities for beginners (students and non-students alike) to engage with visual representations of all kinds, work with charts encountered in real-world contexts, and learn from them. A number of tools have leveraged MLLMs to develop natural-language interfaces for data visualizations (Kavaz et al., 2023; Maddigan & Susnjak, 2023). However, these tools primarily focus on enabling users to formulate queries for chart generation and data analysis, rather than helping individuals better understand the meaning conveyed by charts. Given their extensive knowledge bases, MLLMs hold considerable potential as personalized tutors. Nonetheless, their impact on supporting beginners' understanding of charts is only beginning to be explored.

The inherent visual nature of data representations makes visual elements essential. Yet most existing MLLMs applications largely rely on text-based interactions. When interpreting diagrams, individuals often shift their viewpoint and highlight specific visual features, actively interacting with the visualization (Walny et al., 2018). Active learning theory suggests that such multimodal experiences enhance learning (Schank, 1994). This indicates that text-centered communication, which is common across many MLLMs applications, may create challenges for novices engaging with visual data representations and may ultimately reduce learning effectiveness. While multimodal visual exploration has been proposed for data exploration (Shen, 2022), its impact on improving education in visualizations remains underexplored. This gap is particularly noteworthy as AI becomes increasingly integrated into learning contexts, where issues such as hallucinations (Liu et al., 2023) and ensuring user engagement (Roy et al., 2019; Oh et al., 2018) constitute major areas of concern.

Using prompts to explain realistic mathematical problems (RMPs) that incorporate graphs, with a pedagogical orientation

The use of prompts, or more specifically, the instructions provided to MLLM-based digital assistants on how to solve problems more accurately is an increasingly necessary practice that has gained momentum (Mutanga et al., 2025), especially since MLLMs became part of our everyday lives (Lu et al., 2025). Prompts are described in natural language and activate relevant knowledge that is important for users' interaction with the models. The literature describes different prompting techniques, such as in the study

by Sahoo et al. (2024). In a similar way, explanatory instructions can be provided for the analysis of problems that contain an image or a graph.

Some graph-based problems belong to the category of Realistic Mathematical Problems (RMPs) and are characterized by their connection to real-life events, thereby strengthening the transfer of mathematical knowledge to authentic contexts. Such problems require students to understand the information presented, decode quantities and units, and combine them with their prior knowledge in order to answer the questions posed.

Learning and understanding the information contained in graphs and, therefore, in bar charts is not always easily achieved by students, as various empirical studies indicate (Whitaker & Jacobb, 2017). Interpreting bar charts is neither self-evident nor an automatic process. As documented in research (Cleveland & McGill, 1984; Shah & Freedman, 2011; Gardner et al., 2024), students often struggle to: a) recognize the quantitative meaning of the axes, b) identify relevant differences between values, c) avoid misconceptions arising from visual biases or prior experiences, and d) understand the context of the data. Even when they identify the correct values, they may be unable to translate them into sound arguments or to evaluate claims, such as "category X remains consistently above 0.6 from 2002 to 2006" (OECD, 2023). In the present study, we investigate whether and to what extent the use of MLLMs supports students' understanding and interpretation of information contained in graphs.

A study with student groups

The research was conducted with students divided into groups. They interacted with AI-based tools such as MagicSchoolAI, ChatGPT and WolframGPT under math teacher supervision. The sessions took place in the school computer lab. In the first session, participants were introduced to the research plan and the structure of the following sessions. Audiovisual resources were employed to present instructional content related to artificial intelligence, MLLMs and the research objectives. In the following session, the tools received prompt-based instructions (Vagelatos et al, 2025) and students started their interaction with the chatbots. The prompt design specified that the chatbots α) should provide step-by-step reasoning and b) adopt a pedagogical role aimed at fostering student engagement in the mathematical problem-solving process. The main objective of the research was to evaluate the readiness of MLLMs to adopt a pedagogical role, as specified in the prompt, when interacting with students in scaffolding solution of RMPs involving diagrams and tabular data. The provided problem (OECD, 2025) includes bar charts, true-false questions displayed in a tabular structure and contextual information presented in a descriptive paragraph. Particularly, the analysis assessed whether the MLLMs could approach the problem-solving process using strategies commonly exhibited by math teachers during classroom sessions. For instance, teachers primarily aim to promote conceptual understanding and foster metacognitivie skills. The analysis focused on the interactions between students and chatbots.

The interactions were recorded and stored and constitute the qualitative data of the study (Giannisi & Konstantakos, 2026). The results of the analysis highlighted the AI tools' capabilities and limitations in problem-solving RMPs using a pedagogical approach, highlighting the need for further investigation and additional research.

Results

The findings showed that AI tools interpreted the RMP, by extracting the relevant mathematical data from charts and tabular data in Greek. Furthermore, they demonstrated guidance for students by segmenting the solution and raised questions to enhance student reasoning (Giannisi & Konstantakos, 2026, p. 1-4). Overall, the models adopted the guidance role with stepwise explanations of bar charts and tabular data. However, differences identified along three dimensions: (a) comprehension of Greek language and mathematical terms, (b) adoption of guidance role and enhancement of metacognition and (c) chart comprehension and interpretation.

Initially, MLLMs demonstrated understanding of both the Greek language and the data, as well as the RMP requirements. They adopted an instructional and explanatory tone and encouraged students' engagement. They identify the mathematical terms involved in the problem and analyzed them to the students (Giannisi & Konstantakos, 2026, p. 1-2). WolframGPT recognized a mathematical misconception of the notion of «average», and it clarified that the bar charts already displayed the requested mean value. Although one term was mistranslated in the Greek translation, *chicks* was not rendered as *hatchlings*, prompting students to interrupt to address the issue, the model's mathematical reasoning remained consistent. (Giannisi & Konstantakos, 2026, p. 5). ChatGPT linked the decimal with the corresponding percentage, thus enabling students' interpretation in comparison with axis values. MagicSchoolAI appeared to be focused on visual instructions, limiting deeper explanations.

Regarding guidance and reflection, WolframGPT followed the instructions adhered to the prompt, emphasizing that the data presented were not suitable for making predictions. However, it occasionally advanced the steps more rapidly. This observation was noted by students who made a comment ("We would like to solve it…"). It illustrated the need for a more detailed process and steps to allow more students' engagement and reflection. Additionally, ChatGPT applied the prompt guidelines and made specific comprehension questions and task reframing. However, in certain moments, it appeared to provide the reasoning without requiring student input. MagicSchoolAI worked as answer provider, it bypassed the prompt direction as it used non-open questions ("Do you have any questions") and limited the reflections (Giannisi & Konstantakos, 2026, p. 3-4).

Finally, all three chatbots guided students, explained bar charts and conducted comparative analysis based on them. In this respect, WolframGPT appeared to stand out, as it taught the principle "You cannot conclude something which is not based on verified data" when the problem required an understanding of decimals displayed on the axis. As well, ChatGPT supported reliably the interpretation of decimal on the axis. Lastly, MagicSchoolAI provided the solution automatically without engaging students in reasoning and without establishing correlation between data displayed on the axes.

Conclusion

This study, although limited in scope, suggests that MLLMs can support middle school students in the reading and interpretation of bar charts and math problems. Provided that a well-defined pedagogical guideline and a step-by-step guidance have been

embedded in the prompt, all tools addressed the requirements of the RMP and successfully retrieved critical information from the diagrams and tabular data. They succeeded in providing students with a step-by-step guidance and presenting the right solution. Nevertheless, little differences were observed in the pacing of instructional guidance.

From a pedagogical perspective, WolframGPT demonstrated a sequentially elegant solution to a mathematical problem-solving process and sensitivity to data constraints. As a result, it fostered a metacognitive awareness of students. However, its tendency to accelerate the solution process occasionally limited opportunities for students to participate more. Similarly, ChatGPT, while promoting its instructional structure, in some cases its reasoning process accelerated. In contrast, MagicSchoolAI primarily evaluated student responses, and offered guidance with limited conceptual scaffolding. As a result, its pedagogical value for exploratory and inquiry-based learning appeared comparatively limited (Giannisi and Konstantakos 2026, p. 5).

From a linguistic perspective, the tools handle successfully the Greek language and basic mathematical terms. However, an incorrect translation of the word "*chick*" led to students' intervention in order to clarify the context and address the misinterpretation. It occurred with two of the three tools (ChatGPT & WolframGPT). Overall, the step-by-step guidance continued smoothly, without further interruption (Giannisi & Konstantakos, 2026, p. 4-5).

Given the boundaries of this study, i.e a single bar-chart task, a small student sample, one prompt implementation, and three comparable platforms, the findings are context-specific and do not support broad generalization. Nevertheless, we make our findings available to the research community as a basis for further inquiry. According to these, we suggest: a) further investigation on graph interpretation on more complex visualizations, b) more recording of student comprehension through specific evaluations (pre/post-interaction), c) more trial-error on prompt design and d) examination of further interaction on graphs. Finally, e) a larger sample of students.

To conclude, this study indicates that MLLMs could support students' comprehension of mathematical graphs based on a step-by-step guidance when a well-structured prompt is integrated. Furthermore, it shows a) the guidance capacities and limitations of current MLLMs in regards to the Greek secondary education and b) a safe integration example of math problem-solving on teaching, as MLLMs seem to be used as amplifier of teaching and not as substitute of teachers.

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Teacher Training on Cultivating Students' Critical Thinking in the Use of Generative Artificial Intelligence Tools

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Abstract—Recent guidelines for the subject of Informatics in greek middle-school and the new school textbooks introduce the use of Generative Artificial Intelligence tools. The responses produced by Generative Artificial Intelligence tools may contain inaccuracies, errors, and biased ideas. For this reason, it is very important for students to recognize the need to evaluate such responses and to cultivate relevant critical skills. Students are, in general, already familiar with Artificial Intelligence tools, and it is essential for schools to foster a critical approach to their use. In order for schools to effectively respond to the challenges posed by Artificial Intelligence in education, teacher training is required. Taking this need into consideration, a training program was designed on the use of Artificial Intelligence tools in education. The training was addressed to middle-school teachers of all disciplines and was implemented in person, within the framework of each school's in-service training program. One core thematic unit of the training concerned the development of students' critical thinking regarding the use of Artificial Intelligence tools. This paper presents the design of the training program, with emphasis on this particular thematic unit, the experience of its implementation in three middle-schools, and the results of a feedback questionnaire. Based on the results, teachers recognize the importance of cultivating students' critical thinking in the use of Artificial Intelligence tools and the usefulness of the training in this specific thematic area.

Keywords—Generative Artificial Intelligence, In-school teacher training, Critical Thinking

Introduction

Interest in Artificial Intelligence (AI) in K-12 education is rapidly growing (Rizvi, Waite & Sentance, 2023, Azzam & Charles, 2024). The rapid adaption of Artificial Intelligence tools brings multiple opportunities and challenges for education. For this reason, UNESCO developed the Guidance for generative AI in education and research (Miao & Holmes, 2023). Furthermore, UNESCO developed the AI Competency Framework for Students (Miao, Shiohira &, Lao, 2024) and the AI Competency Framework for Teachers (Miao & Cukurova, 2024). The UNESCO AI Competency Framework for Students aims to help educators in the integration of AI learning objectives into official school curricula. This framework emphasizes critical judgement of AI solutions (Miao, Shiohira &, Lao, 2024). The UNESCO AI Competency Framework for Teachers defines the knowledge, skills and values teachers must master in the age of AI (Miao & Cukurova, 2024).

Recent guidelines for the subject of Informatics in greek middle-school (Ministry of Education, Religious Affairs and Sports, 2024a, Ministry of Education, Religious Affairs and Sports, 2024b) and the new school textbooks introduce the use of Generative Artificial Intelligence (GenAI) tools (Athanasakou, et all, 2024a, Athanasakou, et all, 2024b). The responses produced by GenAI tools may contain inaccuracies, errors, and biased ideas. For this reason, it is important for students to recognize the need to evaluate such responses and to cultivate relevant critical skills. Students are, in general, already familiar with AI tools, therefore it is essential for schools to foster a critical approach to their use (Ministry of Education, Religious Affairs and Sports, 2024a, Ministry of Education, Religious Affairs and Sports, 2024b, Miao & Holmes, 2023). In order for schools to respond effectively to the challenges posed by AI in education, teacher training is required (Alexouda, 2024).

In-school teacher training constitutes a form of teachers' professional growth aimed at improving the quality of educational practice. School-based professional development is grounded in processes that conceptualize the school as a learning community, within which its members, through the identification of the school's specific needs, design and implement targeted professional development activities. The benefits of in-school teacher training are twofold: on the one hand, it enhances teachers' professional advancement, pedagogical competence, and reflective practice; on the other hand, it contributes to the overall development, functional improvement, and pedagogical transformation of the school organization (Nika, Vourvouli & Syka, 2024). According to Article 95 of Law 4823/2021, in-school teacher training in Greece is implemented through professional development seminars organized at the level of each school, with the initiative and approval of the school principal.

This study aims to examine the design, implementation and evaluation of a teacher training in cultivating students' critical thinking in the use of GenAI tools.

The Design of the Teacher training

The subject of the teacher training concerns the use of AI tools in education. The training is addressed to middle-school teachers of all disciplines and is implemented in person, within the framework of each school's in-school training program (Law 4823/2021). The duration of the teacher training is 4 hours.

In the training, the use of AI tools in education is examined from the two following perspectives:

- Use by students
- Use by teachers.

The training includes the following two thematic units:

- Cultivating students' critical thinking in the use of AI tools (2 hours)
- Magic School AI: An AI tool for teachers (2 hours).

The present paper focuses on the thematic unit "Cultivating students' critical thinking in the use of AI tools".

The following introductory questions were posed as a starting point at the beginning of the training:

- How do students use AI tools?
- Have they been trained in the critical use of AI tools?
- How do they address critical issues such as information evaluation, personal data protection, and respect for copyright and plagiarism, etc?
- Are parents informed and aware of issues related to the use of AI tools by themselves and their children? Are they aware of these tools? Are they aware of their terms of use?

The thematic unit "Cultivating students' critical thinking through the use of Artificial Intelligence tools" includes the following components:

- The teaching instructions for the middle school Informatics course for the 2024-25 school year - Special section entitled "Instructions for the use of generative Artificial Intelligence tools"
- Examples of activities from the Student's Book – Supplementary educational material
- Examples of prompts – responses in a GenAI tool
- Presentation of two lessons (Design – Implementation experience – Results of feedback questionnaires).

The first lesson was implemented in a section of the Informatics course of the 2nd grade of the 2nd Modular Gymnasium of Thessaloniki in the school year 2023-24, that is, prior to the issuance of the official instructions for the use of GenAI tools by the Institute of Educational Policy. The implementation of the lesson was approved by the Scientific Supervisory Board of the Modular School. Also, the students' parents gave their consent. The learning scenario entitled "Searching and evaluating online sources – Utilizing Artificial Intelligence tools" was implemented by the Informatics Education Consultant in two consecutive instructional hours in the computer lab. Emphasis was placed on the formulation of prompts within a GenAI tool, focusing on topics familiar to the students, as well as on the development of their ability to critically evaluate the sources suggested by the tool (Alexouda, 2024, Alexouda, 2025).

The second lesson was implemented in a section of the Informatics course of the 3rd grade of the 1st Gymnasium of Toumba in the school year 2024-25. The subject of the lesson was "Evaluation of responses from Generative Artificial Intelligence

applications". The lesson was implemented by the Informatics Education Consultant in one instructional hour in the computer lab. Emphasis was placed on the formulation of prompts in two GenAI tools for topics that were unfamiliar to students, on cross-checking the responses produced by the two tools, and on verifying these responses against the results of the Google search engine (Alexouda, 2026).

The Implementation of the Teacher training

The training took place in June and in September 2024 in middle schools of Eastern Thessaloniki in Greece. In particular, the training was implemented at the 1st Gymnasium of Toumba (June 2024), the 4th Gymnasium of Charilaou (June 2024) and at the 2nd Gymnasium of Ano Toumba (September 2024). A total of 48 teachers participated in the training.

Upon exploring the teachers' prior knowledge and perceptions at the beginning of the training, it was found that only a few had attended previous training sessions related to the use of AI tools in education. As expected, Informatics teachers were familiar with the recent guidelines for the subject of Informatics in Greek middle schools. However, several teachers from other disciplines expressed surprise at the rapid implementation of measures related to the use of GenAI tools. During the training the participants showed strong interest by raising questions and actively participating in the discussion. On their own initiative, some participants entered prompts into GenAI tools using their mobile phones, experimenting with alternative prompts and contributing to the discussion based on the responses generated by the tools. A discussion was held on how teachers can contribute to cultivating students' critical thinking in the use of GenAI tools. In addition, attention was given to students' use of GenAI tools for homework tasks and to the implications of this use for the design and assignment of homework within the instructional framework.

More specialized interests were expressed depending on the participants' field of specialization. For example, many philologists expressed a special interest for the relationship between cultivating students' critical thinking in information evaluation and using sources in History. Also, some philologists expressed their interest for investigating the impact of orthography on prompting. Specific examples of alternative word spellings in prompts were studied. Relevant tests conducted on the trainees' mobile devices showed that AI-generated responses were influenced by alternative word spellings, which increased the trainees' interest and active participation.

Results of feedback questionnaire

Out of 48 participants, 34 answered the anonymous online feedback questionnaire. That is, the response rate was 70.83%.

Based on the questionnaire results regarding the respondents' profile, the 76.47% of the respondents were female teachers (Figure 1). As shown in Figure 2, the 76.47% of the respondents were 51 and above years old. The 17.65% of the respondents were 41-50 years old and the 5.88% of the respondents were 31-40 years old. As shown in Figure 3, the majority of respondents (58.82%) had 21 and above years of teaching experience in secondary and primary education. The 26.47% of the respondents had 16-20 years of teaching experience in secondary and primary education. The 5.88% of the

respondents had 11-15 years of teaching experience in secondary and primary education. The 5.88% of the respondents had 6-10 years of teaching experience in secondary and primary education. Only the 2.94% of the respondents had 1-5 years of teaching experience in secondary and primary education.

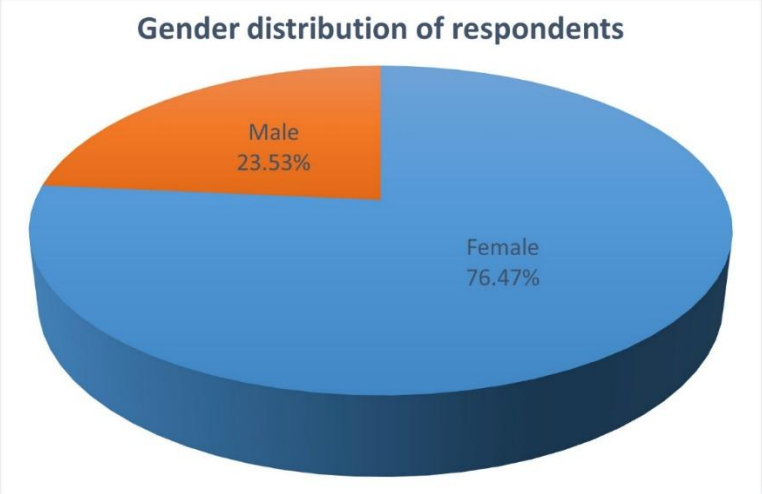


Figure 1: Gender distribution of respondents

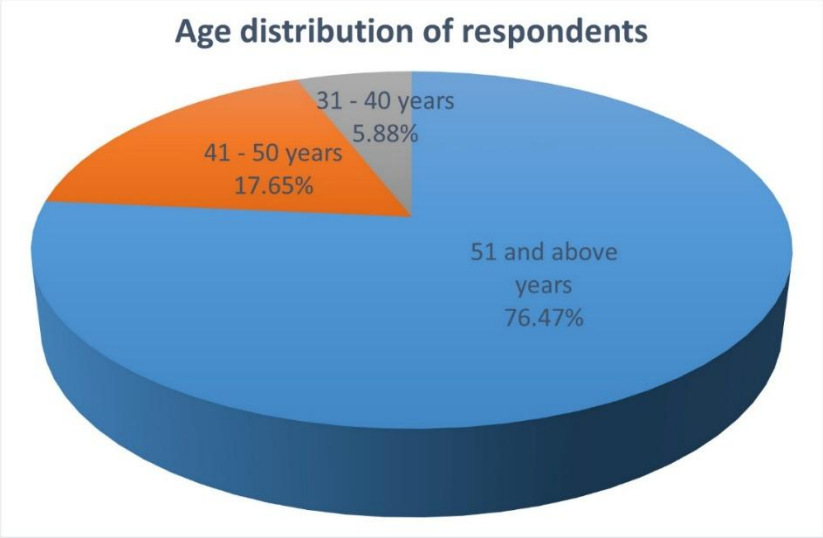


Figure 2: Age distribution of respondents

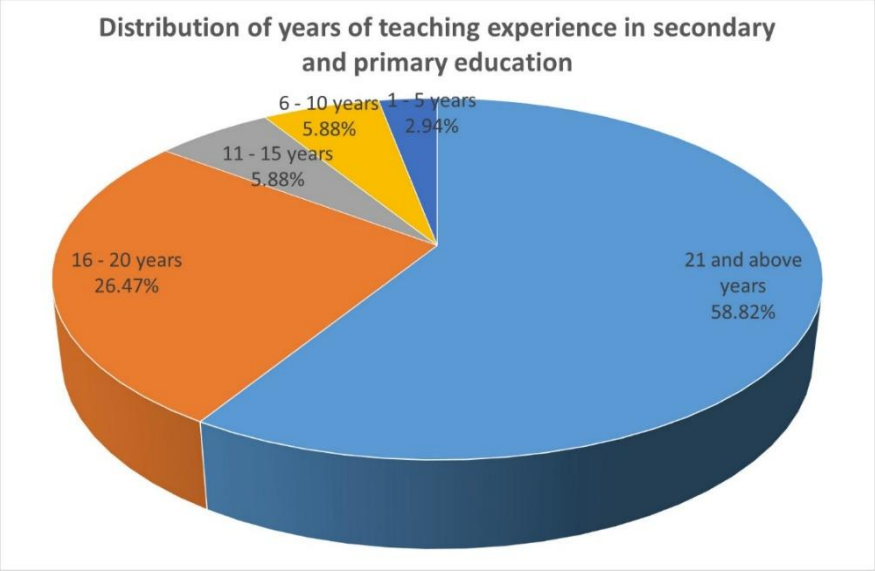


Figure 3: Distribution of years of teaching experience in secondary and primary education

As illustrated in Figure 4, using a five-point Likert scale, half of the respondents found the Thematic Unit "Cultivating students' critical thinking in the use of Artificial Intelligence tools" useful to a large extent, while the other half found it useful to a very large extent. Similarly, as shown in Figure 5, half of the respondents found the presentation of teaching experiences aimed at cultivating students' critical thinking in the use of AI tools useful to a large extent, while the remaining respondents rated it as useful to a very large extent.

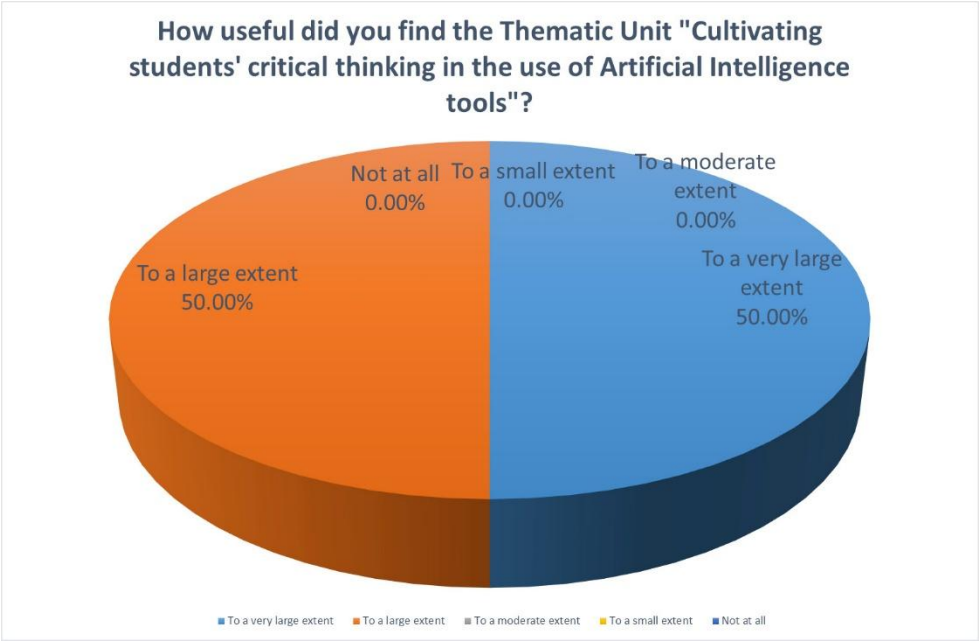


Figure 4: Results of responses to the question "How useful did you find the Thematic Unit "Cultivating students' critical thinking in the use of Artificial Intelligence tools"?"

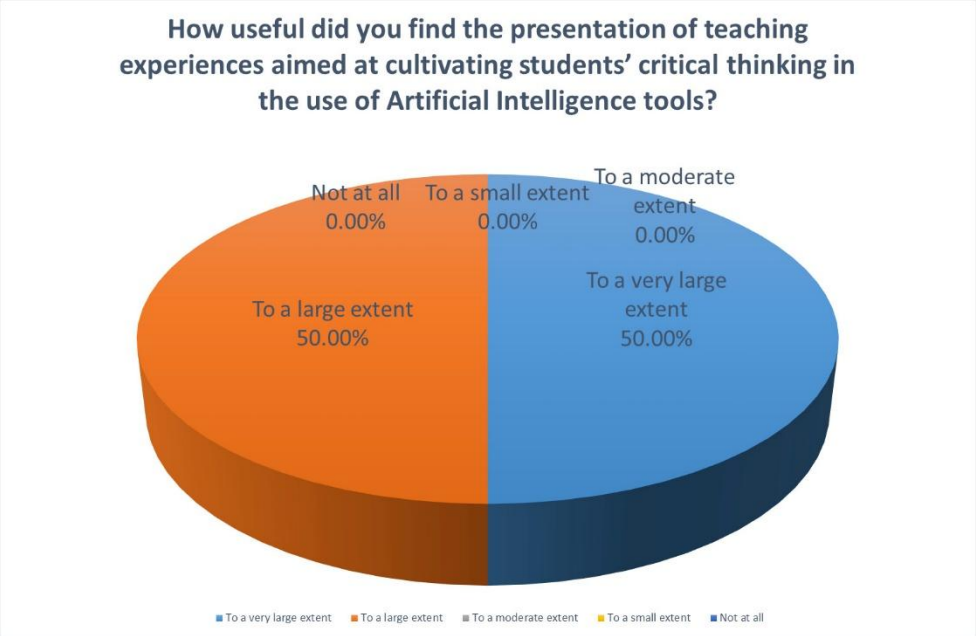


Figure 5: Results of responses to the question "How useful did you find the presentation of teaching experiences aimed at cultivating students' critical thinking in the use of Artificial Intelligence tools?"

As illustrated in Figure 6, using a five-point Likert scale, the majority of respondents (73.53%) considered the cultivation of students' critical thinking in the use of AI tools to be important to a very large extent. In addition, 23.53% of respondents considered it important to a large extent, while only 2.94% rated it as important to a moderate extent.

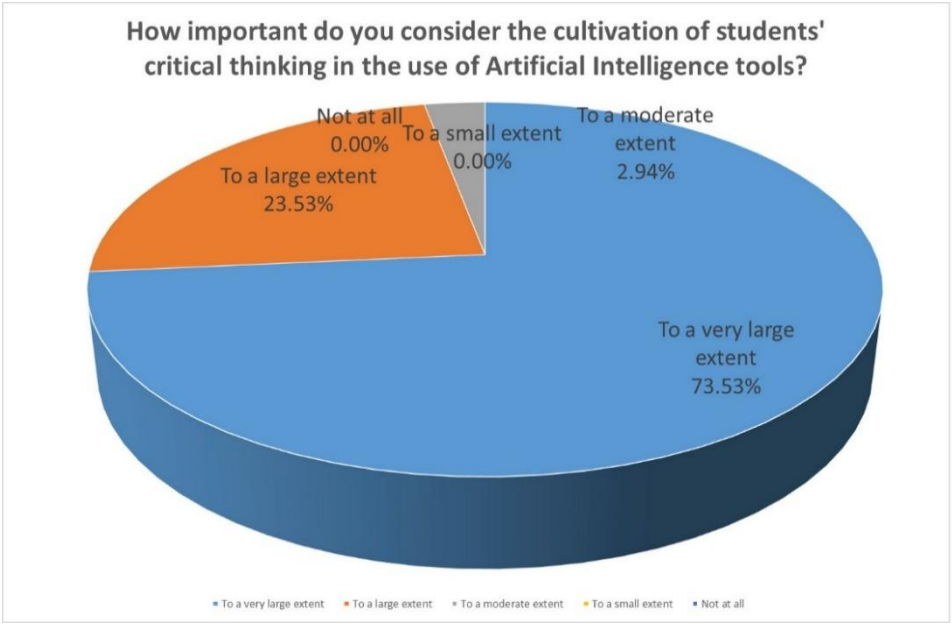


Figure 6: Results of responses to the question "How important do you consider the cultivation of students' critical thinking in the use of Artificial Intelligence tools?"

As shown in Figure 7, the vast majority of the respondents (79.41%) intend to contribute to the cultivation of students' critical thinking in the use of AI tools in teaching practice.

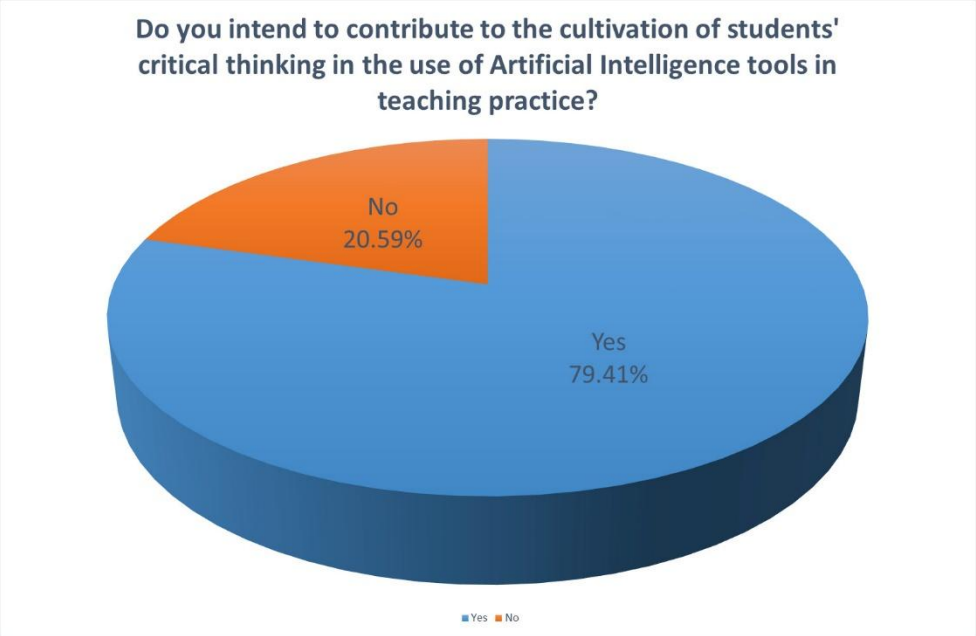


Figure 7: Results of responses to the question "Do you intend to contribute to the cultivation of students' critical thinking in the use of Artificial Intelligence tools in teaching practice?"

Respondents who answered positively to the previous question were asked to respond to the following open-ended question: "How do you intend to contribute to the cultivation of students' critical thinking in the use of Artificial Intelligence tools in teaching practice?". The answers varied and included the following:

- Comparing AI tool responses with trusted sources
- Comparing AI-generated products with student-created work (e.g., presentations)
- Using AI tools for problem solving and checking solution correctness
- Comparing AI-generated content with human-authored texts
- Comparing student-generated summaries with AI-generated summaries
- Initially comparing student responses with AI-generated responses and subsequently cross-referencing them with trustworthy sources
- Using activities that incorporate students' personal perspectives.

Two respondents indicated that they needed more time to reflect before putting forward a concrete proposal.

In the submitted proposals, references were made to the following courses:

- Informatics
- Language
- Foreign Languages
- Skills workshops
- Mathematics
- Ancient Greek
- History
- Geography
- Religion.

In addition, some proposals referred to cross-curricular activities.

Conclusions and Suggestions

Based on the implementation experience and the results of the anonymous online feedback questionnaire, the following conclusions were drawn: The vast majority of the teachers participated in the training

- recognize the importance of cultivating students' critical thinking in the use of AI tools
- recognize the usefulness of the training in this specific thematic area
- recognize the usefulness of the presentation of teaching experiences that seek to cultivate students' critical thinking in the use of AI tools
- intend to contribute to the cultivation of students' critical thinking in the use of AI tools in teaching practice
- submit specific proposals for their contribution to the cultivation of students' critical thinking in the use of AI tools in teaching practice.

Regarding cultivating students' critical thinking in the use of AI tools the following are recommended

- the systematic integration of AI tools into teaching practice, beyond the Informatics course
- the training of teachers across all specialties
- the use of prior experience in implementing relevant teaching interventions in teacher training
- the use of in-school training and collaborative school planning action plans
- the study of all subjects based on their specific characteristics and the subject-specific didactics of each disciplinary field, along with the design of specialized professional development programs by teaching specialization
- the use of communities of practice and learning in teachers' professional development in these areas.

Communities of practice and learning could support teachers in sharing reflections and experiences, as well as in exchanging instructional practices for cultivating students' critical thinking in the use of AI tools. Teacher communities are proposed as one of the key approaches to addressing the continuously increasing professional development needs of teachers (Vangrieken, et all, 2017). Online teacher communities are gaining increasing prominence (Lantz-Andersson, et all, 2018).

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Integration of Artificial Intelligence Tools in European Programs: Pedagogical Approaches and Learning Implications

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions

Abstract—The rapid development of Artificial Intelligence (AI) technologies is bringing about significant changes in the educational landscape, affecting both teaching practices and forms of learning interaction. Its pedagogical use in the context of European collaborative actions, such as eTwinning programmes, highlights new perspectives for the development of 21st century skills, differentiated teaching and the cultivation of digital and metacognitive competence.

This paper presents practical applications of Artificial Intelligence that have been implemented over the past three years in eTwinning programmes, highlighting the multiple benefits for students and teachers. In order to overcome the language challenge of English- speaking collaborations, students used translation tools (ChatGPT, Google Translate AI) to communicate effectively with their partners. While, through Suno, they created original songs combining lyrics of their own inspiration with music produced by Artificial Intelligence, enhancing linguistic expression, imagination and collaborative creativity. ChatGPT and DeepSeek contributed to the design and improvement of interview and podcast scripts, while Clipchamp was used to automatically generate subtitles, facilitating the dissemination of the material.

Regarding, tools such as Canva AI and Bing Image Creator supported the creation of digital posters and illustrated material, enhancing multimodal expression and the connection between words and images. Students also produced illustrated stories and interactive comics with DALL·E, while for their virtual presence they created avatars through Vidnoz AI, enhancing the multicultural dimension of the projects. In addition, they collaboratively used documents with Artificial Intelligence functions for co-writing and reviewing content, and applied Google Sheets AI for questionnaire data analysis, developing research and data interpretation skills.

The integration of Artificial Intelligence into these activities was not limited to its technical dimension, but provided an opportunity for pedagogical innovation and reflection on learning processes. Students took an active role in the creative process, learning to use the tools with critical thinking, collaborative spirit, and respect for the ethical principles that govern the use of Artificial Intelligence. Teachers, on the other hand, acted as guides, co-creators and motivators, using AI as a tool for pedagogical design, differentiation and multilingual communication. Its use contributed the

reduction of cognitive and workload, allowing greater focus on learning interaction and supporting student autonomy.

The results of the actions demonstrated that AI can act as a catalyst for creative, collaborative and experiential learning, bridging imagination with technology and empowering teachers and students to co-create a modern, innovative learning environment. When integrated into a clear pedagogical framework and with ethical awareness, Artificial Intelligence enhances active participation, the development of metacognitive strategies and the connection with the real world. It does not replace the role of the teacher, but rather enhances it. The teacher is transformed into a motivator, mediator and critical supervisor, promoting responsible, creative and technologically literate citizenship among students. Finally, the use of Artificial Intelligence can be a catalyst for educational innovation, leading to the formation of a new paradigm of collaborative, experiential and multiliteracies learning.

Keywords — Artificial Intelligence in education, pedagogical innovation, 21st century skills, digital literacy

1. Introduction

The rapid development of Genetic Artificial Intelligence and large language models, such as ChatGPT, has begun to shape the landscape of general and special education, influencing both teaching practices and forms of learning interaction (Alier, García-Peñalvo, & Camba, 2024; Law, 2024). The integration of Artificial Intelligence tools into the educational process is no longer limited to the dimension of technological innovation, but is directly linked to pedagogical design, differentiated teaching, and the cultivation of 21st-century skills. The ability to produce rich and personalised content, combined with flexible responses to questions, highlights language models as powerful tools for supporting the educational process (Resnick, 2024).

However, the pedagogical integration of Artificial Intelligence technologies is accompanied by significant challenges, which concern their responsible use, the protection of personal data, and ensuring accessibility and equal participation in the learning environment (Yan et al., 2024). Despite growing research interest in Artificial Intelligence in education, there are still limited studies examining its systematic pedagogical use in the context of European collaborative primary education programmes, with an emphasis on experiential learning, collaboration, metacognitive development and the transformation of the role of the teacher. In this context, European collaborative programmes such as eTwinning offer a particularly prolific pedagogical environment for the creative and experiential use of Artificial Intelligence. Through intercultural and multilingual collaboration between students and teachers from different countries, new opportunities for the development of digital literacy, collaborative skills and critical thinking are emerging, while simultaneously reducing language and expression barriers.

The use of Artificial Intelligence tools in such collaborative projects allows for the production of multimodal educational content (text, image, sound, video), supports the personalisation of learning and enhances students' creativity and initiative. Moreover, it contributes to the reduction of teachers' workload, enabling them to focus more on their role as guides, coordinators and motivators of the learning process.

Despite these advantages, the pedagogical use of Artificial Intelligence requires a critical approach and ethical awareness. Issues such as the reliability of the information produced, the responsible use of tools, the protection of personal data and the risk of over-dependence make it necessary to integrate Artificial Intelligence into a clear pedagogical framework that promotes critical thinking, metacognitive awareness and digital citizenship among students.

This paper focuses on the pedagogical use of Artificial Intelligence tools in European eTwinning collaborative projects, presenting practical applications that have been implemented in primary education over the past three years. Its aim is to highlight the learning and pedagogical benefits of the creative and responsible integration of Artificial Intelligence, as well as to explore the transformation of the teacher’s role in a modern, collaborative and multiliteracies learning environment.

2. Theoretical framework

Artificial Intelligence in education refers to the use of digital systems and algorithms that can analyse data, generate content and support learning processes in a way that is tailored to the needs of students. These systems are based on machine learning and natural language processing techniques and can mimic or enhance cognitive functions such as language production, problem solving and decision support in the learning environment.

A special category of Artificial Intelligence applications consist of large language models, which have the ability to create and offer a flexible response to users inquires. These characteristics make them particularly suitable for educational applications (Resnick, 2024). Recent research by Dos Santos & Cury (2023) and Dai et al. (2023) highlight the contribution of systems such as ChatGPT in enhancing teaching differentiation and providing immediate, personalised feedback, which effectively supports students' learning progress.

The use of Artificial Intelligence in education is directly linked to the personalisation of learning and differentiated teaching, as it allows educational content to be tailored to the needs, interests and learning profile of each student. According to Luckin et al. (2016),
Artificial Intelligence systems can contribute to an in-depth understanding of the learning process and the factors that influence it, enhancing the effectiveness of instructional design. Additionaly, the use of Artificial Intelligence tools extends beyond the cognitive dimension of learning, contributing to the development of social and communication skills. The integration of tools such as ChatGPT into educational activities can support collaborative learning through interactive scenarios, dialogues, and joint projects. Research, such as that by Carrión et al. (2023), point out that digital tools encourage social interaction among students, contributing to the improvement of teamwork, communication skills and active participation in the learning environment.

The integration of Artificial Intelligence into educational practice is based on contemporary pedagogical theories that highlight the active role of the student and learning as a social and dynamic process. Constructivism emphasises the importance of building knowledge through active engagement, while Vygotsky's sociocultural theory highlights the role of interaction and collaboration. Furthermore, cognitivism approaches learning as the result of networked relationships and digital connections, which is in line with collaborative and multinational learning environments.

Furthermore, pedagogical approaches such as Inquiry-Based Learning, Universal Design for Learning (UDL) and the metacognitive approach reinforce the use of Artificial Intelligence as a tool to support differentiated and inclusive learning. In this context, Artificial Intelligence tools can function as cognitive and metacognitive supports, enhancing students' self-regulation and reflection.

The above theoretical approaches acquire particular pedagogical value in the context of European collaborative programmes, such as eTwinning, where multilingualism, collaboration and experiential learning are key elements of the educational process. In addition, the pedagogical integration of Artificial Intelligence is accompanied by significant challenges concerning ethical use, personal data protection, the reliability of the information produced and accessibility. For this reason, it is necessary to integrate

Artificial Intelligence into a clear pedagogical and ethical framework that promotes critical thinking and digital citizenship.

In summary, the theoretical framework of this paper is based on the perception of Artificial Intelligence as an educational tool which, when integrated into appropriate educational and ethical planning, can support collaborative, experiential and multiliteracies learning, as well as contribute to the transformation of the role of both the teacher and the student in the modern school.

2.1 Artificial Intelligence in Education

Artificial Intelligence in education refers to the systematic use of digital tools and intelligent systems that have the ability to analyse data, produce content and support learning processes in a way that is based on the needs, interests and learning profile of students. These systems are based on machine learning and natural language processing techniques and can mimic or enhance cognitive functions such as language production, problem solving and decision-making support in the learning environment.

Genetic Artificial Intelligence tools and large language models, such as ChatGPT, are particularly dynamic, as they have the ability to produce rich, flexible and customized content according to the level and needs of users. In an educational context, these tools can be used for writing and revising texts, formulating questions, creating learning scenarios, and supporting multilingual communication, acting as cognitive and metacognitive supports for the learning process.

The integration of Artificial Intelligence into teaching practice is not intended to replace the teacher, but to serve as a tool to support and enhance their pedagogical role. Teachers retain their main role in the design, guidance and evaluation of learning, using Artificial Intelligence to enhance students' autonomy, cooperation and active participation. In this context, their role is transformed from that of a knowledge transmitter to that of a guide, coordinator and motivator of the learning process.

Moreover, the use of Artificial Intelligence tools contributes significantly to overcome language and expression barriers, especially in multilingual and multicultural learning environments. Through translation, support and creative functions, students are able to participate equally in collaborative activities, express ideas and co-create multimodal content, regardless of their level of language proficiency.

Furthermore, research data highlights the importance of students themselves understanding how Artificial Intelligence works. Those who understand how Artificial Intelligence systems work, as well as the types of problems they can and cannot solve, are able to use these technologies in a more effective, critical and responsible way in their daily lives.Developing this form of digital and technological literacy is becoming increasingly important, starting even the primary education stage. In the same context, Ayanwale et al. (2022) highlight the need to design and implement appropriate Artificial Intelligence courses in school, with the aim of developing basic skills that will enable students to interact consciously and creatively with intelligent digital systems.

However, the pedagogical use of Artificial Intelligence requires clear pedagogical planning and ethical awareness. Issues related to the responsible use of tools, the reliability of the information produced, the protection of personal data and accessibility make it necessary to integrate Artificial Intelligence into a clear pedagogical and ethical framework. The cultivation of critical thinking and digital citizenship is emerging as a basic prerequisite for its effective and responsible use in the school environment.

In summary, Artificial Intelligence can serve as a powerful educational tool, when used with appropriate educational and ethical planning, supports collaborative, experiential and multiliteracies learning in modern education.

2.2 Pedagogical theories supporting the integration of Artificial Intelligence

The integration of Artificial Intelligence into the educational process is based on strong pedagogical foundations, which highlight the active, social and self-regulating role of the student during learning. Contemporary pedagogical theories approach learning as a dynamic and participatory process in which the student builds knowledge through experience, interaction and reflection, elements that can be effectively supported by Artificial Intelligence tools.

Constructivism plays a main role, according to which knowledge is not passively transmitted, but actively constructed by the student through exploration, experimentation and the solving of authentic problems. The use of Artificial Intelligence, through interactive tools, adapted learning environments and personalised feedback, reinforces this active learning process, supporting pedagogical approaches such as inquiry-based and project-based learning (Chen et al., 2020).

In addition, Vygotsky's Sociocultural Theory highlights the decisive role of social interaction and the Zone of Proximal Development in the learning process. In this context, AI tools can function as digital mediation and scaffolding tools, providing guidance and feedback adapted to the student's level of development. Through collaborative activities and dialogues, Artificial Intelligence helps support learning at a level slightly above the student's autonomous capabilities.

This theoretical approach is linked to Connectivism, perceives learning in the digital age as the result of an individual's participation in broad, networked spaces of knowledge. According to Siemens (2014), knowledge is built through the connection of information, people and digital resources. Artificial Intelligence facilitates the creation of and navigation within such networks, enhancing the collective construction of knowledge and access to multimodal and multilingual educational content.

Moreover, Universal Design for Learning (UDL) focuses on creating flexible, accessible and differentiated learning environments that meet the needs of all learners. IT applications can offer multiple ways of presenting information, expressing oneself and interacting, supporting students with different learning profiles, abilities and cultural backgrounds (Cast, 2018; Zimmerman, 2013).Finally, the Metacognitive Approach highlights the importance of awareness and self- regulation of cognitive processes. The use of Artificial Intelligence in providing targeted feedback, reflective questions and learning strategy support can enhance students' self- assessment and

metacognitive awareness skills, which are critical for lifelong learning. Overall, the above pedagogical theories form a unified and coherent theoretical framework that substantiates the pedagogical value of Artificial Intelligence. When Artificial Intelligence is integrated into a clear pedagogical and ethical design, it can support personalised, active, collaborative and inclusive learning, while contributing to the transformation of the role of the teacher from a transmitter of knowledge to a guide and coordinator of the learning process.

2.3 European collaborative programmes (eTwinning) and pedagogical approaches

European collaborative programmes, eTwinning in particular, provide a dynamic educational framework that encourages the implementation of modern student-centred approaches and the use of innovative digital tools, such as Artificial Intelligence.

ETwinning promotes cooperation between schools from different European countries, enhancing intercultural communication, multilingualism and the co-creation of knowledge through joint educational projects.

The philosophy of eTwinning is largely aligned with the principles of constructivism and sociocultural theory, as students learn through authentic activities, collaborative processes and interaction with peers from different cultural and linguistic backgrounds. Learning is organised around common interests and real-life problems, reinforcing the experiential approach and the active participation of students in the learning process.

At the same time, eTwinning projects largely adopt the principles of constructivism, as they are based on the creation of communication and learning networks, where knowledge is co-constructed through digital platforms, collaboration tools and brainstorming. Students are encouraged to search, evaluate and synthesise information from a variety of sources, developing digital literacy and critical thinking skills.

In this context, the integration of Artificial Intelligence tools into eTwinning programmes can reinforce these pedagogical approaches. AI tools facilitate the production of multimodal educational content (text, image, sound, video), support differentiated teaching and help reduce the language and expression barriers that often arise in multinational learning environments. In this way, the equal participation of all students in collaborative activities is enhanced.

Furthermore, the pedagogical framework of eTwinning is particularly well suited to the implementation of Universal Design for Learning (UDL), as it promotes flexibility, differentiation and inclusion. Artificial Intelligence can support multiple means of knowledge accessing knowledge and expression of learning, responding to the different needs, abilities and learning profiles of students.

The development of metacognitive skills in the context of eTwinning collaborative projects is also particularly important. Through the use of AI tools, students have the opportunity to receive immediate feedback, reflect on their learning process and improve their strategies, enhancing self-regulation and responsibility in learning.

Finally, in the context of European collaborative programmes, the role of the teacher is essentially transformed. The teacher does not act as a mere transmitter of knowledge, but as a pedagogical coordinator, guide and motivator of the learning process, designing activities, supporting collaboration and ensuring a pedagogically appropriate and ethically grounded use of Artificial Intelligence.

3. Methodology

Artificial Intelligence was used creatively in three European eTwinning collaborative programmes: Our GREEN podcast (2023–2024), Tales turned upside down: Reversing stereotypes in fairy tales (2024–2025) and A.C.T.I.V.E (2025–2026). The programmes were implemented over a period of eight (8) months each and were aimed the students target group age was 10–12, taking into account the developmental, cognitive and socio-emotional characteristics of this age group.

A key element of the methodological approach was project-based learning, with students working in mixed transnational teams and using eTwinning's digital collaboration platforms for communication, co-creation and brainstorming. The learning process was organised around authentic problems and topics related to the real world, enhancing experiential and collaborative learning.

Artificial Intelligence was integrated into teaching as a supportive tool for learning and creation, rather than as a substitute for the learning process. Specifically, AI tools were used to support brainstorming, the production, reformulation and improvement of texts, the creation of scenarios, audio editing, and the organisation and analysis of information. In all phases of the projects, the use of Artificial Intelligence was carried out with systematic pedagogical guidance from the teacher, who acted as a coordinator and facilitator of the learning process.

In the "Our GREEN podcast" programme, the methodology focused on exploring environmental issues and creating digital radio content. Students developed research, collaboration and digital literacy skills, while their environmental awareness was enhanced through the collective production of podcasts.

In the programme "Tales turned upside down: Reversing stereotypes in fairy tales", Artificial Intelligence was used to retell traditional fairy tales and while contributing to the critical deconstruction of social and gender stereotypes. This approach promoted creative writing, imagination and critical thinking among students, encouraging them to recontextualize familiar narrative structures.

Finally, in the "A.C.T.I.V.E." programme, which focused on active citizenship and social action, Artificial Intelligence served as a tool to support idea generation, action planning and reflection on social issues. Students were asked to explore problems in the local and wider community and propose solutions, using digital and collaborative tools.

4. Practical Applications of Artificial Intelligence

4.1 Language Support and Multilingual Communication

In the context of the aforementioned eTwinning programmes, Artificial Intelligence was used as an educational tool for linguistic scar folding and multilingual communication, enhancing student participation in transnational collaborations. Applications such as ChatGPT and Google Translate AI were used in a guided manner to understand and produce English speech, both in written and oral form, taking into account the different levels of language proficiency of the students.

More specifically, students used Artificial Intelligence tools to translate words and short phrases, listen to correct pronunciation and gradually improve their phonological awareness. At the same time, Artificial Intelligence supported the process of indexing and editing texts, allowing students to identify key information, rephrase meanings, and enrich their vocabulary in a functional way.

The use of these tools contributed significantly to overcoming the language barriers that often arise in international collaborations, enhancing the active participation of all students in the learning process and in the production of joint collaborative deliverables. The educational benefits of this practice were numerous, as it fostered learning autonomy, boosted students' confidence in using English, and ensured the inclusion of students with language or learning difficulties.

Overall, Artificial Intelligence acted as a support mechanism that promotes language development, intercultural communication, and digital literacy, contributing to the creation of a more inclusive and collaborative learning environment in the modern school.

4.2 Creative Expression and Content Production

Artificial Intelligence was used as a means of enhancing creative expression and multimodal content production, offering students new ways of artistic and communicative creation. The pedagogical use of AI tools focused on the process of creation and collaborative learning, with the teacher acting as a guide and coordinator of the learning process.
Tools such as Suno were used for music composition, allowing students to experiment with sounds, rhythms and musical motifs, linking musical creation to the themes of the programmes. Through this process, students developed their imagination and cultivated their aesthetic perception, transforming ideas, messages and emotions into forms of musical expression.

Additionally, applications such as ChatGPT and DeepSeek were used to write interviews and podcast scripts, supporting the structure of spoken and written language, the development of arguments and the creation of authentic content. The students engaged in collaboratively formulating questions, developing dialogue flow and adapting content to the target audience, enhancing their communication, collaboration and critical thinking skills. Finally, Clipchamp was used to produce automated captions produced, facilitating accessibility and enhancing multimodal communication. This practice contributed to the inclusion of students with different learning needs, as well as to improve the understanding of the content by a wider audience.

Overall, the educational benefits of using Artificial Intelligence were evident, as creativity, imagination and a culture of collaboration were enhanced, transforming students from passive consumers of digital content into active creators.

4.3 Visualisation and Multimodal Learning

The use of Artificial Intelligence in the production of visualised and multimodal educational material was a key element of the programmes, enhancing students' creativity, imagination and collaboration. The pedagogical approach focused on the active participation of students in the process of creating original content, with Artificial Intelligence serving as a supportive means of learning and expression rather than an end in itself.

Applications such as Canva AI and Bing Image Creator were used to create digital posters and illustrated material, enabling students to combine images, colours and text in a creative and targeted way. At the same time, DALL-E was used to produce visual content for stories and digital comics, encouraging imagination, creative writing and storytelling through multimodal media.

In addition, Vidnoz AI was used to create avatars and virtual presence forms, facilitating interactivity and student representation in digital collaborative environments. Through this process, students developed expression, communication and critical thinking skills, as they were asked to select, combine and evaluate visual and digital content using pedagogical and aesthetic criteria.

The collaborative production of multimodal material strengthened teamwork and interaction among students, while the creation of personal and group projects promoted autonomy, self-motivation and active participation in the learning process. Overall, Artificial Intelligence acted as a catalyst for the development of creative expression and digital literacy skills, making students active and critically thinking creators of multimodal content.

4.4 Collaborative Writing and Data Analysis

Through collaborative digital documents with built-in Artificial Intelligence tools, students worked together to write texts, take notes and compile reports, receiving immediate support in organising, writing and optimising content. This process promoted collective decision- making, the co-creation of ideas and the development of collaboration skills at a transnational level.

Moreover, the use of tools such as Google Sheets AI enabled the processing and analysis of data obtained from questionnaires, enabling students to identify patterns, draw conclusions and substantiate their interpretations based on real data. Working with data contributed significantly to the cultivation of scientific literacy, critical thinking, and information interpretation and evaluation skills.

The pedagogically guided integration of Artificial Intelligence into collaborative writing and data analysis engaged students, enhanced their autonomy, and shaped a learning environment in which knowledge is built collectively, documentedly, and reflectively. Overall, Artificial Intelligence served as a tool that bridges content creation

with learning research, enhancing the development of complex digital and scientific literacy skills.

5. Pedagogical Benefits and Learning Implications

The pedagogically guided integration of Artificial Intelligence into eTwinning collaborative projects has revealed a wide range of learning and teaching benefits which extend beyond the development of digital skills and have a significant impact on the overall learning experience of students, as well as the role of the teacher. The use of AI tools has acted as a catalyst for enhancing creativity and experiential learning, enabling students to experiment, express themselves and create authentic multimodal content, linking knowledge with personal experiences, emotions and interests. Through the process of producing texts, images, sound and digital projects, students actively constructed knowledge, transitioning from passive recipients to active creators.

Additionally, the use of Artificial Intelligence contributed significantly to the development of metacognitive strategies and critical thinking. Students were asked to evaluate, reflect upon, and reshape the suggestions of AI tools, making conscious decisions about the content and form of their work. This process enhanced self-regulated learning, awareness of their cognitive processes and the ability to make informed judgements, all of which are considered critical for the development of 21st century skills.

In terms of social interaction, Artificial Intelligence supported the creation of collaborative, multicultural and inclusive learning environments. In the transnational context of eTwinning, the use of AI tools has helped to overcome language and communication barriers, allowing equal participation of students with different linguistic, cultural and learning characteristics. In this way, collaboration was strengthened, intercultural understanding was cultivated, and a climate of acceptance of diversity was promoted, in which each student could contribute meaningfully to the collective learning process.

The contribution of Artificial Intelligence to improving students' language proficiency and learning confidence was also particularly important. The guided use of AI tools for understanding and producing speech provided a safe and supportive learning environment in which students could experiment with language, make mistakes and gradually improve. This process led to increased confidence in using English and enhanced their active participation in international collaborations.

Finally, the pedagogical benefits of integrating Artificial Intelligence extended to the role of the teacher. Artificial Intelligence acted as a supportive tool that helped reduce cognitive and workload, especially in terms of organising material, diversifying activities, and providing feedback. At the same time, it elevated the teacher to the role of guide, coordinator, and motivator of the learning process, reinforcing a modern, collaborative, and multiliteracies pedagogical orientation.

6. Conclusions

This paper has shown that Artificial Intelligence can act as an effective catalyst for educational innovation, enhancing creative, collaborative and experiential learning in

the modern school environment. When its integration is carried out within the framework of a clear and targeted pedagogical design, Artificial Intelligence supports active student participation, self- motivation and the development of metacognitive skills, contributing significantly to the development of 21st century skills.

The findings of the study show that Artificial Intelligence does not replace the role of the teacher, but rather upgrades it, transforming them from a simple transmitter of knowledge to a guide, co-creator and motivator of the learning process. Teachers retain their main pedagogical role, using AI tools as supportive means that enhance differentiation, collaboration and qualitative feedback.

Furthermore, throught the use of Artificial Intelligence in European collaborative programmes, such as eTwinning, has emerged as a decisive factor in strengthening multilingual and multicultural collaborations. The reduction of language and communication barriers has paved new ways for interconnection, enabling the equal participation of all students and enhancing intercultural understanding.

Overall, Artificial Intelligence contributes to the creation of a modern, multilingual and inclusive learning environment, in which learning is essentially linked to the real world and its contemporary social and technological challenges. Its responsible and pedagogically documented use can be a powerful tool for transforming educational practice and strengthening the role of the school as a place of creativity, collaboration and active citizenship.

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Govering Fear in AI-Driven Education: Affective Leadership for Ethical Schools

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Abstract—Artificial Intelligence (AI) is increasingly embedded in educational governance, reshaping assessment practices, accountability mechanisms, and professional judgment. While existing research has extensively addressed ethical principles such as fairness, transparency, and accountability, considerably less attention has been paid to how educators emotionally experience AI-driven reforms and what these experiences reveal about institutional governance. This paper examines the affective dimension of AI adoption in education, focusing on fear, anxiety, and moral unease as governance-relevant signals rather than individual adaptation problems. Drawing on organizational justice theory, sociotechnical systems theory, and emotional capital, the study introduces the Affective Foresight Model (AFM) as a conceptual framework for interpreting emotional responses as early indicators of ethical tension, legitimacy risk, and governance misalignment. The analysis shows that AI-related fear emerges at the intersection of technostress, surveillance, moral uncertainty, and perceived loss of professional autonomy. Rather than being incidental side effects, these affective responses function as evaluative judgments through which teachers assess fairness, trust, and professional recognition. The AFM demonstrates how leadership mediation plays a critical role in determining whether such emotions escalate into resistance and disengagement or are transformed into institutional learning and anticipatory governance. The paper further reframes ethical school leadership as an anticipatory and relational practice. Ethical AI governance is shown to extend beyond regulatory compliance toward systematic attention to emotional climates, participatory implementation, transparency, and ethical dialogue. The Greek educational context, characterized by reform intensity, evaluation pressure, and low institutional trust, is used as an illustrative case to highlight how affective signals acquire particular diagnostic value under conditions of governance strain. Overall, the study argues that ethical AI governance in education cannot be achieved through principles and technical safeguards alone. Attending to educators' emotional experiences enables earlier detection of governance vulnerabilities and supports more legitimate, sustainable, and human-centered AI adoption.

Keywords— Artificial Intelligence in Education, Ethical School Leadership, Teacher Emotions

1. Introduction: AI, Governance, and the Neglected Affective Dimension

The rapid expansion of Artificial Intelligence (AI) across educational systems is reshaping not only teaching practices and learning environments, but also the modes through which schools are governed. From algorithmic assessment and predictive analytics to data-driven performance monitoring, educational institutions are increasingly embedded within infrastructures of automated decision-making and computational governance (Holmes et al., 2022; Williamson & Eynon, 2020). These developments signal a gradual reconfiguration of authority, accountability, and professional judgment, positioning AI not merely as an instructional or support technology, but as a governance mechanism with ethical, organizational, and political consequences (Grek & Landri, 2021; Wang, 2024).

In response to these transformations, scholarly and policy debates in AI in Education (AIEd) have largely concentrated on the development of ethical and regulatory frameworks. Principles such as fairness, transparency, accountability, and human oversight have become central reference points for responsible AI adoption (Jobin et al., 2019; Mittelstadt, 2019).

Yet, despite these important advances, a critical dimension of AI-driven educational change remains under-examined: the affective experiences of educators working within algorithmically mediated environments. Teachers' emotional responses to AI, ranging from anxiety and moral unease to cognitive overload, are often framed as individual adaptation challenges or transitional side-effects of innovation (Susarla et al., 2023).Within dominant ethics-oriented and technocratic accounts, affect tends to appear as a secondary concern: either as noise to be managed or as a psychological variable detached from questions of governance and institutional legitimacy.

This affective blind spot is not merely an analytical omission; it has tangible governance implications. Emotions function as interpretive judgments through which educators assess fairness, legitimacy, professional recognition, and ethical responsibility under conditions of uncertainty (Kelchtermans, 2005; Zembylas, 2021). A growing body of international research suggests that stress and technostress are not marginal phenomena in digitally intensified education, but recurring patterns associated with data-driven work, monitoring practices, and accelerated reform tempos (Fernández-Batanero et al., 2020).

Evidence from European contexts reinforces the relevance of this affective lens. Empirical studies in Spain, for example, document technostress as a measurable occupational risk among teachers using digital technologies (Rey-Merchán & López-Arquillos, 2021) and report significant associations between technostress, emotional exhaustion, and burnout (Pagán-Garbín et al., 2024). At the same time, survey research indicates generally positive attitudes toward AI alongside limited classroom integration, revealing a persistent gap between policy discourse and institutional readiness (Galindo-Domínguez et al., 2024). Such gaps constitute fertile ground for anxiety and moral uncertainty, especially when expectations of AI adoption outpace professional support.

These emotional patterns should not be read as idiosyncratic reactions or resistance to innovation. Rather, they are socially patterned signals of organizational and ethical

strain. Anxiety surrounding algorithmic monitoring often reflects concerns about surveillance and the erosion of pedagogical autonomy (Williamson, 2023), while moral discomfort with predictive analytics exposes tensions between professional values and data-driven decision logics (Jarke & Breiter, 2020; Holmes et al., 2022). Gendered asymmetries further complicate this picture, suggesting that AI adoption may reproduce existing inequalities, as women educators disproportionately report technostress and digital insecurity (Holmes et al., 2022).

Despite evidence of these affective dynamics, prevailing approaches to ethical AI governance in education remain predominantly technocratic. They prioritize compliance mechanisms, risk classification, and design principles, while offering limited conceptual tools for interpreting how reforms are lived, negotiated, and emotionally evaluated within schools. As a result, educational governance often lacks a language for treating affect not as pathology or resistance, but as a meaningful source of institutional knowledge.

This paper starts from the premise that affective responses to AI, particularly fear, anxiety, and moral unease carry governance-relevant information. Rather than focusing on educator resilience, the paper asks what these emotional responses reveal about legitimacy, justice, leadership capacity, and institutional readiness in AI-mediated education systems.

1.1 Research gap and contribution

While existing research has extensively addressed ethical AI, algorithmic accountability, and technostress, less attention has been paid to the governance significance of affective responses generated by AI-driven educational reform. Studies of technostress underline important psychological consequences, yet they largely frame emotion as an individual adaptation problem rather than as an organizational signal of legitimacy tension, ethical strain, or leadership vulnerability.

This paper addresses this gap by reconceptualizing fear and related affective responses as governance-relevant signals embedded within algorithmic educational change. Building on Organizational Justice Theory (Colquitt, 2001), Sociotechnical Systems Theory (Orlikowski & Scott, 2015), and Emotional Capital Theory (Reay, 2004), the paper introduces the Affective Foresight Model (AFM) as an integrative framework for interpreting emotion as anticipatory institutional intelligence. The paper makes three contributions: first, it integrates affect into AI governance analysis in education; second, it develops a theoretically grounded model linking fear to legitimacy, justice, and leadership capacity; and third, it offers a governance-oriented lens for educational leaders and policymakers to anticipate ethical tensions before they turn into resistance, disengagement, or reform failure.

2. Why Fear Matters in AI-Driven Education

Fear in technologically mediated education is frequently described as an individual psychological response to rapid innovation. (Williamson, 2023; Grek & Landri, 2021). Fear in technologically mediated education is often described as an individual psychological response to rapid innovation. In AI-driven school environments, however, fear rarely originates solely within the individual; it is shaped by institutional

arrangements, data infrastructures, and shifting expectations of professional performance. When algorithmic systems mediate assessment, monitoring, analytics, and decision-support, teachers' fear signals uncertainty about legitimacy, autonomy, competence, and ethical responsibility rather than simple resistance to change (Williamson, 2023; Grek & Landri, 2021).

This interpretation aligns with broader sociotechnical research showing that educational technologies are not neutral, but embedded in governance arrangements that redistribute authority and professional value (Selwyn, 2023; Knox et al., 2020).

2.1 AI-Induced Technostress and Professional Anxiety

According to Tarafdar et al. (2019) one way fear appears in AI-mediated education is through technostress, when technological demands feel overwhelming for teachers. In practice, AI tools can increase workload and pressure, leading to anxiety, fatigue, and reduced confidence. Importantly, research shows that this stress is often linked to institutional expectations rather than individual skills. As feedback becomes faster and less negotiable, teachers may experience a subtle but significant shift from professional judgment toward performance defined by data-driven expectations. (Susarla et al., 2023).

Empirical evidence across educational technology consistently documents elevated stress and anxiety associated with intensified digitalization (Fernández-Batanero et al., 2020). In AI related contexts, this stress can be stronger because such systems are often seen as evaluative and authoritative. Importantly, such stress is rarely reducible to individual skill deficits; rather, it reflects institutional tempo, fragmented professional development, and policy regimes that normalize permanent adaptation.
Spanish research provides a particularly informative European anchor. Rey-Merchán and López-Arquillos (2022) identify ICT-related technostress as a measurable occupational risk among teachers rather than a marginal inconvenience. A regional study in Murcia reports significant associations between technostress, emotional exhaustion, and burnout dimensions (Pagán-Garbín et al., 2024). These findings mark fear within broader stress ecologies in which monitoring expectations, rapid reform, and digital intensification interact.

At the same time, survey evidence suggests an important asymmetry between discourse and practice. Studies among in-service teachers in Spain report generally positive attitudes toward AI alongside limited classroom integration, revealing a persistent gap between policy enthusiasm and institutional readiness (Galindo-Domínguez et al., 2024). This gap constitutes a fertile site for anxiety: educators may feel compelled to adopt tools whose pedagogical value, ethical implications, and operational boundaries remain uncertain.

2.2 Moral Uncertainty, Surveillance, and Pedagogical Autonomy

Beyond workload, fear in AI-driven education is also linked to moral uncertainty. Teachers often feel unsure about how much they should trust or rely on algorithmic recommendations in their everyday practice. A major source of concern is AI-enabled monitoring. Although often presented as a quality or efficiency tool, such monitoring

can make teachers feel constantly observed and evaluated, affecting trust and professional autonomy (Williamson, 2023).

Building on earlier work, Knox et al. (2020) contend that related scholarship on learning analytics and algorithmic education further demonstrates the performative effects of classification and measurement: algorithmic categories do not merely describe educational activity but actively reshape what counts as legitimate performance. Which means that fear emerges not as an ancillary emotion but as a response to perceived shifts in epistemic authority. Educators may fear being judged by metrics they did not design, cannot interpret, or cannot meaningfully contest.

Recent studies show that teachers interpret AI through questions about professional identity and values, not only usefulness. As a result, fear often signals deeper concerns about what should remain a human judgment in education (Zembylas, 2021).Fear thus becomes a signal that the ethical foundations of professional work are being renegotiated, often without sufficient participatory design, institutional dialogue, or safeguards.

2.3 Gendered and Structural Dimensions of AI-Related Fear

Fear related to AI does not affect all educators in the same way. Existing inequalities influence whether technological change is experienced as an opportunity or as a source of pressure. Research on digital inequality has long demonstrated that uneven access, institutional support, and professional confidence produce differentiated burdens during digital transformation (OECD, 2023).

Gender plays a key role in how educators experience AI-related change. Studies suggest that women educators often report lower institutional support and higher emotional pressure during digital transformation (Lynch, 2022; Oshlyansky et al., 2023). Seen through a governance lens, the issue is not simply that gender differences exist, but that AI adoption can quietly reproduce inequalities if uneven impacts are not anticipated.

In practice, these differences may appear as higher anxiety around evaluation, increased emotional labor, or lower confidence in using AI tools. Recognizing fear as an organizational signal rather than an individual weakness is therefore essential for ethical AI governance. More broadly, these patterns highlight the need for governance approaches that recognize and address structural vulnerability in AI adoption.

2.4 From Individual Reaction to Organizational Signal

When fear is treated primarily as an individual psychological reaction, governance responses tend to be limited. Additional training, compliance messaging, or personal coping strategies are offered as solutions. While not without value, such responses obscure the governance insight embedded in affective patterns. If fear consistently clusters around particular tools, phases of implementation, or evaluative practices, it may indicate opacity, legitimacy deficits, or misalignment between algorithmic logics and pedagogical values (Grek & Landri, 2021).

A governance-sensitive interpretation therefore shifts the question itself. Rather than asking how fear can be reduced, it asks what fear reveals about institutional conditions. From this perspective, fear operates as an early warning signal of sociotechnical imbalance; an affective indicator that human, technological, and policy components of reform are out of alignment. Research on educational datafication supports this diagnostic reading by demonstrating how data infrastructures reorganize power relations, accountability mechanisms, and professional identities (Williamson & Eynon, 2020).

This reframing is particularly consequential in AI contexts, where claims of objectivity and efficiency coexist with uncertainty about interpretability, responsibility, and value conflict (Mittelstadt, 2019). When fear is read as organizational information, leaders can move from reactive symptom management toward anticipatory governance: strengthening transparency, enabling contestability, fostering ethical dialogue, and designing implementation processes that treat emotional feedback as institutional intelligence. This conceptual move prepares the ground for the Affective Foresight Model developed in the following sections.

2.5 Contextual Illustration: The Greek Educational System

The governance relevance of fear is particularly evident in reform-intensive education systems, such as the Greek context. Over the past decade, successive reforms have introduced evaluation frameworks and data-driven governance, leading to the institutionalization of teacher and school evaluation under Law 4823/2021 (OECD, 2023).

A substantial body of research documents the emotional consequences of this reform trajectory. Research consistently shows that policy instability in Greece is associated with increased stress, reform fatigue, and sustained socio-emotional strain among teachers (Saiti, 2019).

Within such conditions, the introduction of AI-enabled monitoring or analytics is unlikely to be experienced as a neutral technological upgrade. Instead, it interacts with pre-existing affective climates shaped by accountability pressures, uncertainty, and low institutional trust. In this context, fear functions less as resistance to technology and more as a signal of governance fragility.Taken together, the Greek case illustrates how affective responses acquire diagnostic value during rapid digitalization under institutional strain.

3. From Emotion to Governance: Theoretical Positioning

The central theoretical challenge addressed in this paper concerns how emotional responses to AI can be understood not as peripheral reactions, but as analytically meaningful indicators within educational governance. Much of the existing scholarship on AI in education has approached ethical risk through regulatory frameworks, design principles, and compliance mechanisms, while research on technostress has focused on individual coping and psychological adaptation. Although both strands offer valuable insights, neither fully captures what fear reveals about institutional legitimacy, governance arrangements, and leadership capacity in algorithmically mediated settings.

What is missing, this paper argues, is a conceptual shift: from treating emotion as an outcome of technological change to understanding it as a form of institutional intelligence. Fear does not simply follow reform; it often appears at the point where governance arrangements are experienced as opaque, misaligned, or ethically fragile. Interpreted in this way, affect becomes a lens through which institutional tensions surface before they are articulated through formal resistance, performance decline, or policy failure.

3.1 Limits of Ethics-Only and Policy-Driven Approaches

Ethical governance of AI has become a key focus in education policy, with frameworks stressing fairness, transparency, accountability, and human oversight (Jobin et al., 2019; UNESCO, 2022; OECD, 2024). In Europe, the AI Act reflects this risk-based approach by placing educational AI systems under stricter regulatory requirements (European Commission, 2025). These developments mark a significant step toward responsible innovation.

According to recent research, ethical frameworks often remain abstract and offer limited guidance on how ethical tensions are experienced and negotiated in everyday school practice (Floridi, 2023; Mittelstadt, 2019). In education, this gap is often intensified by accountability pressures, professional cultures, and existing trust relations (Williamson & Eynon, 2020; Grek & Landri, 2021).

Many ethical frameworks pay little attention to emotion, even though research shows that emotions strongly shape how reforms are interpreted and accepted in schools (Kelchtermans, 2005; Zembylas, 2021). When teachers experience anxiety, mistrust, or moral unease in relation to AI systems, these responses function as evaluative judgments about legitimacy, procedural justice, and professional recognition rather than deviations from ethical compliance.

In light of the above, ethics remain essential for AI governance, but without attention to affective responses it cannot capture early signals of misalignment or legitimacy risk.

3.2 Why technostress frameworks are not enough

Another common way of understanding fear in AI-mediated education comes from technostress research. According to this literature, digital technologies—and more recently AI systems—can increase stress, anxiety, and burnout among teachers, especially when automation and monitoring intensify work demands (Tarafdar et al., 2019; Fernández-Batanero et al., 2020; Zheng et al., 2024).

However, technostress research mainly focuses on individual coping and psychological outcomes. As a result, it offers limited insight into why similar technologies produce different emotional responses across institutions, particularly around evaluation and accountability practices.

More importantly, technostress frameworks rarely address issues of legitimacy and fairness. In AI-related contexts, anxiety often reflects ethical and organizational concerns, such as opacity or perceived injustice rather than technical difficulty alone (Williamson, 2023; Jarke & Breiter, 2021).

Evidence from Greece support this view, showing that teacher stress is often linked to policy instability and bureaucratic pressure rather than technology itself (Antoniou et al., 2023; Papazoglou et al., 2020).

Ultimately**,** while technostress research is valuable, it remains incomplete without a framework that links affect to governance, legitimacy, and leadership.

3.3 Emotion as Governance-Relevant Institutional Intelligence

Viewing fear as governance-relevant requires combining insights from organizational justice, sociotechnical systems, and emotional capital.

According to organizational justice research, emotional reactions often reflect perceptions of fairness and legitimacy. In AI-mediated settings, opacity and unequal access to decision rules can make these perceptions fragile, with anxiety signaling justice concerns rather than simple resistance (Colquitt, 2001; Mittelstadt, 2019).

Sociotechnical research shows that emotional discomfort often appears when AI systems clash with professional values and established ways of exercising pedagogical judgment (Orlikowski & Scott, 2015; Decuypere, 2021).

Research on emotional capital highlights the role of leadership in recognizing and working with affective signals. In AI-driven contexts, this capacity shapes whether fear is ignored as disruption or used as a source of governance insight (Reay, 2004).
Notably, these perspectives show that emotion operates at the intersection of technology, governance, and professional legitimacy, providing the basis for the Affective Foresight Model introduced next.

4. The Affective Foresight Model (AFM)

This section introduces the Affective Foresight Model (AFM), which treats emotional responses to AI, such as fear and anxiety, as early signals of governance tension rather than side-effects of reform. Drawing on organizational justice, sociotechnical systems, and emotional capital, the model translates affective signals into governance-relevant foresight.

4.1 Conceptual foundations and core assumptions

The AFM draws on three theoretical traditions. Organizational justice explains how emotions reflect perceptions of fairness and legitimacy, especially in opaque AI-mediated settings (Colquitt, 2001; Mittelstadt, 2019). Sociotechnical research shows that emotional discomfort often emerges when AI systems clash with institutional norms and professional values (Orlikowski & Scott, 2015; Decuypere, 2021). Emotional capital highlights the role of leadership in recognizing and working with these affective signals (Reay, 2004; Day, 2022).

Based on these foundations, the AFM rests on four assumptions: (a) affective responses to AI are socially patterned; (b) emotions express judgments about legitimacy and fairness; (c) affect often appears earlier than formal resistance or performance decline;

and (d) leadership mediation shapes whether fear becomes disruptive or generative for organizational learning (Kelchtermans, 2005; Hargreaves, 2020).

4.2 Key constructs

The AFM includes four interrelated constructs: (1) AI-related technostress and anxiety (Tarafdar et al., 2019; Zheng et al., 2024); (2) moral uncertainty and ethical tension linked to accountability and surveillance (Jarke & Breiter, 2021); (3) perceived loss of autonomy and justice in AI-mediated governance (Colquitt, 2001; Williamson, 2023); and (4) leadership emotional capital and governance capacity (Reay, 2004).

4.3 Process logic: from affective signal to governance insight

The AFM proposes a four-stage process. Stage 1 (signal emergence): AI implementation generates affective signals; anxiety around monitoring, fear of misclassification, moral unease about automated recommendations, and insecurity regarding competence. Stage 2 (institutional filtering): these signals are shaped by organizational conditions, including justice perceptions, trust relations, and institutional culture; where transparency is low and participation constrained, fear intensifies (Williamson, 2023). Stage 3 (leadership interpretation): leaders with developed emotional capital can detect patterns across tools, roles, and reform phases, distinguishing transient adaptation stress from structural governance risk (Hargreaves, 2020). Stage 4 (anticipatory intervention): governance responses follow—redesigning implementation processes, strengthening contestability, revising evaluation criteria, conducting ethical reviews, and creating reflective forums where moral uncertainty can be articulated (UNESCO, 2022; European Commission, 2025). Through this mechanism, fear is treated as institutional intelligence rather than disruption. The logic of the Affective Foresight Model is illustrated in Figure 1.

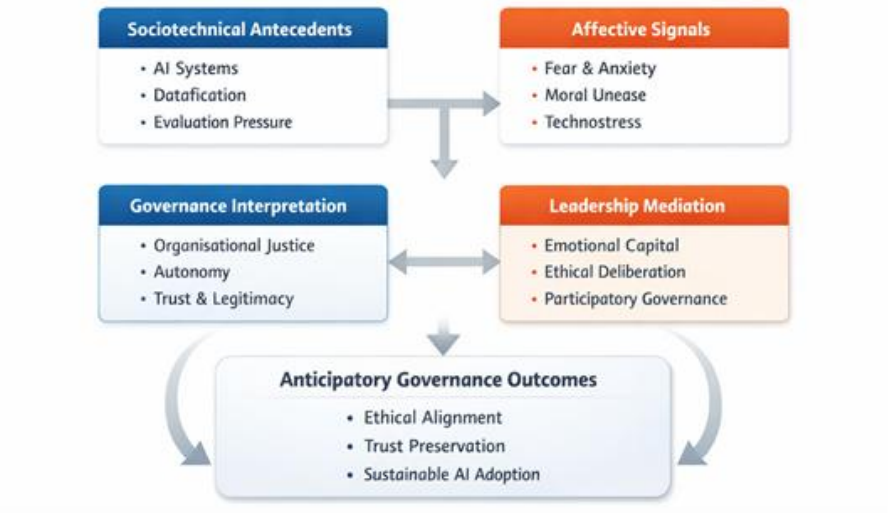


Figure 1: The Affective Foresight Model (AFM).

4.4 Operationalizing the AFM: instruments and empirical pathway

Although conceptual, the AFM can be operationalized through established instruments, supporting empirical validation and practical application. Technostress can be assessed

using the Technostress Creators Scale (Tarafdar et al., 2007, 2019), complemented by emerging measures of AI-related anxiety and adapted computer anxiety instruments (Wang et al., 2024; Zheng et al., 2024). Moral uncertainty and ethical tension can be examined through measures of ethical climate and moral distress, such as the Ethical Climate Questionnaire (Victor & Cullen, 1988) and moral distress instruments (Epstein & Hamric, 2009), supplemented with items targeting perceptions of algorithmic fairness and accountability (Martin, 2019). Perceived loss of autonomy and justice can be captured through the Organizational Justice Scale (Colquitt, 2001) alongside validated teacher autonomy measures used in educational leadership research (Day, 2022). Leadership emotional capital can be approached through emotional intelligence and ethical leadership instruments (Wong & Law, 2002; Boyatzis, 2007; Brown et al., 2005), as well as trust measures relevant to accountability contexts (Hargreaves, 2020).

Greek research supports the feasibility of this operationalization: studies examining teacher stress, emotional labor, and leadership under reform conditions have used validated burnout, organizational climate, and leadership instruments, demonstrating the relevance of affective measurement for governance analysis (Saiti, 2019; Antoniou et al., 2023).

4.5 Theoretical contribution and illustrative governance pathway

The AFM contributes to the literature in three ways. First, it reframes fear from an individual psychological outcome to a governance-relevant signal, integrating affect into AI ethics and educational leadership theory (Holmes et al., 2022; Williamson & Eynon, 2020). Second, it bridges fragmented literatures on technostress, organizational justice, and sociotechnical systems through a unified governance framework (Tarafdar et al., 2019; Colquitt, 2001; Orlikowski & Scott, 2015). Third, it advances an anticipatory model of ethical leadership, positioning emotion as a strategic resource for navigating algorithmic change (Day, 2022; Zembylas, 2021).

In the Greek context, the AFM can be expressed as a four-domain governance pathway: (1) sociotechnical antecedents (opacity, surveillance-linked evaluation, intensified datafication, rapid reform), (2) affective manifestations (autonomy anxiety, moral uncertainty, gendered insecurity, cognitive overload), (3) organizational interpretation (justice-informed analysis of emotional clusters, especially around evaluation), and (4) leadership response (participatory redesign, transparent communication of criteria, ethical deliberation forums, and leadership development in emotional-ethical competence) (OECD, 2023; Saiti, 2019). A pilot application could focus on schools with varying digital maturity (urban, semi-urban, rural), engaging teachers, school leaders, and digital coordinators through cycles of affective signal mapping, ethical-justice review workshops, and leadership response planning informed by affective feedback. An illustrative application of the AFM in the Greek educational context is presented in Figure 2.



Figure 2: Illustrative application pathway of the Affective Foresight Model (AFM) in the Greek educational context.

5. Implications for Ethical School Leadership

The Affective Foresight Model carries significant implications for how ethical school leadership is understood and enacted in AI-driven educational environments. If fear and related affective responses are interpreted as governance-relevant signals rather than individual pathologies, leadership responsibility can no longer be confined to technical compliance, managerial efficiency, or procedural oversight. Instead, ethical leadership becomes inseparable from the interpretation of legitimacy, trust, and the emotional conditions under which reform is experienced and sustained.

From this perspective, leading AI adoption is not merely a technical or regulatory task. It is a relational and interpretive practice, requiring sensitivity to how algorithmic systems are lived, evaluated, and morally negotiated within school communities.

5.1 Affective responsibility as leadership capacity

Ethical leadership in AI-mediated schools requires attention to emotional climates and the recognition of anxiety and moral unease as meaningful institutional signals (Zembylas, 2021).

According to leadership research, emotions strongly shape how reforms are interpreted and whether trust develops within schools (Hargreaves, 2020; Day, 2022). In AI-driven contexts, ignoring these signals can weaken trust and undermine reform legitimacy.

The AFM identifies three aspects of affective responsibility: diagnostic sensitivity (recognizing recurring emotional patterns across tools and roles), ethical interpretation (linking affect to justice, autonomy, and value concerns), and institutional translation (adjusting governance processes and support structures accordingly) (Colquitt, 2001; Goleman, 2018).

Evidence from Greece suggests that emotionally attentive leadership strengthens trust and moderates reform-related tension, highlighting affective responsibility as a core governance competence (Saiti, 2019).

5.2 Governing fear without pathologizing emotion

Fear is often approached in managerial contexts as an individual problem to be corrected. Anxiety is typically framed as a lack of resilience, confidence, or competence, leading to responses such as training, counseling, or performance management. While these measures can be helpful, they remain limited when they overlook the organizational and governance conditions that produce fear in the first place (Martin, 2019).

The Affective Foresight Model offers a different perspective. Instead of treating fear as a personal weakness, it conceptualizes fear as a form of institutional feedback. According to research on ethical climates and professional learning, leadership practices and institutional support structures play a critical role in shaping how educators experience accountability and change (Victor & Cullen, 1988; Passey, 2021; Desimone et al., 2025).When similar anxieties appear across teachers or schools; they often indicate problems in how reforms are designed, communicated, or implemented. In this sense, fear reflects how governance arrangements are experienced in everyday practice rather than individual incapacity (Mittelstadt, 2019).
This interpretation has concrete implications for AI governance in schools. First, transparency matters not only ethically but emotionally. When teachers do not clearly understand how AI systems function, what data are used, or how decisions are made, uncertainty and mistrust tend to increase. Research suggests that clear explanations and open communication can reduce fear by making governance processes more intelligible (Mittelstadt, 2019).

Second, participation is critical. When teachers are excluded from decisions about AI tools that shape their work, fear is more likely to emerge. According to the literature, participatory design and co-implementation processes strengthen perceptions of fairness and voice, making reforms easier to accept and sustain (Holmes et al., 2022; Williamson, 2023).

Finally, studies emphasize the importance of institutional spaces for ethical dialogue around AI. When concerns about surveillance, evaluation, and fairness remain unaddressed, anxiety tends to accumulate. Structured discussion forums allow educators to articulate concerns collectively, reducing the risk that fear escalates into resistance or disengagement (Floridi, 2023; UNESCO, 2022).

Evidence from the Greek educational context supports this view. Low transparency and limited participation during reform implementation are associated with higher emotional strain and reduced trust among teachers (Antoniou et al., 2023). Ultimately, governing fear is less about managing emotions and more about improving the quality and legitimacy of educational governance.

5.3 From reactive compliance to anticipatory ethical leadership

Most current approaches to ethical AI leadership in schools focus on compliance, emphasizing rules, risk management, and technical control (Fullan, 2021). While necessary, these approaches are often reactive, addressing problems only after they become visible rather than helping schools recognize early signs of ethical or organizational tension.

The Affective Foresight Model proposes a different understanding of leadership. It suggests that emotional reactions, such as fear or uncertainty, can function as early signals that AI governance is not working as intended. When such signals are taken seriously, leaders can respond before tensions escalate into conflict, disengagement, or burnout.

From this perspective, ethical leadership is not limited to regulatory compliance. It also involves attention to how reforms are experienced in everyday school life. Emotional responses often reveal concerns about trust, fairness, and professional recognition that have not yet been articulated through formal resistance or complaint (Day, 2022).

According to research on foresight and educational change, complex systems require leaders who can anticipate problems rather than simply manage their consequences (Fullan, 2021). By listening to emotional signals, school leaders can adjust implementation processes, clarify expectations, and create spaces for dialogue before legitimacy is eroded.

This approach is particularly relevant in reform-intensive systems such as Greece, where digital transformation, evaluation reforms, and low institutional trust coexist (Saiti, 2019; OECD, 2023). In such contexts, small signals of fear or unease can quickly escalate if ignored. Treating emotions as early warnings allows leaders to act in time, strengthening trust and supporting more sustainable and ethical AI adoption.

6. Discussion and Conclusion

This paper examined an often-overlooked dimension of AI-driven change in education: the emotional experiences through which teachers make sense of algorithmic reform. These emotional responses often appear early and indicate deeper ethical and organizational tensions.

Three main contributions can be identified. Fear plays a meaningful role in how technological reforms are evaluated. Studies suggest that experiences of technostress, moral uncertainty, surveillance, and reduced autonomy are closely linked to concerns about fairness, legitimacy, and professional integrity (Kelchtermans, 2005; Zembylas, 2021; Mittelstadt, 2019). Rather than being marginal or temporary reactions, these emotional responses often indicate deeper ethical and organizational tensions.

Drawing on organizational justice, sociotechnical research, and emotional capital, the model interprets emotional reactions as sources of governance insight. Approaches that focus only on ethical principles or individual adaptation tend to miss how technology, leadership, and institutional trust interact in practice (Holmes et al., 2022; Williamson & Eynon, 2020; Floridi, 2023). The AFM addresses this gap by placing affect at the centre of these interactions.

Finally, the study highlights a shift in how ethical school leadership can be understood. Governing AI is not limited to compliance, risk management, or technical oversight. It also involves relationships, interpretation, and trust. Leaders' ability to notice, understand, and respond to emotional signals becomes especially important in reform-intensive systems marked by strong accountability pressures and institutional fragility, such as the Greek educational context (Saiti, 2019).

6.1 Limitations and future research

This study is not without limitations. As a conceptual contribution, the AFM does not provide empirical validation of its constructs or mechanisms. Future research should therefore pursue mixed-method and longitudinal designs capable of testing the model's explanatory power across diverse institutional settings. Particular attention should be given to the development of AI-specific affective instruments, the mapping of emotional patterns across reform phases, and the examination of how leadership mediation shapes trajectories of trust, resistance, and legitimacy. Comparative studies across educational systems would further illuminate how governance cultures condition the affective politics of AI adoption (Antoniou et al., 2023; OECD, 2023).

6.2 Concluding reflections

Yet the broader implication of this work extends beyond methodological refinement. The ethical risks of AI in education are not confined to distant futures or speculative harms. They are already present in everyday emotional climates: in hesitation before dashboards, in unease during evaluation meetings, in silent doubts about fairness and judgment. These micro-affective experiences constitute the living interface between algorithmic systems and human institutions.

If ethical AI governance is to become more than a formal architecture of principles and compliance, it must learn to listen to these signals. Emotion, in this sense, becomes not an obstacle to rational governance but one of its most sensitive instruments.

And perhaps this is the final lesson of affective foresight: that the future of AI in education will not first announce itself in codes or policies, but in the quiet fears already felt by those who teach, decide, and lead.

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Does "vibe coding" change the way programming is taught?

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Abstract—Vibe coding is emerging as a new paradigm in software development and programming education. Rather than focusing on manual code writing, it emphasizes computational thinking, digital project design, and strategic guidance through natural language interaction with artificial intelligence. Students articulate their ideas and goals, while AI generates and refines software solutions in real time.

Within this approach, students become architects of ideas and managers of digital projects, while AI functions as an active collaborator. The reduction of syntactic demands enables learners to concentrate on problem decomposition, abstraction, and iterative improvement, thereby fostering creativity and exploratory learning. A core competence in vibe coding is effective communication with AI through clear and structured prompts, which supports faster prototyping and improved learning outcomes.

However, vibe coding also raises pedagogical and ethical challenges. Excessive dependence on AI may weaken student autonomy and critical thinking. Consequently, AI should operate as a supportive tool rather than a substitute for human reasoning. Integrating vibe coding into curricula requires strategic planning, teacher training, and an emphasis on responsible and reflective use of AI.

Overall, vibe coding has the potential to transform programming education by making it more participatory, creative, and accessible, while strengthening students' strategic thinking and ethical awareness.

Keywords —Vibe coding, AI, teaching, programming, computational thinking

Introduction

The rapid advancement of Artificial Intelligence (AI) is reshaping software development and transforming the way programming is taught and learned. Traditionally, programming education has focused on mastering syntax, understanding programming languages, and correcting errors. Although these skills remain important, AI-driven environments introduce a new educational paradigm in which natural language becomes the primary medium for creating software.

Within this context, vibe coding emerges as a novel pedagogical and technological approach. Instead of writing code line by line, learners describe what they aim to build and guide AI systems through iterative dialogue. This shift moves the emphasis from syntactic accuracy to higher-order cognitive processes such as problem analysis, abstraction, design, and evaluation of solutions. Programming is no longer limited to technical execution but becomes a process of strategic thinking and creative problem solving.

The emergence of vibe coding is closely associated with advances in large language models, which transform programming from a syntax-driven activity into a dialogic human–AI interaction based on natural language and iterative guidance.

In vibe coding environments, students adopt new roles. They are no longer merely code writers but become architects of ideas and managers of digital projects. Artificial Intelligence acts as an active collaborator that proposes solutions, assists in debugging, and supports refinement. Recent empirical research provides support for this reconceptualization of programming practice. Sarkar and Drosos (2025) describe vibe coding as an iterative workflow in which developers alternate between goal formulation, AI prompting, rapid code evaluation, testing, and selective manual intervention. Their findings indicate that programming expertise is not eliminated but redistributed toward context management, critical assessment of generated code, and strategic decision-making about when to rely on AI and when to intervene manually. This perspective reinforces the view of vibe coding as a collaborative human–AI practice rather than an automated replacement of programming activity. Such two-way interaction encourages experimentation, autonomy, and exploratory learning, while lowering the entry barrier for students with limited programming experience.

Recent educational applications of vibe coding further demonstrate its pedagogical potential. Ng and Chow (2025) show that AI-assisted vibe coding enables educators without extensive programming backgrounds to design interactive educational applications aligned with specific learning objectives. Their study highlights that natural language interaction with AI can significantly reduce technical barriers to software creation while preserving pedagogical intent. These findings support the argument that vibe coding does not merely automate programming tasks but repositions AI as a design partner in educational innovation.

A central element of this approach is the development of effective communication with AI systems. Students must learn to construct clear, structured, and purposeful prompts in order to guide software creation. Prompt design becomes a cognitive activity that requires planning, precision, and reflection. Through this process, learners strengthen

metacognitive skills and gain greater awareness of how problems are represented and solved.

Despite its advantages, vibe coding introduces important pedagogical and ethical concerns. Over-reliance on AI may reduce opportunities for developing foundational skills and may encourage uncritical acceptance of generated solutions. Learners must therefore be trained to evaluate AI outputs, verify correctness, and reflect on their decisions. Ethical dimensions such as privacy, fairness, and responsible use of technology also become central components of programming education.

The purpose of this paper is to examine vibe coding as a new paradigm in programming education. It explores its educational value, the skills it promotes, the challenges it raises, and its implications for curriculum design and teaching practices. By adopting a pedagogical perspective, this study seeks to demonstrate how AI can support learning without replacing human reasoning and creativity.

Vibe Coding in Educational Practice: Pedagogical Perspectives

Differentiated Meanings of Vibe Coding Across User Groups

Recent educational discourse suggests that vibe coding cannot be conceptualized as a uniform practice across all user populations. Its effectiveness and pedagogical relevance depend strongly on learners' prior knowledge and levels of expertise.

For professional developers, vibe coding primarily functions as a strategy for rapid prototyping and exploratory development. Practitioners rely on generative AI systems to produce and debug code through natural language prompts, often reinserting error messages into the system to iteratively refine outputs. Their technical competence enables them to assess the quality, correctness, and appropriateness of AI-generated solutions.

In contrast, novice learners lack the conceptual and procedural foundations necessary to critically evaluate or repair AI-generated code. Consequently, they cannot engage in vibe coding in the same manner as professionals, since the practice presupposes the ability to interpret program logic and validate outcomes. This discrepancy reveals a fundamental pedagogical tension: vibe coding requires forms of expertise that many learners have not yet developed.

This distinction between expert and novice users is further supported by empirical evidence. Sarkar and Drosos (2025) show that experienced programmers engage in rapid scanning and high-level evaluation of AI-generated code rather than line-by-line inspection. Trust in AI outputs is developed dynamically through testing and verification rather than through unconditional acceptance. Such practices presuppose a level of technical literacy that novice learners often lack, thereby reinforcing the pedagogical tension between professional and educational uses of vibe coding.

Student Groups and the Emergence of a Digital Divide

The integration of AI into programming education exposes an emerging digital divide among students. Two broad learner groups can be distinguished.

The first group comprises students with high levels of digital and programming literacy. These learners can interpret AI-generated code, formulate effective prompts, and detect logical or syntactic errors. For this group, AI functions as a productivity-enhancing tool that supports higher achievement and engagement with more complex problem-solving tasks.

The second group consists of students with limited programming literacy. For these learners, AI tools often amplify confusion and frustration rather than facilitate learning. Difficulties in prompt construction and error diagnosis lead to the accumulation of misconceptions, including misunderstandings of indexing, loops, or conditional structures. As a result, rather than serving as an equalizing resource, AI risks reinforcing pre-existing educational inequalities when introduced without structured pedagogical mediation.

Empirical evidence from educational settings indicates that vibe coding supports rapid prototyping and creative exploration but also reveals significant variability in code quality and learner understanding (Gama et al., 2025). Their study of novice programmers shows that effective learning depends on structured guidance in prompt formulation and critical evaluation of AI-generated solutions, reinforcing the need for pedagogical scaffolding in AI-assisted programming environments.

This divergence underscores the necessity of scaffolding and instructional guidance to ensure that AI contributes to inclusion rather than exclusion.

Pedagogical Strategies for Responsible Integration

To mitigate these challenges, several pedagogical strategies have been proposed for the responsible integration of vibe coding into programming instruction.

One strategy involves the delayed introduction of AI tools until students have acquired fundamental programming concepts. This approach ensures that learners can distinguish between code, the integrated development environment, and the AI system itself, enabling more critical engagement with AI-generated outputs.

Ng and Chow (2025) emphasize that successful implementation of vibe coding must be guided by pedagogical priorities rather than technological novelty. They argue that educators should begin by identifying learning challenges and objectives before engaging in tool development, encapsulated in the principle of asking “How can I teach this better?” instead of “Can I build this?”. Their findings demonstrate that when each feature of an AI-generated application is explicitly mapped to a learning objective, the resulting tools are more coherent, effective, and educationally meaningful. This approach aligns with the need to ensure that vibe coding supports learning goals rather than becoming an end in itself.

Another strategy conceptualizes AI as a “shoulder buddy”, a peer-like assistant that offers limited support with syntax or logic before students consult their teacher. This framing positions AI as a supplementary learning resource rather than an authoritative problem solver, thereby preserving learner agency and responsibility.

Additionally, the concept of "slow AI" introduces intentional friction into the learning process. By reducing automation and encouraging stepwise interaction with generated code, students are required to reflect on solutions rather than accept them passively. Such friction promotes cognitive engagement, metacognitive awareness, and deeper conceptual understanding.

Metacognition, Self-Regulation, and Ethical Tensions

A central challenge in AI-supported programming education concerns learners' capacity for self-regulation and ethical judgment. Students experience tension between using AI to obtain rapid solutions and investing effort in understanding underlying principles. This dilemma reflects broader concerns regarding superficial learning and dependency on automated systems.

AI has been metaphorically described as "junk food" or "chocolate": immediately gratifying but potentially detrimental if consumed without moderation. These metaphors underscore the importance of cultivating reflective decision-making and metacognitive awareness. Students must learn not only how to use AI tools but also when and why to use them.

While vibe coding lowers technical barriers and broadens participation in programming, concerns persist regarding the reliability of AI-generated code and the risk of over-reliance, which may undermine the development of foundational computational skills and critical judgment.

Sarkar and Drosos (2025) further conceptualize vibe coding as an early manifestation of what they term material disengagement, whereby practitioners orchestrate software creation through AI while maintaining selective oversight of the generated code. This mode of interaction requires continuous calibration of trust and deliberate verification practices. From an educational perspective, this finding underscores the necessity of cultivating metacognitive awareness and ethical responsibility, ensuring that learners remain cognitively engaged and do not relinquish control over the problem-solving process to automated systems.

Ethical considerations further complicate this landscape. Learners must evaluate the reliability of AI outputs, question their validity, and apply principles of responsibility, fairness, and transparency. These competencies are essential for the formation of critical and informed digital citizens.

Implications for Assessment and Skill Development

The integration of vibe coding necessitates a re-examination of assessment practices. While AI-assisted learners often perform well in conventional examinations, evidence suggests that open-ended and creative project-based tasks reduce performance gaps between experienced and inexperienced students. Such assessments emphasize design, reasoning, and evaluation rather than mere code production.

Within this framework, essential skills are redefined. Code reading becomes as important as code writing. AI literacy, prompt engineering, and critical evaluation of automated outputs emerge as core competencies alongside computational thinking.

Programming education thus shifts from technical execution toward higher-order cognitive and metacognitive development.

The shift from code production to code evaluation aligns with empirical observations that vibe coding privileges higher-level reasoning over syntactic manipulation. According to Sarkar and Drosos (2025), programmers increasingly engage in contextual judgment, error diagnosis, and iterative refinement rather than direct authorship of code. These findings support the argument that educational objectives should emphasize critical reading of code, evaluation of AI-generated solutions, and reflective prompt construction as core competencies in contemporary programming education.

The work of Ng and Chow (2025) further illustrates that vibe coding promotes a shift from technical execution to design-oriented reasoning. Educators translate learning objectives into interactive tools through structured prompting and iterative refinement, thereby modeling higher-order cognitive processes for learners. This supports the view that programming education should prioritize skills such as critical evaluation, reflective design, and alignment between problem formulation and solution strategies.

Educational Positioning of Artificial Intelligence

Educational discourse increasingly converges on the view that Artificial Intelligence should function as a springboard rather than a crutch. Educators are encouraged to resist technological determinism and preserve learning opportunities that do not rely exclusively on digital tools. Moreover, involving students in the co-construction of classroom guidelines for ethical AI use fosters ownership, autonomy, and reflective engagement.

Practical experiences with AI-assisted vibe coding further highlight the importance of ethical responsibility and reflective practice. Ng and Chow (2025) report that the development and deployment of educational applications require careful attention to data privacy, transparency, and continuous evaluation of pedagogical effectiveness. They stress that poorly designed or insufficiently tested tools may lead to unintended learning consequences. These observations reinforce the argument that Artificial Intelligence should function as a supportive educational resource rather than an autonomous authority and that educators must remain actively involved in guiding and evaluating AI-generated learning environments.

Such an approach situates AI within a broader pedagogical framework that prioritizes human reasoning, creativity, and ethical responsibility.

Conclusion

Vibe coding represents a significant shift in programming education, moving the focus from syntactic mastery to conceptual understanding, strategic design, and collaboration with Artificial Intelligence. By enabling students to express ideas in natural language and refine solutions through dialogue with AI, this approach supports creativity, experimentation, and computational thinking.

The transformation of students into architects of ideas and managers of digital projects highlights a new educational role in which problem formulation, evaluation, and ethical reflection become central learning objectives. Effective communication with AI through structured prompts emerges as a critical skill that connects technical competence with higher-order cognitive processes.

At the same time, responsible integration of vibe coding is essential. Artificial Intelligence must function as a supportive partner rather than a substitute for human reasoning. Without careful pedagogical guidance, there is a risk of reduced autonomy, superficial understanding, and dependence on automated solutions. Therefore, curriculum design should emphasize critical thinking, self-regulation, and ethical awareness alongside technical innovation.

The integration of vibe coding into educational contexts therefore requires curricular adaptation and systematic teacher preparation, with an emphasis on metacognitive regulation, ethical responsibility, and the critical evaluation of AI-supported solutions.

Empirical evidence further confirms that vibe coding does not diminish the importance of human expertise but transforms its nature. Studies of real-world practice indicate that successful vibe coding depends on continuous evaluation, trust calibration, and strategic human intervention (Sarkar & Drosos, 2025). These findings strengthen the argument that programming education must evolve toward fostering critical judgment, metacognitive awareness, and ethical responsibility rather than focusing exclusively on syntactic proficiency.

Overall, vibe coding has the potential to transform programming education into a more participatory, creative, and accessible learning experience. When implemented through strategic planning and reflective teaching practices, it can prepare students for a future in which human intelligence and artificial intelligence coexist as collaborative agents in digital creation and problem solving.

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Artificial Intelligence-Enhanced Literature Teaching: A Didactic Intervention Based on C. P. Cavafy's "Ithaca"

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Abstract—This paper presents a fully developed, AI-enhanced teaching scenario for upper secondary literature education centered on the poem "Ithaca". The instructional design combines close reading, comparative interpretation, collaborative inquiry, and multimodal creative production supported by AI tools. The aim is to connect poetic meaning with students' lived experience while cultivating critical, digital, and multimodal literacies. The scenario is structured as a two-hour intervention implemented in a computer lab and based on a flipped classroom model. Students engage with the poem and three "Cavafyesque" texts prior to class and then participate in a sequence of guided in-class activities including audiovisual stimulus, word-cloud elicitation, expressive listening, personal response writing, comparative thematic and stylistic analysis, AI-based visualization, AI-assisted music generation, and reflective self-assessment.

AI tools are positioned as creative and analytical instruments rather than answer engines, and all generated outputs must be interpretively justified by learners. The teacher acts as facilitator and coordinator, supporting dialogue, collaboration, and critical reflection. The design also incorporates comparison between human-authored and AI-generated literary texts in order to strengthen students' awareness of style, authorship, and textual quality. The paper details the pedagogical framework, learning objectives, instructional phases, assessment strategy, and classroom management model. It argues that AI-supported multimodal pedagogy can deepen poetry engagement when grounded in interpretive practice, collaborative meaning-making, and reflective evaluation.

Keywords— AI in education, literature teaching, C.P. Cavafy, multimodal learning, collaborative learning

Introduction

Artificial intelligence has rapidly entered educational practice and has begun to reshape discussions about literacy, authorship, and interpretation. In humanities education the challenge is not simply technological integration but pedagogical alignment. Literature teaching in particular faces a dual challenge: maintaining interpretive depth and aesthetic engagement while incorporating emerging digital practices that shape contemporary literacy. Poetry instruction often faces motivational barriers among students who perceive poetic texts as obscure, distant, or overly abstract. At the same time, poetry offers unique affordances for reflective thinking, symbolic interpretation, and personal meaning-making and can benefit especially from pedagogical approaches that connect textual interpretation with experiential, creative, and multimodal processes.

This paper proposes that AI-supported multimodal pedagogy can serve as a bridge between canonical poetic texts and contemporary learner practices when implemented within a structured interpretive framework. The study presents a detailed teaching scenario designed for upper secondary education that combines collaborative inquiry, guided interpretation, and creative AI-supported production. The purpose is not to automate literary analysis but to extend interpretive engagement through multimodal transformation tasks. The scenario treats AI systems as cognitive and creative partners whose outputs must be evaluated, selected, and justified. In this way, technological novelty is subordinated to interpretive depth and pedagogical coherence. The scenario also introduces a comparative dimension involving AI-generated literary text, prompting students to examine whether stylistic imitation constitutes poetry and how authorial voice is perceived. In doing so, it supports both literary understanding and AI literacy.

Learning Objectives and Expected Outcomes

The learning objectives are distributed across knowledge, skills, and attitudes. At the *knowledge level*, students identify thematic and stylistic characteristics of the poem, including symbolic journey structure, second-person address, and philosophical tone. They recognize how metaphor and narrative voice shape interpretive meaning. Through comparative reading, they examine how later or parallel texts transform a canonical model. Students are also introduced to the concept of AI-generated literary text and reflect on similarities and differences between human and machine-produced writing.

At the *skills level*, students practice comparative textual analysis, collaborative reasoning, multimodal representation, and prompt design for generative systems. They learn to evaluate whether a generated image or musical output corresponds interpretively to a textual passage. Digital skills include collaborative document creation, interactive polling participation, shared board posting, and AI tool use for creative production.

At the *attitudinal level*, students articulate personal responses to poetry, connect literary themes with lived experience, and develop a reflective stance toward AI-generated cultural artifacts. A further objective is the cultivation of critical AI literacy, defined as the ability to question, evaluate, and contextualize machine-generated outputs.

Theoretical Background

Literature Teaching and Reader Engagement
Modern approaches to literature pedagogy emphasise active student involvement, personal response, and experiential meaning-making. (Rosenblatt 1978, Iser, 1980) Literary texts are not treated merely as objects of formal analysis but as cultural artefacts that invite dialogue with readers' identities and experiences. (Benton etc. 1988). Cavafy's *"Ithaca"* is particularly suited for such pedagogical engagement due to its universal themes of journey, self-knowledge, and existential reflection.

Digital Literacy and Multiliteracies
The concept of literacy has expanded beyond traditional print-based skills to include multimodal forms of communication, digital competence, and critical media awareness. The multiliteracies framework highlights the importance of engaging learners in diverse semiotic modes, such as visual, auditory, and digital forms of meaning-making. (Cope etc. 2000) Incorporating ICT tools into literature teaching supports participatory learning and motivates students through creative digital production.

Artificial Intelligence in Education
Recent scholarship has examined the opportunities and risks associated with AI in educational settings. AI language models, such as ChatGPT, introduce new possibilities for text generation, dialogue, and creative experimentation, while simultaneously raising concerns about authenticity, critical thinking, and ethical use (Gavriilidou, 2024). The present intervention positions AI not as a replacement for human interpretation but as a pedagogical catalyst for reflection on the boundaries of literary creation.

Digital tools in the scenario function as environments for literacy practice rather than simple presentation media. Interactive polling tools are used to aggregate interpretive impressions and visualize collective responses. Collaborative boards support short written reflections and peer visibility. Shared slide environments enable co-construction of multimodal interpretive artifacts. AI image and music generators are used for transformation tasks in which students convert textual interpretation into visual and auditory form. Crucially, each AI-supported production task includes a justification requirement. Students must explain how stylistic choices, prompt parameters, and output selection correspond to their reading of the poem. This constraint ensures that AI use remains anchored in interpretation rather than novelty.

Instructional Context and Design Principles

The scenario is designed for first-year upper secondary students and implemented in a computer laboratory over two teaching hours. It is aligned with curriculum themes concerning values, choices, and life journeys. The instructional model follows a flipped classroom approach in which students complete preparatory reading before class. (Bergmann etc. 2012) Pre-class preparation includes reading the core poem and three thematically related texts as well as attempting an initial informal comparison. This structure allows classroom time to focus on higher-order interpretive, comparative, and creative tasks rather than first exposure. The design draws on inquiry-based learning (Edelson etc. 1999), collaborative group work, guided dialogic interpretation, and multimodal composition. Students are organized into heterogeneous groups with

rotating roles such as coordinator, recorder, digital operator, and presenter in order to ensure balanced participation and accountability. (Matsagouras 2000) The teacher's role is primarily facilitative and supervisory, including technical support, interpretive prompting, and dialogic moderation.

Digital Technologies

The instructional design incorporated a range of digital technologies aimed at fostering interaction, creativity, and formative assessment. An interactive whiteboard and four computers served as the core infrastructure, supporting multimodal presentation, real-time annotation, and collaborative engagement during classroom activities.

Mentimeter was employed as an audience response system to facilitate live polling, instant feedback, and student participation, thereby promoting active learning and reflection. Padlet functioned as a collaborative digital workspace where learners could share ideas, texts, and multimedia artifacts, encouraging peer interaction and collective knowledge construction. (Aslam etc. 2024)

Leonardo.ai was utilized as an AI-supported visual creation tool, enabling students to explore imaginative representations and enhance digital literacy through guided experimentation. (Kress etc. 2020) Google Slides supported structured presentation and co-creation of content, allowing learners to organize and communicate their work effectively.

Aisonggenerator.ai was introduced as a creative AI environment for generating music-based outputs, enriching multimodal expression and fostering engagement through artistic experimentation. Finally, Google Forms was used for formative assessment and data collection, providing immediate feedback and supporting reflective learning practices.

Teaching Sequence and Activity Flow

The instructional sequence unfolds in six structured phases.

The *first phase* (Pre-reading activities) activates prior conceptions through a short film excerpt ("Dead Poets Society") depicting the social and existential function of poetry. Students collaboratively produce a word cloud through Mentimeter, identifying key associations with poetic discourse.

The *second phase* (During Reading: Interpretive Response) includes students' listening to an expressive recitation of *"Ithaca"* and posting personal reflections on Padlet, focusing on emotions, thoughts, and connections to their own experiences. This stage encouraged an initial interpretive encounter grounded in reader-response pedagogy.

The *third phase* (During Reading: Comparative Literary Inquiry) involves collaborative comparative analysis between "Ithaca" and three "Cavafyesque" texts (*"Ithaca II"* by Koukoulas, *"Ithaca III"* by Brodsky and *"Thessaloniki"* generated by ChatGPT) with groups identifying thematic parallels, stylistic features, and possible AI authorship. All group responses are posted on Padlet.

The *fourth phase* (Post-reading activities) consists of multimodal production tasks: two groups create AI-generated visualizations of selected stanzas and post them on collaborative GoogleSlides, while two groups create AI-assisted musical settings. All groups publish outputs on Padlet and short rationales. These activities promoted creativity, digital literacy, and deeper engagement with poetic meaning.

The *fifth phase* (Closing Reflection) introduces a contemporary application context through a short video of a high-risk exploratory moment accompanied by poetic recitation, prompting interpretive transfer. In particular, an astronaut recites verses of *"Ithaca"* in English before launch, highlighting the poem's global resonance, therefore prompting students' reflection on the timeless relevance of Cavafy's work.

The *sixth phase* implements structured reflection and self-assessment.

Assessment and Reflective Evaluation

Assessment is primarily formative and process-oriented. Evidence includes individual written responses, group comparative analyses, multimodal artifacts, and justification statements. Peer feedback through Padlet comments and whole-class dialogue functions as dialogic assessment. A structured self-assessment on Google Form measures perceived participation, engagement, and interpretive understanding. A short reflective protocol (3-2-1 technique) invites learners to identify key learning gains and memorable textual elements. This layered model supports metacognition and learner agency.

Preliminary findings indicate that: student motivation increased significantly due to gamified and participatory practices, multimodal AI activities fostered multiliteracies and digital competence, discussions on AI-generated poetry enhanced critical thinking regarding authorship and creativity

Pedagogical Implications – Limitations – Future Directions

The scenario illustrates that AI can be productively integrated into literature teaching when framed by interpretive accountability and collaborative inquiry (Georgopoulou etc. 2024). Multimodal transformation tasks increase engagement while preserving textual centrality. Comparing human and AI-generated literary texts strengthens stylistic awareness and critical judgment. The teacher's facilitative role remains essential in orchestrating dialogue and maintaining interpretive focus. Such designs suggest a pathway for humanities pedagogy that neither rejects nor uncritically adopts AI technologies.

Implementation requires reliable technical infrastructure and sufficient time for group production and discussion. AI outputs may vary in quality and require selective judgment. Future iterations may extend duration, incorporate analytic rubrics for multimodal artifacts, and include longitudinal measurement of interpretive skill development.

Conclusion

Preliminary findings indicate that the intervention supported the development of digital literacy and multiliteracies, increased student motivation through gamified and

participatory practices, and encouraged deeper critical discussion regarding authorship, creativity, and the pedagogical implications of AI in humanities education.

AI-enhanced multimodal pedagogy can deepen poetry engagement when embedded in structured interpretive practice and reflective collaboration. When students justify and evaluate AI-supported outputs, technology becomes a medium of inquiry rather than substitution. The presented scenario demonstrates a balanced, replicable model for AI-supported literature teaching at the secondary level.

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Appendix A — Worksheets

Worksheet — Group 1

1. BEFORE READING — Group Activity

After watching the film excerpt, write which spaces and which activities poetry is associated with in the scene.
Submit short answers (1–2 words) so that a word cloud can be generated.
Group response on Mentimeter

2. DURING READING — Individual Activity

Describe your thoughts and feelings after listening to the poem.
Connect the poem's ideas with your own experiences.
Answer the question: What is poetry for me?
Individual post on Padlet

3. COMPARISON TASK – Group Activity

Compare the three related texts ("Ithaca II", "Ithaca III", "Thessaloniki") with Cavafy's "Ithaca" in theme, message, and style.
Select your preferred text and justify your choice.
Indicate which text may be AI-generated and explain why.
Group post on Padlet

4. AI VISUALIZATION TASK – Group Activity

Create three images representing assigned stanzas of Cavafy's "Ithaca"
Use detailed prompts.
Insert images and matching lines into the shared slides (Google Slides).
Check stylistic consistency with the partner group.

Group post on Padlet

5. FINAL TASK – Group Activity

Discuss the possible reasons an astronaut might recite verses from Cavafy's *"Ithaca"* prior to launch.
Group post on Padlet

6. SELF-ASSESSMENT – Individual Activity

Complete a) the questionnaire provided via Google Forms form
and b) the 3-2-1 reflection (Individual post on Padlet).

Worksheet — Group 2

1. BEFORE READING — Group Activity

After watching the film excerpt, write which spaces and which activities poetry is associated with in the scene.
Submit short answers (1–2 words) so that a word cloud can be generated.
Group response on Mentimeter

2. DURING READING — Individual Activity

Describe your thoughts and feelings after listening to the poem.
Connect the poem's ideas with your own experiences.
Answer the question: What is poetry for me?
Individual post on Padlet

3. COMPARISON TASK – Group Activity

Compare the three related texts ("Ithaca II", "Ithaca III", "Thessaloniki") with Cavafy's "Ithaca" in theme, message, and style.
Select your preferred text and justify your choice.
Indicate which text may be AI-generated and explain why.
Group post on Padlet

4. AI VISUALIZATION TASK – Group Activity

Create three images representing assigned stanzas of Cavafy's "Ithaca"
Use detailed prompts.
Insert images and matching lines into the shared slides (Google Slides).
Check stylistic consistency with the partner group.
Group post on Padlet

5. FINAL TASK – Group Activity

Discuss the possible reasons an astronaut might recite verses from Cavafy's *"Ithaca"* prior to launch.
Group post on Padlet

6. SELF-ASSESSMENT — Individual Activity

Complete a) the questionnaire provided via Google Forms form
and b) the 3-2-1 reflection (Individual post on Padlet).

Worksheet — Group 3

1. BEFORE READING — Group Activity

After watching the film excerpt, write which spaces and which activities poetry is associated with in the scene.
Submit short answers (1–2 words) so that a word cloud can be generated.
Group response on Mentimeter

2. DURING READING — Individual Activity

Describe your thoughts and feelings after listening to the poem.
Connect the poem's ideas with your own experiences.
Answer the question: What is poetry for me?
Individual post on Padlet

3. COMPARISON TASK – Group Activity

Compare the three related texts ("Ithaca II", "Ithaca III", "Thessaloniki") with Cavafy's "Ithaca" in theme, message, and style.
Select your preferred text and justify your choice.
Indicate which text may be AI-generated and explain why.
Group post on Padlet

4. AI MUSIC SETTING TASK – Group Activity

Create a musical version of Cavafy's "Ithaca" using an AI generator.
Choose genre, mood, voice, and tempo.
Upload and justify choices.
Group post on Padlet

5. FINAL TASK – Group Activity

Discuss the possible reasons an astronaut might recite verses from Cavafy's *"Ithaca"* prior to launch.

Group post on Padlet

6. SELF-ASSESSMENT — Individual Activity

Complete a) the questionnaire provided via Google Forms form
and b) the 3-2-1 reflection (Individual post on Padlet).-

Worksheet — Group 4

1. BEFORE READING — Group Activity

After watching the film excerpt, write which spaces and which activities poetry is associated with in the scene.
Submit short answers (1–2 words) so that a word cloud can be generated.
Group response on Mentimeter

2. DURING READING — Individual Activity

Describe your thoughts and feelings after listening to the poem.
Connect the poem's ideas with your own experiences.
Answer the question: What is poetry for me?
Individual post on Padlet

3. COMPARISON TASK – Group Activity

Compare the three related texts ("Ithaca II", "Ithaca III", "Thessaloniki") with Cavafy's "Ithaca" in theme, message, and style.

Select your preferred text and justify your choice.
Indicate which text may be AI-generated and explain why.
Group post on Padlet

4. AI MUSIC SETTING TASK – Group Activity

Create a musical version of Cavafy's "Ithaca" using an AI generator.
Choose genre, mood, voice, and tempo.
Upload and justify choices.
Group post on Padlet

5. FINAL TASK – Group Activity

Discuss the possible reasons an astronaut might recite verses from Cavafy's *"Ithaca"* prior to launch.
Group post on Padlet

6. SELF-ASSESSMENT — Individual Activity

Complete a) the questionnaire provided via Google Forms form
and b) the 3-2-1 reflection (Individual post on Padlet).

Appendix B — Text Summaries

Cavafy's "Ithaca": Journey as metaphor for lifelong learning and inner growth.
Koukoula's "Ithaca" (Ithaca II): Return marked by nostalgia and loss of adventure.
Brodski's "Ithaca" (Ithaca III): Return marked by alienation and disillusionment.
ChatGPT Generated "Thessaloniki": City as mirror of self-knowledge.

C. P. Cavafy "Ithaca" (1911)

Σα βγεις στον πηγαιμό για την Ιθάκη,
να εύχεσαι να 'ναι μακρύς ο δρόμος,
γεμάτος περιπέτειες, γεμάτος γνώσεις.
Τους Λαιστρυγόνας και τους Κύκλωπας,
τον θυμωμένο Ποσειδώνα μη φοβάσαι,
τέτοια στον δρόμο σου ποτέ σου δεν θα βρεις,
αν μέν' η σκέψις σου υψηλή, αν εκλεκτή
συγκίνησις το πνεύμα και το σώμα σου αγγίζει.
Τους Λαιστρυγόνας και τους Κύκλωπας,
τον άγριο Ποσειδώνα δεν θα συναντήσεις,
αν δεν τους κουβανείς μες στην ψυχή σου,
αν η ψυχή σου δεν τους στήνει εμπρός σου.

Να εύχεσαι να 'ναι μακρύς ο δρόμος.
Πολλά τα καλοκαιρινά πρωιά να είναι
που με τί ευχαρίστηση, με τί χαρά
θα μπαίνεις σε λιμένας πρωτοϊδωμένους·
να σταματήσεις σ' εμπορεία Φοινικικά,
και τες καλές πραγμάτειες ν' αποκτήσεις,
σεντέφια και κοράλλια, κεχριμπάρια κι έβενους,
και ηδονικά μυρωδικά κάθε λογής,
όσο μπορείς πιο άφθονα ηδονικά μυρωδικά·

σε πόλεις αιγυπτιακές πολλές να πας,
να μάθεις και να μάθεις απ’ τους σπουδασμένους.

Πάντα στον νου σου να ’χεις την Ιθάκη.
Το φθάσιμον εκεί είν’ ο προορισμός σου.
Αλλά μη βιάζεις το ταξίδι διόλου.
Καλύτερα χρόνια πολλά να διαρκέσει·
και γέρος πια ν’ αράξεις στο νησί,
πλούσιος με όσα κέρδισες στον δρόμο,
μη προσδοκώντας πλούτη να σε δώσει η Ιθάκη.

Η Ιθάκη σ’ έδωσε τ’ ωραίο ταξίδι.
Χωρίς αυτήν δεν θα ’βγαινες στον δρόμο.
Άλλα δεν έχει να σε δώσει πια.

Κι αν πτωχική την βρεις, η Ιθάκη δεν σε γέλασε.
Έτσι σοφός που έγινες, με τόση πείρα,
ήδη θα το κατάλαβες η Ιθάκες τί σημαίνουν.

2. L. Koukoulas “Ithaca” (Ithaca” II)

Μα τώρα στην Ιθάκη που γυρίσαμε
Συχνά τα περασμένα ανιστορώντας,
Την αγωνία τους νιώθουμε γλυκύτερη
Απ της οκνής ζωής μας τη γαλήνη.
……
Κι αχ, γίνεται απροσμέτρητος ο πόνος μας
Πικρός μετανιωμός σα μας παιδεύει
Που δε φυσάνε πια οι καιροί στα ξάρτια μας
Και τέλειωσε για πάντα το ταξίδι.

3. I. Brodski “Ithaca” (Ithaca III)

Να γυρίζεις εδώ μετά από είκοσι χρόνια
και ξυπόλυτος νά 'βρεις στην άμμο τα χνάρια σου.
Ν' αντηχήσει η ακτή απ' του γέρικου σκύλου σου
όχι τη χαρωπή μα την άγρια κραυγή.
Πέτα, αν θες, από πάνω σου τα ιδρωμένα κουρέλια,
η γρια δούλα δεν ζει για να δει το σημάδι σου.
Η γυναίκα που λεν πως εσένα περίμενε
πήγε με όλους και δεν θα τη βρεις.
Το παιδί σου που μεγάλωσε (ναύτης τώρα έχει γίνει)
παγερά σε κοιτάζει σαν νά 'σαι σκουπίδι.
Και τη βάρβαρη γλώσσα που ματώνει τ' αυτιά σου
μοιάζει μάταιο να θέλεις να την αισθανθείς.
Το νησί μου ή δεν είναι το ίδιο ή τα μάτια σου
πλημμύρισαν για πάντα με το χρώμα της θάλασσας:
και το κύμα που σπάει δεν ξεχνά τον ορίζοντα
στη μικρή τούτη κώχη της γης.
(μτφ. Πάτροκλος Γιατράς)

4. ChatGPT generated text “Thessaloniki”

Σαν φτάσεις κάποτε στη Θεσσαλονίκη,
να μην προσμένεις λάμψη και μεγαλεία.
Μια πόλη είναι, γεμάτη με σκιές,
με μύθους που δεν θέλησαν να φύγουν,
με θρύλους που σταθήκαν στην ομίχλη.
Στους πύργους της και στις παλιές στοές,
άκου τις μνήμες που ψιθυρίζουν:
πως τίποτα δε μένει αιώνιο,
και πως τα βήματα ανθρώπων μεγάλων
χάνονται σαν καπνός στα χρόνια που κυλούν.
Μα μην παραπονεθείς αν οι προσδοκίες σου
αποδειχθούν μικρές και γήινες.
Η πόλη αυτή δεν υπόσχεται τον ουρανό,
μα την τέχνη του να ζεις με το λίγο.
Να εύχεσαι να ’ναι πλούσια η στιγμή,
όταν θ’ αγγίξεις το βλέμμα της απ’ το λιμάνι.
Κι όταν γυρίσεις, μην πεις πως σε ξεγέλασε.
Σοφός πια, θα ξέρεις:
οι πόλεις δεν σε λυτρώνουν ούτε σε λυγίζουν.
Μονάχα κρατούν έναν καθρέφτη—
κι εσύ, στον αντίλαλο της Θεσσαλονίκης,
βλέπεις το πρόσωπο που πάντα κουβαλάς.

Artificial Intelligence–Based Escape Room: Enhancing Engagement and Learning in Education

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Abstract—Play, collaboration, and technology can significantly enhance learning when they are meaningfully combined. In particular, Artificial Intelligence (AI) can support innovative teaching approaches when it is used creatively. This study presents the design and implementation of a digital educational escape room created with Genially, aiming to promote student participation, inquiry, and collaborative problem-solving. AI was used as a supportive creative tool in developing the scenario, narrative, and tasks of the escape room. Student engagement was encouraged through an approach that combines learning with elements of entertainment and allows active involvement of all learners (Fotaris, Mastoras & Lameras, 2023). The escape room focused on teaching trigonometry, with emphasis on the law of sines, the law of cosines, and the calculation of the area of a triangle using the sine function. It was designed as a revision activity in which students solved a sequence of interconnected puzzles embedded in a narrative storyline. AI contributed to the creation of the scenario, the formulation of mathematical problems, and the linguistic design of instructions and game elements (Rodríguez-Rivera et al., 2025). In this sense, AI functioned as a "creative partner" during the design phase, supporting imagination and coherence in the learning scenario. The pedagogical approach was grounded in experiential learning, gamification, and collaborative inquiry. Students worked in groups, exchanging ideas and strategies to solve mathematical challenges that required conceptual understanding, trigonometric calculations, and critical thinking. Group work increased participation among students of different performance levels and supported an inclusive learning environment (Gómez Niño et al., 2024). Initial findings showed that the escape room enhanced student engagement, interest in mathematics, and understanding of key trigonometric concepts. Students reported that they felt they "learned through practice," while the teacher observed stronger collaboration and improved problem-solving skills. These results suggest that AI can act as a valuable ally for teachers in designing and implementing experiential learning activities, enriching creativity, differentiation, and student participation in secondary mathematics education.

Keywords— *Artificial Intelligence, Escape Room, Gamification, Experiential Learning, Personalized Feedback*

Introduction

The rapid advancement of technology now permeates all levels of education, offering interactive, engaging, and learner-centered learning experiences tailored to the needs of all children, substantially reshaping traditional approaches to teaching and learning. Digital technologies provide students with opportunities for immersive and experiential approaches to complex topics, using simulations, gamification practices, and virtual experiences (Yaseen et al., 2025). Within this context, game-based learning has emerged as a particularly effective pedagogical strategy, as it enhances active engagement, student participation, and learning outcomes (Garwood, 2020; Sidekerskienė & Damaševičius, 2023).

The design of learning experiences that foster collaboration, as well as the support of dynamic group interaction in digital environments, is further strengthened by generative artificial intelligence, which contributes to the development of innovative educational processes (Rodríguez-Rivera, Rodríguez-Ferrer & Manzano-León, 2025).

Within this framework, digital escape rooms that leverage generative artificial intelligence have emerged as a particularly promising form of gamified learning (Tawafak et al., 2024a). An escape room is a live-action team-based game in which participants search for clues, solve puzzles, and complete missions in one or more spaces, with the aim of achieving a specific goal (usually escaping from a certain space) within a predetermined time limit. It constitutes a type of escape game, consisting of narratively structured challenges that combine puzzles, activities, and time constraints. Other forms include puzzle hunts, breakout boxes, escape books, augmented or virtual reality (AR/VR) escape rooms, as well as portable escape rooms-in-a-box (Fotaris & Mastoras, 2019).

In the educational context, an escape room can be defined as an instructional approach that invites students to participate in collaborative, game-centered activities, specifically designed for the acquisition of knowledge in a particular subject area or the development of skills, in order to achieve a clearly defined goal (e.g., exiting a physical space or opening a box), through the solution of puzzles directly linked to specific learning objectives and within a limited time frame. The existence of a shared framework of action, in which participants collaborate in a game structured around predetermined learning outcomes, creates the conditions for the development of active learning (Fotaris & Mastoras, 2019; Tawafak et al., 2024b; Rodríguez-Rivera et al., 2025). Through these activities, students are called upon to face challenges, puzzles, and missions that largely require critical thinking, problem-solving skills, and knowledge of a specific subject area. Research findings have highlighted the role of virtual escape rooms in improving both cognitive and affective learning outcomes, as they engage students in scenario-based challenges that presuppose collaboration and higher-order cognitive processes (Alabdulaziz, 2023; Nasri et al., 2024; Kim et al., 2024; Chang, Setiani & Yang, 2024).

Although escape rooms have the potential to introduce new forms of teaching and substantially transform the learning experience, they constitute a relatively recent practice, and research evidence regarding their effectiveness remains limited, particularly in the field of mathematics. In a related study, Piñero Charlo (2020) investigated the effectiveness of using an escape room as an active instructional

methodology for teaching mathematics in secondary education in Spain. The results showed that the learning experience designed through the escape room led to a significant improvement in students' performance, motivation, and autonomy, while simultaneously contributing to a reduction in anxiety levels. Similarly, the study by Saleh Alabdulaziz (2023), which examined whether escape rooms can function as an active instructional approach in teaching mathematics in secondary education in Saudi Arabia, demonstrated increased motivation, improved learning performance, and enhanced student autonomy, alongside a reduction in negative attitudes toward mathematics and anxiety.

However, in the Greek educational context, following a relevant literature review, no study was identified that examines the outcomes of implementing artificial intelligence–based educational escape rooms, either at a general educational level or more specifically in the teaching of mathematics. Based on the above, the purpose of the present study is to investigate the effectiveness of an escape room designed and implemented with secondary education students in the context of mathematics teaching, and more specifically in the subject area of trigonometry.

Methodology

Experimental design – intervention

An educational intervention was conducted in October 2025 in a first-grade upper secondary (Grade 10) class of a European School in Luxembourg, designed on the basis of activity theory. An educational intervention is defined as the process of introducing and implementing a new approach, tool, or feature within an educational context, with the aim of improving learning outcomes. Activity is defined as a process of mutual transformations between the poles "subject–object". Within the framework of the activity, the object is assimilated by the subject and transformed into an internal cognitive structure, while at the same time the activity itself is expressed through its tangible and observable outcomes, namely the products generated through it (Garwood, 2020). In the learning environment, this implies that educational content, learning tasks, and the broader context are transformed into subjective forms, such as understanding, skills, competencies, attitudes, and the overall learning experience.According to this theoretical perspective, children engage in an activity due to the presence of a motive, which is shaped by the connection of a need with an object that can satisfy it, that is, by a desired goal expected to be achieved through participation in the activity. Stronger motives contribute to the formation of personal meaning, namely the development of a sense of value and significance of the activity in the everyday life of each individual (Ilishkina, 2025).

The educational escape room was developed in a digital environment using genial.ly and aimed to enhance participation, inquiry-based learning, and collaborative problem-solving, utilizing artificial intelligence as a creative and supportive means for the design of the scenario and the narrative. Active student engagement was pursued through a framework that combines the learning process with elements of entertainment and encourages the participation of all learners (Fotaris, Mastoras & Lameras, 2023).

The content of the escape room focused on the application of fundamental trigonometric concepts through activities connected to real-life situations. More specifically, it was based on the teaching of trigonometry, with emphasis on the law of

sines, the law of cosines, and the calculation of the area of a triangle using the sine. In particular, the objectives of the intervention were formulated as follows:
a) To familiarize students with the law of sines and enable them to apply it in practical examples.
b) To enable students to apply the law of cosines in more complex problem situations.
c) To enable students to calculate the area of a triangle using the sine.
d) To cultivate students' ability to transition from the "standard exercise" to the "learning challenge".

Thus, students were asked to solve a series of successive puzzles connected to a narrative plot, to which Artificial Intelligence contributed through the creation of the scenario, the formulation of the problems, and the linguistic shaping of the instructions and game elements (Rodríguez-Rivera et al., 2025). In this way, Artificial Intelligence functioned as a "creative partner" at the design stage, supporting educational imagination and narrative coherence. Students worked in groups, exchanging ideas and strategies to solve mathematical puzzles that required recognition of relationships, execution of calculations using trigonometric equations, and the development of critical thinking (Gómez Niño et al., 2024).

Theoretical background of the experimental intervention design

The pedagogical approach adopted in this educational intervention was based on experiential learning, gamification, and collaborative inquiry, which constitute contemporary and student-centered instructional practices. Experiential learning is defined as the educational process through which knowledge is constructed via the transformation of direct experience, allowing students to learn actively and meaningfully. Through this process, students do not function as passive recipients of information, but as active participants in the learning process, engaging in activities that simulate or reflect real-world situations.

Experiential learning enables students to participate in authentic experiences directly connected to their field of study, contributing to deeper knowledge, better conceptual understanding, and the development of critical thinking. At the same time, it enhances imagination, creativity, and problem-solving ability, as students are invited to explore, experiment, and make decisions within a safe and supportive learning environment. Moreover, experiential learning appears to be associated with higher levels of intrinsic motivation compared to more traditional, teacher-centered forms of instruction, as it promotes autonomy, active participation, and student interest in learning.

Gamification and collaborative inquiry function complementarily to experiential learning, contributing to increased engagement and active participation of students. Through the integration of game elements and collaboration, conditions are created that foster interaction, exchange of ideas, and the collective construction of knowledge. In this way, the learning process becomes more engaging, meaningful, and effective, enhancing both the cognitive and the social and emotional dimensions of learning.

Furthermore, tools and activities based on artificial intelligence have emerged as exploratory learning means due to their interactive and adaptive nature (Sun & Deng, 2025). Artificial intelligence offers the possibility of adapting learning experiences to the needs and preferences of students, enabling their participation in ways that

correspond to their individual characteristics. Thus, a learning environment is formed that encourages exploration and innovation within the context of experiential learning, elements that can enhance students' creativity (Rodríguez-Rivera et al., 2025).

Gamification refers to the practice of integrating game design elements into environments not directly related to games. The ultimate goal of gamification is to engage students, motivate them to collaborate, increase user participation in an unpleasant or difficult subject, make learning more enjoyable, stimulate students' interest, and enhance experiential learning. Unlike game-based learning, which uses actual games, gamification incorporates game mechanisms such as narratives, progression systems, and rewards into traditional educational structures. This approach can transform abstract concepts into concrete ones, provide experiential learning opportunities, and enhance students' collaborative skills (Gómez Niño et al., 2024).

Collaborative learning enhances students' motivation, supports both the emotional and cognitive dimensions of learning, and promotes autonomy, as well as dialogue based on inquiry and shared responsibility. The utilization of group dynamics through collaborative inquiry was chosen because it encourages the participation of all students, regardless of performance level, contributing to the formation of an inclusive learning environment.

Collaborative inquiry around a tool has a positive effect on the learning process, as students learn more effectively in a collaborative environment, both due to increased interaction with the tool and because they are encouraged to explain concepts to one another. At the same time, the advantage of integrating artificial intelligence into the learning process has been highlighted when it is utilized in combination with collaborative instructional strategies (Gómez Niño et al., 2024).

The Escape Room

The class consists of 17 students who generally show a genuine interest in learning new things, especially when learning takes place through inquiry-based activities or playful, hands-on experiences. All students demonstrate a strong enthusiasm for mathematics, and although there are three or four students who are weaker in the subject, they make a sincere effort to improve and participate actively. With continued guidance and consistent reinforcement, the class is gradually developing greater awareness of respectful communication and appropriate classroom behavior.

This lesson serves as a comprehensive review of trigonometry, focusing on basic angles, right triangle relationships, and the Laws of Sines and Cosines, as well as the area of a triangle using sine. The review is presented through an interactive escape room experience created entirely by the teacher using Genially, allowing for interactive presentations that integrate multimedia elements, step-by-step explanations, and instant feedback. Students are placed in the context of a narrative adventure on a desert island, where they must use their trigonometric knowledge to solve real-life challenges and ultimately escape. Each puzzle represents a closed-ended question or a word problem based on practical applications of trigonometric laws. The approach blends gamification, problem-solving, and collaborative inquiry, encouraging students to think critically and apply mathematics beyond formula memorization. Students must interact with both the teacher and their environment (posters to reinforce problem-solving

skills), searching for hidden clues and mathematical ideas around the classroom that guide them toward the next stage of the escape. The teacher plays an active role by guiding students, prompting discussion, and providing hints, creating a collaborative learning environment. By incorporating real-world contexts and examples, this lesson is designed to help students draw meaningful connections between trigonometry and their everyday experiences. Ultimately, it aims to cultivate not only a stronger grasp of trigonometric concepts but also curiosity, engagement, and confidence in applying mathematical reasoning. By embedding the trigonometry review within an escape room narrative, students are motivated to engage with the content while developing critical thinking and application skills. The review progresses from basic concepts to more complex applications, ensuring gradual mastery and confidence building. Students work in groups to solve challenges, encouraging peer learning, communication, and teamwork.

Regarding the learning objectives pupils should learn to:
• Recall and apply trigonometric ratios in right triangles.
• Use the Laws of Sines and Cosines to solve non-right triangles.
• Calculate the area of a triangle using sine.
• Apply trigonometry to real-world word problems.
•Collaborate effectively and communicate mathematical reasoning under time constraints.

By combining interactive digital tools, a gamified classroom activity, and guided teacher support, this review session aims to reinforce understanding, boost engagement, and improve problem-solving skills in trigonometry. Differentiation is achieved via the following:

- Puzzles are designed with varied difficulty levels to engage all learners.
- The teacher provides targeted support for students who need conceptual reinforcement.
- Students who finish early take on the role of Game Masters, offering small hints to teams requiring assistance, fostering peer support and collaboration.
- Visual and narrative elements are incorporated to accommodate different learning styles and enhance understanding (Figure 1).

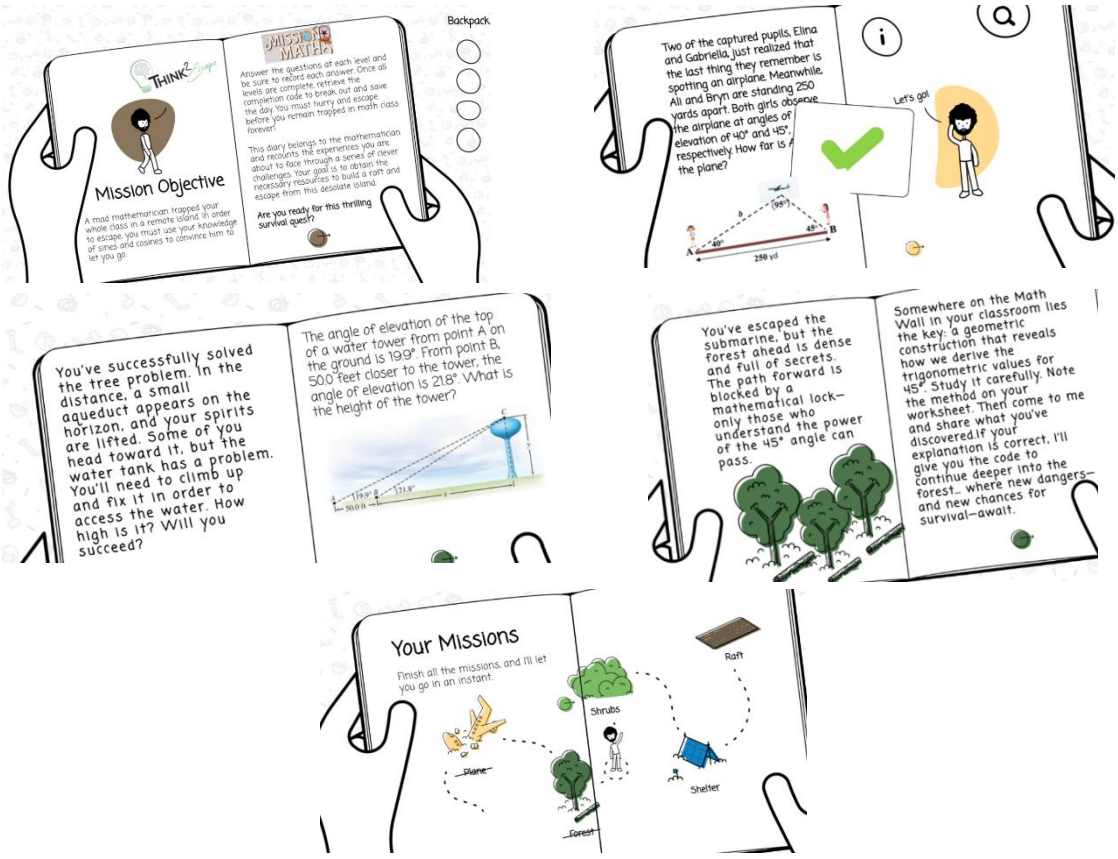


Figure 1. Aspects of the Escape room created by genial.ly.

Data Collection

For data collection, the method of systematic observation was selected, using predefined evaluation indicators. Observation, which is conducted directly on participants (students), educational processes, and pedagogical phenomena, constitutes an active research practice in which the researcher selects, organizes, and interprets information in relation to the research objectives and its theoretical background. Through observation, a multimodal, direct, careful, and systematic approach to educational reality is achieved.

The observation process was implemented using an evaluation rubric. The rubric constitutes a tool for the qualitative assessment of students' work and educational practice, as it includes clearly defined evaluation criteria, descriptions of quality levels, and a specific scoring strategy (Table 1). The evaluation criteria reflect the main dimensions of the process or task being assessed, which are taken into account when estimating the quality of learning performance and educational interaction. The scoring strategies are based on the use of rating scales, allowing for systematic and comparable assessment of the data. The use of rubrics enhances the reliability, validity, and transparency of the evaluation process for both students and teachers (Ling, 2024).

Domain	**Observation Elements**

Learning Objectives	Understanding of abstract concepts Student engagement in learning Increase in students' interest in mathematics Enhancement of critical thinking skills Enhancement of collaborative problem-solving skills
Classroom climate	Creation of an environment of respect and solidarity Student collaboration within the framework of inclusion

Table 1. Domains and observation elements (Assessment rubric)

Thus, observation rubrics constitute a particularly effective tool for the evaluation of educational interventions, as they provide structured, consistent, and transparent criteria for assessing teaching practices and the level of student engagement. Through their use, subjective judgments are reduced and clear reference points for performance levels are established, while at the same time specific pedagogical actions by teachers that align with the objectives of the intervention are identified. In addition, rubrics facilitate the provision of usable and targeted feedback aimed at improving educational practice. At the same time, they contribute to the development of a shared understanding of success criteria, ensure standardization of evaluation among different observers, and link observed behaviors to the intended learning and pedagogical outcomes of the educational program.

For the observation, specific domains and indicators were defined for each domain, as presented in the table above (Table 1). The teacher evaluated each element according to four levels of achievement: Insufficient (1–3), Basic (4–6), Adequate (7–9), Very adequate (10–12).

Results

The results of the observation based on the four levels of achievement are presented in the table below (Table 2).

Domain	**Observation Elements**	**Rating**
Learning Objectives	Understanding of abstract concepts Student engagement in learning Increase in students' interest in mathematics Enhancement of critical thinking skills Enhancement of collaborative problem-solving skills	10 11 10 9 10
Classroom climate	Creation of an environment of respect and solidarity Student collaboration within the framework of inclusion	10 10

Table 2. Scores of observation elements by domain

The teacher who implemented the activity observed significant changes in classroom dynamics, the quality of collaboration, and the way students approached mathematical problems. More specifically:

a) A deeper understanding of trigonometric concepts was identified, along with activation of prior knowledge and the connection of abstract concepts to realistic challenges.

b) Increased collaboration and mutual support among students were observed.

c) Students showed greater persistence in challenges, without the usual anxiety related to the "correct answer."
d) Skills of critical thinking, problem-solving, and strategic solution planning were developed, which constitute important 21st-century skills.
e) The game functioned as a differentiation tool, allowing all students to participate at different levels and enhancing inclusive pedagogy.

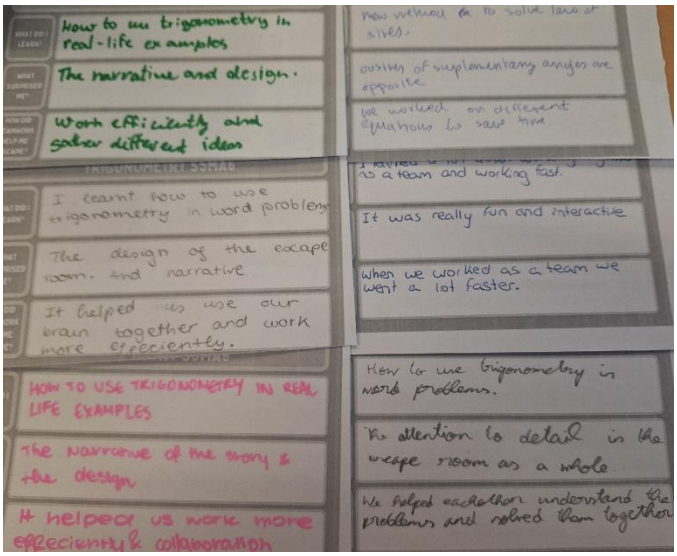


Figure 2. Exit ticket. Feedback from the students.

Discussion

An important finding of the implementation of this instructional approach was the increase in students' understanding of abstract mathematical concepts. Tawafak et al. (2024b) also report that artificial intelligence–based escape rooms can lead to increased academic performance of students. The fact that students showed increased interest in mathematics is consistent with the claim by Piñero Charlo (2020) that gamification can play a significant role in the teaching of STEM subjects, and particularly mathematics, as well as increase students' positive attitudes toward these subjects, which are generally low.

The way in which the educational escape room developed the narrative flow, connected the elements, and provided appropriate supportive tools contributed substantially to facilitating the learning process and mathematization. Mathematization is defined as the process of transforming problems originating from the real world into mathematical representation and symbolic language. From this perspective, two main approaches are distinguished: horizontal and vertical mathematization. Horizontal mathematization refers to the transition from the experiential world to the world of mathematical symbols and focuses on formulating a problem in a way that makes it accessible to mathematical processing. In contrast, vertical mathematization focuses on the further mathematical processing of the problem, regardless of its level of complexity.

For the effective support of mathematization, learning activities should be designed with emphasis on linking natural language with mathematical symbolic representation, using appropriate tools and models, searching for regularities and relationships, recognizing isomorphisms between similar problems, and identifying critical

mathematical data. Once the real-world problem is rendered into mathematical form, the process can evolve into stages of reasoning, processing, and generalization. Accordingly, educational escape rooms function as effective learning environments, as they provide tools for data collection, exploration of relationships, and recognition of regularities, while simultaneously emphasizing problem mathematization and the generalization of conclusions (Piñero Charlo, 2020).

More specifically, the results of the implementation of the escape room demonstrated that it enhanced active engagement, interest in mathematics, and understanding of basic trigonometric concepts. Students reported that they felt they "learned through practice," while the teacher observed increased collaboration and the development of problem-solving skills. The contribution of artificial intelligence was recognized as valuable at the creative stage, enhancing the narrative, flow, and coherence of the learning scenario (Tawafak et al., 2024a). In particular, the escape room used promotes teamwork and collaboration (Tawafak et al., 2024b), leading to increased levels of engagement and motivation, as students perceive game-based learning as more interesting. Improved analytical skills such as critical thinking, problem-solving, and creativity that were observed have also been highlighted by related studies. Another advantage observed is that students are willing to engage in activities with a high level of challenge, which has also been reported by Rodríguez-Rivera et al. (2025).

Furthermore, a high level of acceptance of the educational escape room as a learning tool by students was identified. This finding is considered particularly important, as the concept of acceptance reflects the degree of willingness of both students and teachers to adopt and utilize this technological approach in the learning process. The level of acceptance also reflects the impact of educational games on the achievement of learning objectives, as well as on the formation of positive attitudes, the enhancement of motivation, and the active participation of students.

The use of educational escape rooms in mathematics teaching transforms the learning process into a playful experience, enhancing students' motivation, active participation, and problem-solving skills. Through their involvement in narratively structured puzzles, students are invited to collaborate, develop critical thinking, and apply mathematical concepts to identify clues and achieve the goal of "escape." This approach contributes to improved learning performance and to the reduction of anxiety often associated with mathematics.

Conclusions

The combination of game-centered practices, collaborative learning, and the use of technology can function as a powerful and multidimensional pedagogical means for the learning process, particularly when artificial intelligence is integrated in a creative, pedagogically grounded, and clearly targeted manner. The findings of the present educational intervention highlight that artificial intelligence can serve as a substantial supportive mechanism for the teacher, both during the instructional design phase and during the implementation of experiential learning experiences. In particular, it contributes to the improvement and rationalization of design, as well as to the enhancement of the quality of educational scenarios, while simultaneously strengthening creativity, imagination, instructional differentiation, and student participation in mathematics teaching in Secondary Education.

More specifically, the combination of play, experiential learning, and artificial intelligence appears to have the potential to transform instructional practice, making the learning process more creative, engaging, collaborative, and effective. The educational escape room functioned as an innovative and alternative pathway to mathematical understanding, as the integration of narrative and puzzles activated students' learning curiosity, critical thinking, and persistence in problem-solving. At the same time, the collaborative nature of the activity highlighted the potential of each student, enhancing interaction, a sense of belonging to the group, and the development of social and metacognitive skills. It is also worth noting that the positive learning climate that was formed contributed substantially to improving students' attitudes toward mathematics, strengthening their relationship with the subject matter and reducing potential feelings of anxiety or disengagement.

However, it is important to note that the above findings arise from the implementation of a specific educational escape room in only one secondary education class and in a specific instructional unit of the mathematics curriculum. In addition, the evaluation of the intervention was based exclusively on the teacher's assessment, which limits the multidimensionality of the analysis and may affect the objectivity of the results. Taking these limitations into account, generalization of the conclusions to broader student populations or different educational contexts is not feasible.

Despite these limitations, the positive results of the intervention provide fertile ground for further research. In particular, future studies are suggested that:
a) examine the effectiveness of educational escape rooms on students' learning performance and conceptual understanding, either through pre- and post-measurements or through comparative studies between intervention and control groups in relation to conventional instruction;
b) investigate the acceptance, attitudes, and perceptions of students and teachers regarding the use of escape rooms as educational tools in mathematics and in school practice more broadly; and
c) extend the application of this instructional model to other subject areas, both within the domain of the natural sciences and STEM subjects and beyond this framework, exploring its interdisciplinary and cross-curricular potential.

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RAAF: Responsible AI-Supported Assessment and Feedback – From Technical Appraisal to Institutional Accountability

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Abstract—The rapid expansion of Large Language Models (LLMs) in educational contexts foregrounds the urgent challenge of integrating automated assessment and feedback systems while safeguarding pedagogical validity, psychometric integrity, and ethically grounded governance. Most existing techno-centric implementations prioritize efficiency at the expense of accountability, producing opaque algorithmic systems ill-suited for consequential evaluative decisions. This study addresses this gap by proposing the RAAF (Responsible AI Assessment & Feedback) model as a comprehensive framework that reorients AI-supported assessment from technical grading toward an architecture of transparency and institutional accountability. RAAF is structured as a four-stage, interdependent cycle. Stage I operationalizes multidimensional automated assessment, in which LLMs generate criterion-level, rubric-aligned evaluations accompanied by explicit justification. Stage II translates these judgments into formative, actionable feedback directed at learners, emphasizing clearly specified next steps aligned with learning objectives and supporting self-regulated revision. Stage III provides educators with diagnostic analytics and early-warning mechanisms, including confidence indicators and bias alerts, which flag potentially unstable or unfair evaluations for timely human review prior to finalization. Stage IV institutionalizes explicit human validation of all consequential decisions: final grades are confirmed by instructors and documented through a comprehensive audit trail that records both machine-generated reasoning and human interventions. A formal right to contestation is simultaneously established, ensuring legal and ethical defensibility. A synthetic review of recent literature indicates that while LLMs can approximate human judgment and improve revision quality and learner motivation, their effectiveness depends on contextualized deployment and robust human oversight. RAAF transforms these requirements into structurally embedded procedures. By positioning AI as a justified recommender and mandating human validation for every contestable judgment, the model preserves human pedagogical authority in relation to algorithmic systems. Overall, RAAF offers a realistic and ethically grounded pathway for integrating AI into educational assessment without compromising fairness or human oversight. The study concludes with an evaluation design specifying indicators for reliability, perceived fairness, and impact on measurable learning outcomes.

Keywords: RAAF, Responsible AI, automated assessment, formative feedback, fairness, human accountability

1 Introduction

The massification of assessment in secondary and tertiary education has exposed the limitations of a model in which the teacher operates as the sole evaluator. Despite successive reform efforts, assessment practices remain constrained by severe time pressures, heterogeneous criteria, and feedback of limited pedagogical value for substantive revision. Recent advances in large language models (LLMs) have foregrounded the potential of automated appraisal and personalized feedback which, under controlled conditions, are associated with improvements in the quality of revised work, learner motivation, and metacognitive awareness (Meyer et al., 2024; Fleckenstein, Liebenow, & Meyer, 2023; Araujo, López-Ostenero, Plaza, & Martínez-Romo, 2025).

In written discourse and structured responses, LLM-based approaches can approximate human judgment when explicitly aligned with rubric-based criteria (Pack, Barrett, & Escalante, 2024; Tate et al., 2024; Tang, Chen, Lin, & Li, 2024). In higher education, experimental use of ChatGPT-4 for assessing short written answers has yielded encouraging yet still equivocal findings (Jauhiainen & Garagorry Guerra, 2024). However, technical adequacy does not equate to pedagogical or institutional legitimacy. Persistent concerns remain regarding judgment stability, potential bias, and the need for explainability and contestability (Doewes et al., 2022; Kortemeyer & Nöhl, 2025; Fischer, 2024; Bulut et al., 2024).

Against this dual backdrop, the present study advances the RAAF (Responsible AI Assessment & Feedback) model as a cyclical framework for responsible assessment and feedback. Its central premise is that AI does not function as the final arbiter but as a recommending mechanism embedded within an institutionally defensible process characterized by human final authority. Stage I introduces multidimensional appraisal with explicit, rubric-aligned justification (Tang et al., 2024; Tate et al., 2024). Stage II translates evaluative judgments into formative, actionable feedback with concrete next steps, with documented benefits in writing and programming contexts (Meyer et al., 2024; Araujo et al., 2025). Stage III provides educators with class-level diagnostics and alerts regarding potential bias or instability, enabling targeted pedagogical intervention (Doewes et al., 2022; Kortemeyer & Nöhl, 2025). Stage IV institutionalizes human validation, documented reasoning, and a comprehensive audit trail that renders decisions explainable and open to appeal (Memarian & Doleck, 2024; Henderson et al., 2025; Reina Marín et al., 2025).

The contribution of RAAF is twofold. First, it operationalizes principles of responsible AI into a concrete workflow with clearly delineated control points. Second, it proposes an evaluation design for assessing the workflow itself under authentic conditions. Automated assessment is thus reframed from a “black box” technology into a substantiated advisory judgment embedded within a cycle of pedagogical responsibility and institutional accountability.

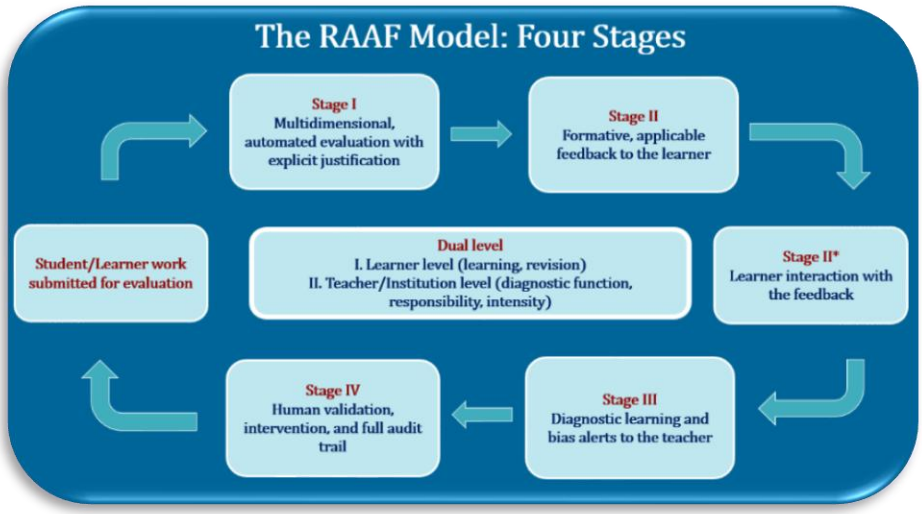


Figure 1. The RAAF model: Four-stage AI-supported assessment and feedback framework.
Note. Figure developed by the author.

2. Foundations: Validity, Reliability, and Pedagogical Implications of AI in Assessment

2.1 Validity and Reliability of Automated Assessment

The legitimation of automated assessment does not hinge merely on whether "AI grades correctly," but on whether its judgments demonstrate psychometric validity, operational reliability, and institutional defensibility without producing systematic injustices. Recent research shows that large language models (LLMs) can approximate holistic human evaluation in written discourse, particularly when explicitly aligned with analytic rubrics, achieving high agreement with expert raters in low- to medium-stakes contexts (Pack, Barrett, & Escalante, 2024; Tate et al., 2024). The shift from monolithic scores to multidimensional, criterion-referenced appraisal enhances evidential validity and transparency, insofar as decisions are articulated in natural language and mapped onto rubric descriptors (Tang, Chen, Lin, & Li, 2024). Explicit justification therefore constitutes a prerequisite for pedagogical usability and institutional oversight.

Reliability extends beyond average correlations. It presupposes stability across repeated judgments and predictable variance at the individual level. Minor fluctuations in scoring may be tolerable for formative purposes but become problematic in high-stakes assessment (Pack et al., 2024). Accordingly, confidence indices and criterion-level stability thresholds have been proposed, such that low stability triggers mandatory human confirmation prior to finalization (Kortemeyer & Nöhl, 2025). At the same time, fine-tuning strategies and the incorporation of linguistic complexity indicators improve the accuracy and human-alignment of LLM-based scoring systems, strengthening their psychometric adequacy (Liu, Qi, & Lu, 2025).

Fairness remains a central concern. Automated appraisals may penalize discourse profiles that diverge from dominant academic conventions even when argumentative substance is adequate (Doewes, Saxena, Pei, & Pechenizkiy, 2022). Systematic discrepancies in handwritten responses further intensify the need for controllable features and transparent indicators (Yiğiter & Boduroğlu, 2025). Hybrid architectures

combining LLMs with interpretable features and knowledge-retrieval techniques improve evidentiary grounding and mitigate arbitrariness (Atkinson & Palma, 2025).

Explainability and contestability bridge psychometric and institutional validity. Machine-generated judgments must be accompanied by evidence and a documented decision trail in order to be intelligible and open to appeal (Fischer, 2024; Bulut et al., 2024; Reina Marín et al., 2025). The human-in-the-loop principle acquires substantive meaning only when educators can accept, modify, or reject machine recommendations on the basis of articulated reasoning (Memarian & Doleck, 2024; Henderson et al., 2025).

Taken together, LLMs can approximate human judgment when they operate in a multi-criteria mode with explicit justification (Pack et al., 2024; Tate et al., 2024; Tang et al., 2024). Validity becomes institutionally defensible practice only when coupled with stability indicators, hybrid interpretability, and mandatory human validation, in line with the logic underpinning the RAAF model.

2.2 Automated Feedback: Learning, Cognitive, and Affective Outcomes

Automated feedback should not be understood as a secondary by-product of grading but as an autonomous pedagogical intervention with a distinct contribution to learning, provided that it is explicitly aligned with learning objectives and rubric-based criteria. Experimental evidence from secondary education demonstrates that targeted, actionable feedback generated by LLMs leads to substantial improvements in argumentative structure and evidentiary quality in revised text versions, while also producing positive effects on scores assigned by independent raters and strengthening learner motivation and positive affect toward revision (Meyer et al., 2024). These findings converge with meta-analytic evidence indicating medium-sized effects of automated feedback on writing performance when comments are specific and oriented toward concrete improvement actions (Fleckenstein, Liebenow, & Meyer, 2023). Comparative studies between teacher and AI feedback on informational texts further report similar levels of improvement in organization and clarity, with differences emerging primarily in tone and in learners' perceptions of pedagogical support (Baz & Hasırcı Aksoy, 2025), thereby reinforcing the complementary role of AI in instructional feedback ecosystems.

In tertiary contexts, particularly in programming education, immediate code-level feedback accelerates self-correction, strategic reorganization, and the consolidation of conceptual understanding beyond surface-level error fixing, especially when feedback addresses correctness, efficiency, and scalability (Araujo, López-Ostenero, Plaza, & Martínez-Romo, 2025; Mohamed et al., 2025; Yousef et al., 2025). Comparable benefits are documented across STEM disciplines, where LLM-based feedback functions as an "external mirror" of reasoning that enables targeted real-time revision and supports deeper conceptual engagement (El-Adawy, MacDonagh, & Abdelhafez, 2024; Grandel, Schmidt, & Leach, 2024).

Beyond improvements in the final product, automated feedback contributes to a broader shift toward a formative learning culture. Learners appropriate the language of the rubric, identify weaknesses more systematically, and increasingly perceive their work as a revisable artifact, thereby strengthening self-regulation and metacognitive

awareness (Fleckenstein et al., 2023; Meyer et al., 2024). The impact extends to collaborative learning dynamics, as the degree and type of feedback scaffolding modulate cognitive depth and group coherence (Ba, Yang, Yan, Looi, & Gašević, 2025; Ba, Zhan, Huang, & Lu, 2025). In authentic course settings, the design of workflows that embed feedback within the ergonomics of assessment has been associated with improved quality, consistency, and timeliness of comments (Venter, Coetzee, & Schmulian, 2025; Abiad, Richter, Padilla, & Flores, 2025).

At the same time, effectiveness is accompanied by pedagogical risks. Overreliance on AI may convert support into an outsourcing of metacognitive labor (Ding, Zou, & Kohnke, 2025), while in L2 contexts, conformity to standardized academic style has been linked to perceptions of diminished authentic voice (Shi, Chai, Zhou, & Aubrey, 2025; Escalante, Pack, & Barrett, 2023). Acceptance of feedback is consistently higher when it is intelligible and actionable, and when professional autonomy and final control by the instructor are preserved (Henderson et al., 2025; Martin, Kim, Bolliger, & DeLarm, 2025).

Accordingly, the literature converges on a dual design principle. Pedagogically, AI feedback must be specific, criterion-aligned, and translated into actionable next steps (Meyer et al., 2024; Araujo et al., 2025). Ethically, it must remain visible to the educator, embedded within an accountability cycle, and accompanied by mechanisms that protect authentic voice and prevent overdependence, with explicit human validation as stakes increase (Henderson et al., 2025; Reina Marín et al., 2025). Under these conditions, AI functions as a formative recommender of learning rather than as a final arbiter, in alignment with the logic of the RAAF model.

2.3 Governance, Fairness, and Human Oversight in AI-Supported Assessment

The debate on integrating AI into assessment is increasingly shifting from the question of "Does it work?" to "Is it institutionally defensible?". Contemporary scholarship converges on the view that, particularly in consequential assessment contexts, the use of AI presupposes an explicit governance framework with clearly delineated roles, decision explainability, avenues for appeal, and a documented accountability trail; absent these conditions, the process remains politically and pedagogically precarious (Fischer, 2023; Bulut et al., 2024; Reina Marín et al., 2025). Human oversight must therefore be operationalized rather than merely asserted. Educators require access to multidimensional, criterion-level justifications, the capacity to accept, adapt, or reject the machine's recommendation, and an obligation to document the rationale underlying the final decision (Memarian & Doleck, 2024; Henderson et al., 2025). Without such affordances, oversight degenerates into a nominal endorsement of algorithmic output.

Fairness constitutes a second, non-negotiable pillar. Even in the presence of high average human–system agreement, individual- or group-level biases may persist that disadvantage particular learner profiles or discourse styles, necessitating systematic mechanisms for their detection and mitigation. These include bias auditing signals, explicitly interpretable features, and transparent indicators aligned with rubric criteria (Doewes et al., 2022; Bulut et al., 2024; Atkinson & Palma, 2025). Judgment stability must likewise be addressed psychometrically, through dimension-level confidence estimation and escalation rules that trigger human re-review when variability exceeds

predefined thresholds, especially in high-stakes contexts (Kortemeyer & Nöhl, 2025). In parallel, perceived fairness and trust are strengthened when judgments are explainable, stable, and criterion-oriented, and when a visible appeal channel to an identifiable responsible actor is ensured (Henderson et al., 2025; Jones-Jang et al., 2025).

Crucially, contestability must be designed as a right rather than as an exception. Access to explicit justification, mandatory human validation, and a comprehensive audit trail transforms appeals into a substantiated process of reconsideration rather than a symbolic gesture (Fischer, 2023; Bulut et al., 2024; Reina Marín et al., 2025). Under these conditions, AI is situated within a responsible and controllable framework in which final authority and accountability reside unequivocally with the human decision-maker.

2.4 Limits, Constraints, and Preconditions for Responsible Implementation

The use of AI in assessment and feedback is subject to technological, psychometric, and institutional constraints that preclude uncritical adoption. Technologically, LLM performance is sensitive to variations in prompting, model versions, and application domains, producing judgment instability across repeated estimations or heterogeneous tasks. Consequently, systematic test–retest controls and criterion-level confidence bands are required (Pack, Barrett, & Escalante, 2024; Kortemeyer & Nöhl, 2025). Alignment with human raters cannot be treated as a sufficient indicator of validity, as such convergence may mask biases favoring standardized academic style or surface-level linguistic complexity at the expense of argumentative substance and diverse linguistic profiles (Doewes et al., 2022; Tang et al., 2024). Hybrid approaches combining LLMs with interpretable features and knowledge-retrieval techniques improve explainability and robustness but do not eliminate the need for careful calibration (Atkinson & Palma, 2025; Thakur et al., 2025).

Pedagogically, risks include overreliance on automated feedback and erosion of authentic voice, particularly when “actionable” guidance degenerates into ready-made solutions rather than scaffolding of metacognitive processes (Ding et al., 2025; Shi et al., 2025). Mitigation requires explicit second-step use rules, transparent rubric criteria, and quality control of revisions with respect to strategy transfer rather than mere linguistic polishing (Fleckenstein et al., 2023; Meyer et al., 2024).

Organizationally, without institutionalized human validation, protected avenues for appeal, and a comprehensive audit trail, AI use remains politically and legally precarious regardless of learning gains (Fischer, 2023; Bulut et al., 2024; Reina Marín et al., 2025; Memarian & Doleck, 2024).

Accordingly, responsible implementation requires pilot phases with agreement and stability studies, differentiated acceptance thresholds by assessment stakes, mandatory bias alerts with escalation to human review when model confidence is low, and targeted professional development in feedback literacy and digital assessment design (Buckingham Shum et al., 2023; Venter et al., 2025; Martin et al., 2025). Parallel evidence of benefit in authentic contexts such as STEM and programming must be established to substantiate effectiveness without compromising fairness or transparency (Araujo et al., 2025; Mohamed et al., 2025; Yousef et al., 2025; Abiad et al., 2025;

Najafi et al., 2025). Within these boundaries, AI functions as a recommender within a cycle of accountable assessment rather than as an autonomous final judge.

3 The RAAF Model: A Cyclical Framework for Responsible AI-Supported Assessment and Feedback

3.1 Stage I-Multidimensional Automated Assessment with Explicit Justification

In the first stage, AI operates as a recommending mechanism that renders judgments at the level of individual rubric criteria rather than as a "black box" producing a monolithic score. Multidimensional appraisal aligns assessment with the learning object by differentiating, in writing tasks, among claim substantiation, discourse organization, clarity, and critical depth, and, in programming exercises, among correctness, efficiency, and scalability. Contemporary LLMs can generate dimension-level evaluations explicitly mapped to rubric descriptors and accompanied by verbalized justifications that render their reasoning inspectable. Empirical studies report high agreement with human raters in both holistic and criterion-referenced scoring of written responses, while in code evaluation LLM explanations approximate the quality of an experienced teaching assistant by identifying specific faults and underlying strategic weaknesses (Tang, Chen, Lin, & Li, 2024; Tate et al., 2024; Dong & Liang, 2024; Mohamed et al., 2025; Yousef et al., 2025).

Explicit justification serves a tripartite function. For learners, it bridges grade and improvement by functioning as first-line feedback. For instructors, it enables rapid verification of activated criteria and detection of inconsistencies without requiring universal regrading. Institutionally, it transforms scoring into a traceable, substantiated judgment. Educational measurement literature emphasizes that such explainability is a prerequisite for ethically defensible decisions in high-stakes assessment (Fischer, 2023; Bulut et al., 2024).

The stage also incorporates stability control. Average agreement is insufficient if identical responses receive divergent scores across repeated calls. Each appraisal is therefore accompanied by criterion-level confidence estimates and explicit low-stability flags that trigger human inspection at a subsequent stage, consistent with approaches treating AI as a measurement system (Pack, Barrett, & Escalante, 2024; Kortemeyer & Nöhl, 2025).

Finally, multidimensional, justified recommendations function as a fairness filter. Systematic checks of alignment between justification and pedagogically legitimate criteria, together with logging of deviations as potential bias indicators, ensure that AI produces inspectable and revisable judgments. Stage I thus reframes automated grading as the starting point of accountable assessment grounded in validity, reliability, and institutional defensibility.

3.2 Stage II – Formative, Actionable Feedback to the Learner

In the second stage, AI shifts from judge to pedagogical catalyst, translating the criterion-level appraisal of Stage I into concrete improvement actions. Feedback must be task-specific, explicitly linked to rubric criteria, and articulated as actionable "next

steps" in order to foster revision-oriented agency rather than passive compliance. Controlled interventions show that such targeted, paragraph-level feedback measurably improves argumentative structure, clarity, and evidentiary support in final texts, while increasing willingness to revise and reducing negative affect toward critique (Meyer et al., 2024; Fleckenstein, Liebenow, & Meyer, 2023).

In programming contexts, feedback functions as a micro-intervention on the solution itself, identifying sources of failure, proposing alternative strategies, and guiding improvement in correctness, efficiency, and scalability, with documented benefits in faster convergence toward accurate mental models (Araujo, López-Ostenero, Plaza, & Martínez-Romo, 2025; Mohamed et al., 2025; Yousef et al., 2025).

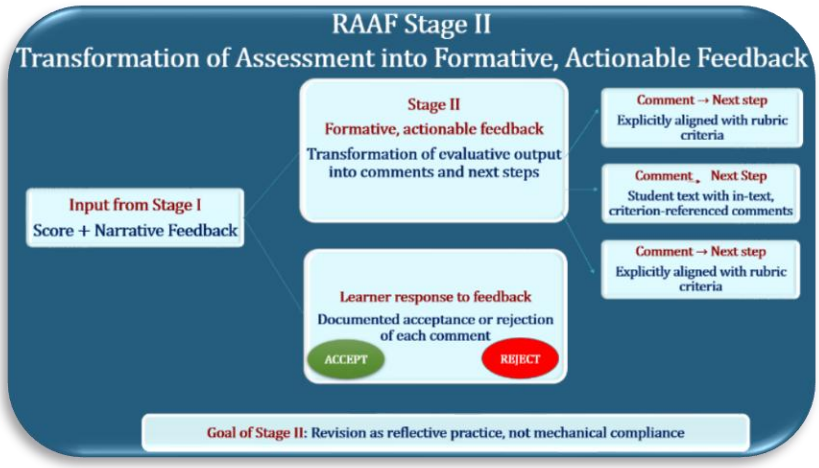


Figure 2. RAAF Stage II: Transformation of assessment into formative, actionable, and learner-centered feedback.
Note. Figure developed by the author.

The affective dimension is central. Many learners perceive AI feedback as functional guidance rather than personalized reproach, which lowers defensiveness and enhances engagement. At the same time, variation in feedback type shapes cognitive depth and group dynamics, underscoring the need for explicit instructional design (Ba, Yang, Yan, Looi, & Gašević, 2025; Henderson et al., 2025). When AI provides ready-made solutions, however, the risk of cognitive outsourcing and erosion of self-regulation increases, while uniform linguistic conventions may undermine authentic voice (Ding, Zou, & Kohnke, 2025; Shi, Chai, Zhou, & Aubrey, 2025). Pedagogically legitimate feedback must therefore preserve learner ownership and orient revision toward conceptual reconstruction rather than surface-level conformity.

RAAF addresses these risks through criterion-level traceability for each comment and a requirement for documented learner acceptance or rejection, while generated feedback simultaneously feeds the learning diagnostics and bias alerts of Stage III. Under this design, Stage II operates as a pedagogical accelerator without becoming a substitute for critical thinking, aligning learning gains with the ethical imperatives of responsible AI use.

3.3 Stage III – Learning Diagnostics and Bias Alerts for the Educator

In the third stage, data derived from multidimensional appraisal and individualized feedback are transformed into professional intelligence for targeted instruction and ethical oversight. The core mechanism is the synthesis of class-level patterns, with the identification of persistent weaknesses by rubric criterion and activity type, enabling instructors to intervene proactively with micro-instructional adjustments aligned with learners' actual cognitive needs. The literature documents that AI-supported interventions in writing and programming surface systemic errors and guide effective reteaching, particularly with respect to claim substantiation and algorithmic efficiency (Araujo et al., 2025; Mohamed et al., 2025; Yousef et al., 2025). In parallel, advanced LLMs combined with visualization tools have been shown to support the detection of learning patterns and the enhancement of metacognitive awareness in domains such as data analysis and STEM (Valverde-Rebaza et al., 2024).

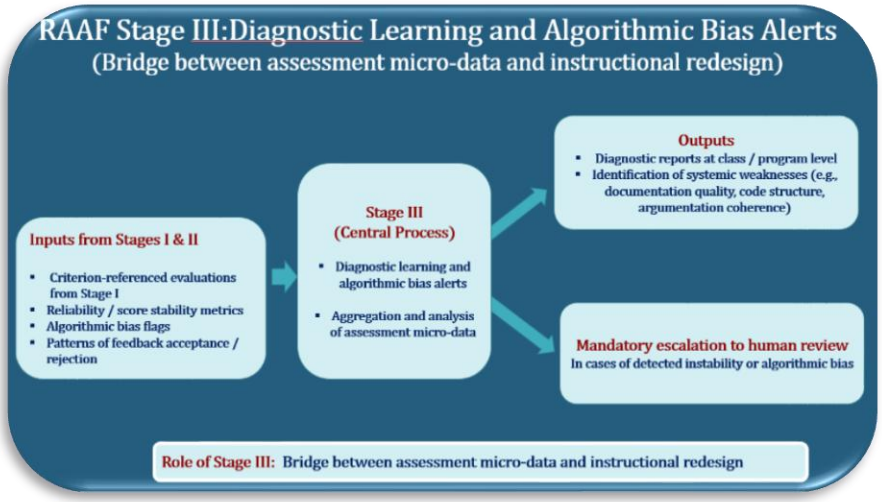


Figure 3. RAAF Stage III: Aggregation of assessment micro-data for diagnostic reporting and bias detection.
Note. Figure developed by the author.

RAAF institutionalizes bias alerts that flag patterns of unfair or unstable judgment, such as systematic downgrading of texts with lower lexical diversity despite adequate argumentation, or test–retest instability in specific dimensions (Doewes et al., 2022; Yiğiter & Boduroğlu, 2025; Pack et al., 2024; Kortemeyer & Nöhl, 2025). These alerts do not function as mere notifications but as mandatory escalation mechanisms to human inspection, as accountability in educational measurement presupposes the prevention of injustices before they crystallize into final decisions (Bulut et al., 2024; Fischer, 2023).

Equally critical is actionability. Diagnostics are delivered as concise, implementable instructional recommendations that reduce cognitive load without diminishing professional autonomy, a design feature associated with higher instructor acceptance of AI tools (Venter et al., 2025). Through this architecture, Stage III converts dispersed micro-information into pedagogically valuable intelligence and introduces explicit safeguards against technologically induced injustice.

3.4 Stage IV – Human Validation, Intervention, and Accountability Trail

In the fourth stage, the process becomes explicitly institutional: no consequential assessment is finalized without human validation. The educator retains final authority,

with the capacity to accept, adapt, or reject the AI's recommended judgment and with an obligation to justify the decision in relation to rubric criteria and the pedagogical aims of the course. This principle constitutes a prerequisite for legitimacy in high-stakes environments, where responsibility must be attributable to an identifiable agent and defensible against scrutiny and appeal (Fischer, 2023; Bulut et al., 2024; Memarian & Doleck, 2024).

Human validation is grounded in a comprehensive audit trail that renders the entire decision-making pathway reconstructible, from the original student artifact to the final judgment. Such traceability transforms appeals from diffuse or generic complaints into structured processes of reviewing concrete evidentiary bases and articulated reasoning, thereby strengthening perceived fairness and trust in the assessment procedure (Reina Marín et al., 2025; Bulut et al., 2024).

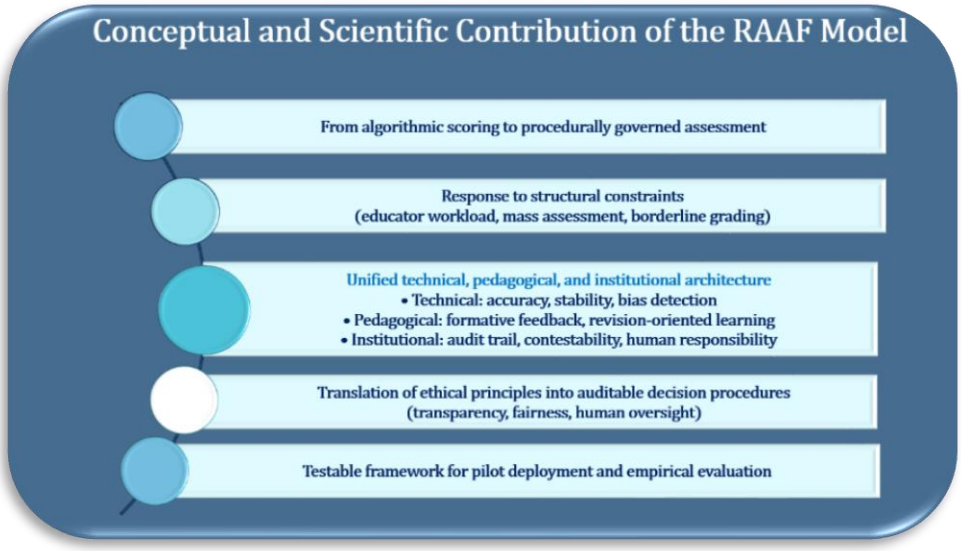


Figure 4. Conceptual and Scientific Contribution of the RAAF Model.
Note. Figure developed by the author.

Concurrently, the systematic linkage of human interventions to patterns of divergence fuels continuous improvement: rubric refinement when legitimate evidence is consistently overlooked, model recalibration when instability or undue bias is detected, and stricter escalation rules for criteria exhibiting low stability (Tang et al., 2024; Tate et al., 2024; Doewes et al., 2022; Kortemeyer & Nöhl, 2025). Through this design, RAAF does not merely append a human signature to machine judgments, but establishes a mechanism of accountable assessment in which AI remains advisory and the human bears final, reasoned responsibility.

4. Evaluation Design for the RAAF Model: Effectiveness, Fairness, and Pedagogical Legitimacy

4.1 Reliability and Stability of Automated Assessment

The evaluation of Stage I of RAAF must demonstrate psychometric adequacy under authentic conditions rather than merely technical soundness. The primary focus is human–system agreement at the level of individual rubric dimensions, not only at the level of the overall score. Recent evidence indicates that LLMs can align satisfactorily

with expert raters in both holistic and criterion-referenced scoring of written work when system design requires explicit criterion mapping and dimension-level justification (Pack, Barrett, & Escalante, 2024; Tate et al., 2024; Tang, Chen, Lin, & Li, 2024). Within RAAF, this alignment is examined through blind double readings and dimension-specific agreement coefficients, ensuring that acceptance of automated judgments is grounded in differentiated evidence and that targeted human intervention is enabled wherever discrepancies emerge.

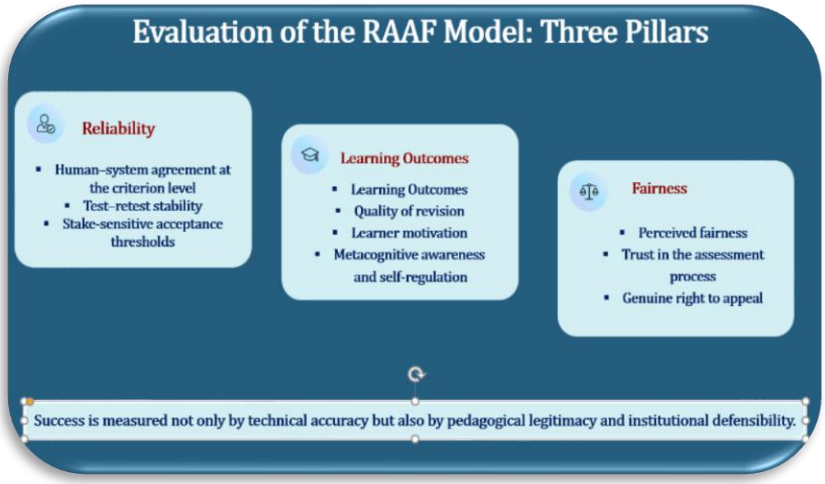


Figure 5. Three-Pillar Evaluation Framework of the RAAF Model: Reliability, Learning Outcomes, and Fairness.
Note. Figure developed by the author.

Judgment stability constitutes a second critical issue. High average agreement is insufficient when minor fluctuations across repeated calls can translate into substantive injustice in high-stakes scenarios. Treating stability as a measurement problem entails the estimation of criterion-level confidence bands and repeatability indices, with mandatory human inspection whenever stability falls below a predefined threshold (Kortemeyer & Nöhl, 2025). In RAAF, each automated appraisal is accompanied by a stability flag that directs escalation to human review when warranted.

Stake-sensitive acceptance thresholds represent a third consideration. In low-stakes uses, documented deviations within narrow bounds may be tolerable, particularly when automated feedback accelerates revision cycles and improves work quality (Meyer et al., 2024; Araujo et al., 2025). By contrast, in high-stakes decisions, clauses of mandatory human validation are activated whenever human–system divergence or low stability exceeds institutionally acceptable limits, a condition necessary for institutional defensibility and transparency (Bulut et al., 2024; Fischer, 2023). Reliability is thus operationalized as a rule of accountability: where its conditions are not met, judgment is obligatorily transferred to the human decision-maker.

4.2 Learning Gains, Revision Quality, and Student Motivation

The central question is not whether AI "works," but whether it substantively transforms learning. Available evidence indicates clear improvements in the quality of final products when feedback is specific, rubric-aligned, and embedded in short revision cycles. In pre–post experimental designs with blind human raters, targeted LLM-generated feedback leads to stronger argumentative structure and more robust

evidentiary support, with gains extending beyond mere linguistic polishing (Meyer et al., 2024; Fleckenstein, Liebenow, & Meyer, 2023). In programming contexts, immediate identification of algorithmic and design weaknesses fosters strategy-level revision and accelerates consolidation of accurate mental models (Araujo, López-Ostenero, Plaza, & Martínez-Romo, 2025; Mohamed et al., 2025; Yousef et al., 2025).

Beyond product improvement, the learning process itself is reshaped. Students appropriate the language of the rubric, independently identify gaps in evidence or coherence, and strengthen self-regulation (Fleckenstein et al., 2023). Simultaneously, reductions in negative affect and increased willingness to revise are documented, as feedback is experienced as guidance rather than personal rejection (Meyer et al., 2024).

Effectiveness is accompanied by risks. Ready-made "next steps" may undermine initial self-correction and position AI as a first resort, eroding autonomy (Ding, Zou, & Kohnke, 2025). In L2 environments, adherence to standardized academic conventions has been linked to perceived loss of personal voice (Shi, Chai, Zhou, & Aubrey, 2025). Within RAAF, feedback remains formative and actionable, yet visible to the instructor and traceable in the audit trail, enabling corrective intervention where overreliance or stylistic homogenization emerges. Only under these conditions can learning gains translate into pedagogically legitimate improvement without sacrificing students' critical autonomy.

4.3 Perceived Fairness, Trust, and the Right to Appeal

The legitimacy of RAAF is not determined solely by technical metrics, but by how the process is experienced by students and instructors. Perceived fairness rests on clear and legitimate criteria, consistency of application, and intelligibility of evaluative reasoning. When learners clearly understand "what counts" and "how it counts," they are more likely to regard the process as fair even when they disagree with particular judgments (Henderson et al., 2025; Reina Marín et al., 2025). RAAF safeguards this through multidimensional, rubric-aligned appraisal and explicit criterion-level justification, ensuring that dialogue centers on concrete elements rather than opaque final scores.

Trust does not equate to uncritical acceptance of AI, but to confidence in the fairness and accessibility of the procedure. Learners know that a human retains final responsibility, that decisions can be explained, and that meaningful recourse exists in cases of disagreement. Empirical findings suggest that acceptance of AI increases when it is clearly positioned as advisory rather than authoritative (Henderson et al., 2025; Jones-Jang et al., 2025; Reina Marín et al., 2025). This principle underpins Stage IV of RAAF, where human validation is documented and recorded.

A decisive condition is the institutionalized right to appeal. Without protected contestability, no degree of accuracy translates into legitimacy (Bulut et al., 2024; Fischer, 2023; Reina Marín et al., 2025). The comprehensive audit trail embedded in RAAF converts appeals into structured processes of re-examination grounded in specific evidence. Trust extends equally to instructors, as the model must preserve their professional autonomy and provide safeguards in quality assurance contexts (Venter et al., 2025; Henderson et al., 2025).

5 Discussion: Implications for Policy, Instructional Practice, and Future Research

This study positions RAAF not merely as a technical workflow but as a governance-oriented reconceptualization of AI-supported assessment. Across recent literature, three convergent findings are evident: large language models can align with analytic rubrics and approximate human judgment in writing and programming contexts (Tang et al., 2024; Tate et al., 2024; Mohamed et al., 2025; Yousef et al., 2025), targeted actionable feedback improves revision quality and learner motivation (Meyer et al., 2024; Fleckenstein et al., 2023; Araujo et al., 2025), and institutional legitimacy hinges on explainability, fairness, and contestability rather than raw accuracy (Fischer, 2023; Bulut et al., 2024; Reina Marín et al., 2025; Memarian & Doleck, 2024). RAAF integrates these strands into a single procedural architecture in which AI outputs are structurally positioned as contestable recommendations rather than authoritative decisions.

Conceptually, RAAF advances a shift from outcome-based to process-based legitimacy in assessment. Instead of asking whether an AI score is correct, the central question becomes whether the pathway leading to a decision is transparent, auditable, and open to challenge. Multidimensional justification and stability flags enable early detection of inconsistency and potential bias (Doewes et al., 2022; Kortemeyer & Nöhl, 2025), while the audit trail transforms appeals from symbolic gestures into evidentiary reconsiderations (Bulut et al., 2024). This design reframes human-in-the-loop from nominal oversight to accountable authorship of final judgments.

At the same time, RAAF exposes structural tensions. Confidence-band escalation and mandatory validation enhance fairness but may constrain scalability (Pack et al., 2024). Actionable feedback accelerates learning yet risks overreliance and stylistic homogenization if not paired with productive friction, such as self-assessment prior to AI consultation (Shi et al., 2025; Ding et al., 2025). These tensions are not failures but boundary conditions that define responsible deployment.

Future research should move beyond proof-of-concept accuracy studies toward experimental implementations that examine how different threshold settings, validation loads, and feedback designs shape learning gains, trust, and workload (Narreddy et al., 2025; Abiad et al., 2025). Under such scrutiny, RAAF can be empirically refined as a model of accountable AI use in educational assessment.

6 Conclusions

This study proposed RAAF as an operational, cyclical framework that connects multidimensional appraisal, formative feedback, instructor-facing diagnostics, and human validation within a process characterized by explicit traceability. A synthetic reading of recent empirical and conceptual literature indicates that the model rests on three interlocking foundations. First, large language models demonstrate practical capacity to align with analytic rubrics and to produce criterion-level, justified evaluations in writing and programming contexts, reaching substantial agreement with human raters when structured appropriately (Tang et al., 2024; Tate et al., 2024; Mohamed et al., 2025; Yousef et al., 2025). Second, targeted, actionable feedback improves product quality, activates revision cycles, and strengthens metacognitive

awareness when embedded in structured pedagogical workflows (Meyer et al., 2024; Fleckenstein et al., 2023; Araujo et al., 2025). Third, institutional legitimacy does not derive from technical accuracy alone but from explainability, fairness safeguards, and contestability mechanisms that position human agents as final decision-makers (Fischer, 2023; Bulut et al., 2024; Reina Marín et al., 2025; Memarian & Doleck, 2024).

Within this architecture, AI is not construed as a substitute for professional judgment but as a recommender that generates inspectable and contestable reasoning. The move from unidimensional scores to multi-criteria, evidence-based judgments enables early identification of instability and bias patterns, strengthening defensibility before inequities become entrenched (Doewes et al., 2022; Kortemeyer & Nöhl, 2025). Simultaneously, the audit trail transforms appeals into structured processes of evidentiary reconsideration rather than exceptional procedural events (Bulut et al., 2024).

The framework also delineates its own boundary conditions. Model variability necessitates confidence estimation and stricter acceptance thresholds in high-stakes contexts (Pack et al., 2024). Moreover, the usability of automated feedback carries risks of overreliance and stylistic homogenization, which require deliberate pedagogical counterbalances such as mandatory self-assessment prior to AI consultation (Shi et al., 2025; Ding et al., 2025).

Overall, RAAF integrates automated assessment, formative feedback, diagnostic analytics, and ethical governance into a coherent architecture of accountable AI use. Future research should prioritize experimental implementations with predefined metrics of effectiveness, stability, and acceptance to delineate conditions of generalizability and refine escalation thresholds and validation loads under authentic deployment scenarios (Narreddy et al., 2025; Abiad et al., 2025).

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Algorithmic Harmony as an Art Form: Artificial Intelligence as a Creative and Ethical Collaborator in Music Education

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Abstract—The interplay between human creativity and machine intelligence in music education is no longer a futuristic concept but a defining feature of contemporary pedagogical practice. Once primarily associated with data processing, Artificial Intelligence (AI) is now entering the domain of artistic creation, assuming an increasingly active role within music education. In today's digital classroom, music educators are called to prepare learners to interact creatively with intelligent systems, to make informed use of their capabilities, and to consider the ethical implications of their integration.

This paper explores how AI can serve as a co-creative partner in music education, supporting students' artistic expression, cognitive development, and social engagement. Evidence from international initiatives—such as Artificial Intelligence for and by Teachers (AI4T) and Magenta Music—suggests that AI integration fosters creativity, self-regulation, and collaborative learning, while simultaneously advancing digital, musical, and artistic literacies. Classroom-based examples further demonstrate that tools like algorithmic composition, sound analysis and synthesis, and adaptive environments responsive to learners' musical profiles enable new forms of experiential, personalized learning.

In these contexts, students are not passive recipients of musical rules but active participants in a dialogic process with algorithmic systems—experimenting, shaping, evaluating, and reimagining musical structures. At the pedagogical level, AI enhances learners' analytical reasoning, creative exploration, and capacity for reflection. Yet the role of the educator remains essential. Intelligent feedback and learning analytics allow teachers to identify patterns, differentiate instruction, and guide intentional artistic growth.

Such developments also raise important ethical and pedagogical questions: Who holds authorship when creative work emerges through human–machine collaboration? How are intellectual property, student data, and creative ownership protected? How can educators recognize and address algorithmic biases that may reinforce dominant aesthetic norms? The paper proposes a framework for ethically grounded music technology, positioning the educator as a mediator between innovation and educational values. Rather than viewing AI as a threat or an end in itself, this approach treats it as an opportunity for critical engagement and pedagogical enrichment.

AI in music education does not displace the educator—it amplifies the possibilities of human creativity. It invites learners to encounter music not only as an expressive art but also as a mathematical, cognitive, and emotional experience. Within this envisioned

paradigm, algorithms and human agency form a dynamic partnership. The educator becomes a curator of meaning, helping students navigate aesthetics, truth, and ethical awareness in a digital soundscape. In this light, AI does not eclipse the soul of music—it illuminates it, offering new creative pathways when placed in service of education and humanity.

Keywords: Artificial Intelligence, Music Education, Creativity, Personalized Learning, Co-creation

1. Introduction

Music education has long been a field in which relational engagement, creativity, and ethical responsibility function as core pedagogical principles. Rather than focusing solely on the transmission of knowledge or the development of technical skills, it offers a space for experiential learning, personal expression, and meaningful social interaction. Within this pedagogical framework, educational practice in music is deeply connected to the cultivation of aesthetic sensitivity, empathy, and students' capacity for both creative and critical thought.

The emergence of Artificial Intelligence (AI) within the educational landscape does not disrupt this tradition; instead, it reconfigures it—prompting renewed reflection on the role of technology in learning. Research shows that, when implemented thoughtfully, AI can serve as a supportive educational tool, enhancing student engagement, enabling responsive feedback mechanisms, and facilitating more personalized and effective learning experiences (Holmes, Bialik, & Fadel, 2019). Thus, the core challenge in education is not the technological innovation itself, but the pedagogical interpretation and meaningful integration of such advancements into practice.

From both artistic and cognitive perspectives, music offers fertile ground for exploring more profound forms of human–machine collaboration. Its inherently creative nature encourages experimentation, dialogue, and open-ended exploration—conditions that invite the coexistence of human intention and algorithmic input. In this context, AI can serve as a medium for expanding musical thought and reflection, without diminishing the central role of the human creator.

Within the theoretical framework of music education as relationship and coexistence—developed in Μουσική Παιδεία σε «ΣΥ» (Music Education in "SY", evoking both "with" and the musical tonality of B/Si; Markea, 2025)—learning is understood as a co-construction of meaning. Musical practice is rooted in the learner's relationship with sound, with others, with the self, and with culture. From this perspective, Artificial Intelligence is not seen as an autonomous creator but as a pedagogical interlocutor—one that enters the learning relationship and supports both creative exploration and critical inquiry.

The integration of AI into music education should not, therefore, be viewed as a technocratic decision, but as a significant pedagogical undertaking. It demands sustained reflection, robust theoretical grounding, and a continuous ethical awareness—ensuring that technology ultimately serves the human subject, the relational dynamics of learning, and music as a cultural and artistic practice.

2. Artificial Intelligence and Education: A Pedagogical Framework

Artificial Intelligence (AI) in education is now widely acknowledged as a technology with considerable potential to enhance personalized learning, offer high-quality feedback, and foster students' active engagement in the learning process (OECD, 2021). Recent systematic reviews in the field of music education emphasize that the pedagogical integration of AI presents a complex array of challenges and opportunities, requiring conceptual clarity and carefully constructed educational frameworks (Merchán Sánchez-Jara et al., 2024). AI-based applications are capable of analyzing

learning patterns, customizing content to meet individual learner needs, and supporting ongoing formative assessment. However, the true educational significance of AI lies not in its technical sophistication or automation capabilities, but in how effectively it is embedded within learner-centered and socioculturally informed pedagogical approaches.

Current pedagogical perspectives stress that AI should complement and support—rather than replace—the human dimensions of the teaching–learning relationship (Holmes, Bialik, & Fadel, 2019). Learning continues to be understood as a fundamentally social and experiential process, shaped through human interaction, meaningful dialogue, and reflective engagement. From this vantage point, AI can serve as a powerful tool for enriching educational experiences, provided that its design and implementation are governed by clearly defined pedagogical intentions and purposes.

In the context of music education, technology has followed a long and evolving trajectory of integration into teaching and learning. From the initial use of digital tools for composition and audio recording to the development of interactive platforms for musical creation, technology has consistently acted as a means of expanding artistic experience and supporting creative expression (Markea, 2014). These tools have enabled learners to explore sound, structure, and form in innovative ways, promoting experiential, inquiry-based, and exploratory modes of learning.

Building on this tradition, Artificial Intelligence introduces new possibilities for musical analysis, generative creativity, and adaptive learning. These advances reshape the roles of both learners and educators. Students are invited to take an active role in shaping musical outcomes, evaluating algorithmic suggestions, and developing a critical understanding of automated outputs. Educators, in turn, gain powerful tools for observing, guiding, and supporting learning without diminishing their central pedagogical agency.

The core challenge, therefore, lies not in the adoption of AI as an innovation per se, but in the establishment of pedagogical frameworks that align technological use with learning, creativity, and relational understanding. In this view, AI functions not as an educational end in itself, but as a means of pedagogical empowerment.

At the level of educational leadership and supervision, the integration of AI into music education highlights the need for shared pedagogical principles and a common conceptual foundation. The conversation surrounding AI thus moves beyond isolated teaching practices, calling for a collective, coherent, and ethically grounded approach to technology in music education—one that prioritizes educational quality, continuity, and meaningful learning experiences.

3. Artificial Intelligence as a Co-creator in Music Learning

The concept of co-creation stands as a foundational principle in contemporary music pedagogy, shifting the focus away from the final musical product and toward the processes of musical thinking, creative inquiry, and interaction. Within this framework, music learning is no longer viewed as an individual or passive activity, but rather as a dynamic, dialogic process rooted in experimentation, collaboration, and the construction of meaning. When integrated thoughtfully and with pedagogical intent,

Artificial Intelligence (AI) can enhance and support this process by serving as a medium for co-creation and reflective engagement.

AI systems based on generative algorithms and machine learning models enable collaborative musical creation by offering melodic, harmonic, and structural suggestions derived from the analysis of large-scale musical datasets (Briot, Hadjeres, & Pachet, 2020). These systems do not replace students' musical ideas; instead, they expand them, encouraging learners to critically engage with algorithmic output by selecting, modifying, or rejecting suggestions in light of their own artistic judgment.
In a representative classroom scenario, a student experiments with a melodic fragment while interacting with alternative harmonic pathways proposed by an AI tool. The goal is not to identify a single "correct" solution, but to engage in creative decision-making: accepting, altering, or discarding algorithmic proposals based on musical intention. In this way, the learning process shifts from replication to reflective exploration, fostering intentional and informed musical thinking.

AI can function as a mirror of the creative process, generating alternative interpretations that reveal paths not previously imagined by the learner. Through such dialogic interaction, students are invited to confront their own creative identity, reflect on their musical choices, and develop a more nuanced, critical stance toward the outcomes of their work (Boden, 2016). In this evolving model, the algorithm does not impose aesthetic standards, but acts as a generative prompt for exploration, discovery, and artistic inquiry.

A defining feature of co-creation is that AI lacks human attributes such as intention, emotional depth, and aesthetic sensitivity. These inherently human dimensions emerge through lived musical experience and pedagogical mediation. As such, students are not expected to adopt algorithmic output uncritically, but to interpret and embed it within frameworks of personal meaning and artistic purpose.

Human–machine co-creation in music education thus nurtures analytical, evaluative, and metacognitive capacities. It challenges learners to compare, discern, and justify their artistic decisions, while cultivating confidence in their creative agency. In this context, AI is best understood as a dialogic partner—one that stimulates inquiry and reflection rather than providing authoritative answers.

Within the broader theoretical lens of music education as relationship and coexistence—as formulated in Music Education in "SY" (Markea, 2025)—the idea of co-creation also carries distinct ethical implications. Music-making is not limited to sound production but encompasses the formation of attitudes grounded in collaboration, mutual respect, and responsibility. Viewed from this perspective, Artificial Intelligence can serve as a pedagogical companion that enables and supports creative exploration, without displacing or substituting the central role of human musical thought.

4. Personalized Learning and the Role of the Educator

Personalized learning is widely recognized as a central objective in the integration of Artificial Intelligence (AI) into education, as it seeks to align the learning process with each student's individual needs, capacities, and interests (Holmes et al., 2019). In this context, AI systems are capable of analyzing learning data, identifying developmental

patterns, and delivering targeted feedback, thereby enhancing student engagement and fostering the development of self-regulated learning.

In the music classroom, the importance of personalized learning is further amplified due to the considerable diversity among students in terms of prior musical experience, proficiency levels, and creative inclinations. Adaptive AI systems can accommodate different learning paces and varying degrees of complexity, allowing learners to interact with music in ways that reflect their unique artistic profiles. Empirical research suggests that such approaches can significantly increase motivation, promote self-directed learning, and improve the overall efficacy of music instruction—provided, of course, that these technologies are embedded within a clearly defined pedagogical framework (Diraksin et al., 2025). Through this approach, music education transitions from uniform instructional models to more personalized pathways, while still preserving the communal and socially constructed nature of musical experience.

However, personalization must not be conflated with the automation of teaching. The educator's role remains essential, as pedagogical judgment, interpretation of data, and the cultivation of learning relationships cannot be outsourced to technology. As emphasized by Markea (2014), technology does not replace the teacher; rather, it extends the teacher's capacity to observe, assess, and intervene meaningfully.

In this redefined landscape, the music educator assumes the role of a curator of meaning—designing learning experiences that integrate technological tools with artistic intention and pedagogical purpose. When used thoughtfully, AI-based resources allow educators to identify learner needs, tailor instruction responsively, and foster reflective engagement with musical practice. In such arrangements, technology does not dictate the learning process but is intentionally embedded within a pedagogical structure shaped by the educator.

Ultimately, the value of AI in personalized music learning depends on its intentional and critical use. When technological tools are aligned with relational pedagogy, creativity, and clear instructional goals, AI becomes an empowering resource for both learners and educators—supporting a human-centered and pedagogically grounded vision of music education.

5. Ethical Issues and Creative Responsibility

The collaboration between humans and machines in musical creation raises complex and pressing questions around intellectual property, creative authorship, and algorithmic bias—issues that are particularly significant in educational contexts (OECD, 2021). When musical works emerge from the interaction of human intention and algorithmic processes, critical considerations arise regarding authorship, accountability for creative choices, and the ownership and appropriate use of the resulting artistic outputs.

In music education, such questions cannot be adequately addressed through purely technical or legal frameworks. Critical pedagogical perspectives emphasize the need to foster AI-related critical literacy—equipping students with the capacity to understand, question, and interpret algorithmic outputs in a meaningful way (O'Leary, 2025). What is needed is a pedagogical and ethical lens, as these concerns are inherently tied to the

formation of students' values, reflective dispositions, and ethical awareness. Algorithmic bias, for instance, may reinforce dominant aesthetic paradigms and limit creative diversity if not mediated by intentional and reflective teaching strategies (Boden, 2016). In this context, educators have a vital role to play in revealing the assumptions, constraints, and contextual foundations of AI systems, helping learners to critically analyze the origins and implications of algorithmic decision-making.

Within the theoretical framework of Music Education in "SY" (Markea, 2025), the cultivation of ethical awareness is understood as a core component of music education. Musical practice is conceptualized as a relational activity, grounded in responsibility—to oneself, to others, and to the wider cultural environment. From this viewpoint, AI is not a neutral or passive tool, but a pedagogical agent that must be intentionally situated within a value-driven educational context.

When used deliberately and reflectively, AI can become a catalyst for ethical inquiry, creativity, and dialogue. Students are encouraged to reflect not only on the outcomes of their artistic work, but also on the means and processes that mediate creation. In this light, AI can be reimagined—not as a threat—but as a resource for ethical reflection and creative empowerment.

Ultimately, the ethical use of AI in music education transcends compliance with rules or policies; it entails cultivating a responsible, critical, and human-centered engagement with technology. When framed pedagogically, AI can support artistic expression while safeguarding human creativity and ethical agency.

6. Conclusions

Artificial Intelligence is transforming music education—not as a technological endpoint, but as a means of reimagining the relationship between learning and creative practice. Its educational value lies not solely in computational capability, but in its potential to enable new modes of pedagogical interaction, creative exploration, and individualized learning—when thoughtfully embedded within a coherent, value-driven educational framework (Holmes, Bialik, & Fadel, 2019; OECD, 2021).

Given its artistic, experiential, and social nature, music education offers a uniquely fertile ground for exploring the interplay between human intention and algorithmic processes. In this context, AI can serve as both a creative and pedagogical collaborator, enriching musical thinking, supporting reflective practice, and expanding possibilities for co-creation—without compromising human agency or ethical responsibility. Music learning becomes a dialogic endeavor in which technology acts as a stimulus for inquiry, rather than as an authoritative guide.

The educator's role remains indispensable. Teachers are responsible for framing AI's use pedagogically and ensuring that it serves the learner and the educational relationship. Within the theoretical model of Music Education in "SY" (Markea, 2025), music education is intrinsically linked to the cultivation of both creativity and ethical awareness. From this standpoint, Artificial Intelligence does not undermine the essence of musical humanity; rather, it has the potential to illuminate it—when situated within an educational vision that prioritizes relationality, responsibility, and music as a living cultural practice.

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Educators and Professional Development for the Utilisation of Large Language Models (Large Language Model)

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Abstract—A Large Language Model (LLM) is a form of Artificial Intelligence trained on vast quantities of text data, capable of understanding, generating, and processing human language in a near-natural manner. These models constitute Generative AI, meaning they are trained to create logical sequences similar to human reasoning. As a subset of AI, they focus on the creation of new, original content (text, images, audio, video, and code) rather than merely analysing or classifying existing data. Prominent examples of LLMs include OpenAI's GPT, Microsoft's Copilot, and Google's Gemini.

Keywords— Large Language Model, Training, Educators, Prompt Engineering, Persona

Introduction

This article explores the professional evolution of educators through the strategic integration of Large Language Models (LLMs). We provide a definition of these computational frameworks and analyze their practical applications in enhancing pedagogical efficacy. Furthermore, the analysis addresses the critical ethical and systemic concerns surrounding their implementation, offering a balanced critique of the risks and responsibilities inherent in deploying AI within the academic landscape.

Applications of Large Language Models

LLMs can be utilized for text generation. However, to achieve optimal results, it is advisable to provide a description of the subject, the intended purpose, the specific objective, and the target audience. They offer the capability to summarise text or other materials. Similarly, they can explain or enrich text once the desired output style has been defined. For example: *"Enrich the initial text by adding details, examples, and a professional tone to create study notes for Year 9 pupils."* This category also includes translation, offering significantly more options than Google Translate; for instance: *"Please translate and explain this specific text to me in 50 words."*

Essentially, they can be employed for the following tasks (Voultsiou & Moussiades, 2025):

- Text comprehension and analysis.
- Interaction and dialogue (e.g., virtual assistants).
- Personalised learning materials or acting as tutors for practical exercises. They can also generate, debug, or explain computer code.

Concerning strategies the exploration of Large Language Models (LLMs) are powerful tools in teacher training. (Cukurova et al. 2024) suggest that AI assistants can create realistic classroom challenges for teachers to practice in a safe environment. These tools can also identify a teacher's specific strengths and weaknesses to build a personalized training plan. The addition of AI-generated images and videos, training becomes much more engaging. Trainers should start experimenting with these tools to make learning more personal and interactive.

To facilitate these processes, LLMs are trained using high-performance processors during their development. Simultaneously, users refine these models through iterative use, tailoring them to individual needs and specific linguistic objectives.

It is now considered highly beneficial for educators to undergo professional development to learn how to request information in a clear, specific, and targeted manner. The terminology for this is Prompt Engineering. Specifically, this involves defining a Persona, where the LLM is asked to act as an expert (e.g., *"Act as a secondary school mathematics teacher"*). It also involves Formatting, such as requesting results in a specific layout (e.g., *"The response should be in table format"* or *"Provide a 100-word summary"*), and using conversation history to refine results (Chain-of-Thought prompting).

Chain-of-Thought (CoT) is a prompting technique used to compel an LLM to present all intermediate reasoning steps rather than simply providing a final answer. This

process can enhance the multi-step logical reasoning capabilities of the model. CoT forces the LLM to generate intermediate justifications, providing a series of reasoning steps. Other aspects, such as the relevance of justifications to the query and the correct sequence of steps, are crucial for effective CoT reasoning (Boshi et al., 2023). CoT is significant because it improves accuracy; by forcing the model to produce a thought chain, the risk of reaching a false conclusion is dramatically reduced. Furthermore, it allows the user to see the model's logic and better internalise the answer. In the event of an incorrect response, while it does not "guarantee" correct steps, it allows for easier identification of the error (Mukherjee et al., 2025).

Educators must be aware that the model returns answers based on probabilities and patterns, rather than actual knowledge or consciousness. This can lead to the generation of false information (hallucinations). Beyond personal awareness, teachers have a responsibility to instruct students on the necessity of verifying information using external sources. Carrascosa (2025) suggests practical techniques for mitigating hallucinations. This highlights the need to develop a sense of digital citizenship and a responsible attitude in both teachers and students. Consequently, a comprehensive understanding of how LLMs can be utilised in education is essential. Teachers should aim to integrate LLMs into their pedagogy rather than using them merely for task completion. Furthermore, LLMs can increase active participation, particularly among diverse learner groups (Lauermann & König, 2016).

According to Luckin & Cukurova, (2019) the implications of AI for education and teacher professional development can be categorised into three groups of activities:

1) Design and use of AI technologies to support teaching and learning
2) Educating people about AI so they can use it effectively and ethically
3) Innovation in education to prepare people for an AI-driven world

We believe that innovating education systems, involves rethinking how we teach and learn bearing in mind AI’s growing influence. This cannot ignore AI into teaching methods for more process-oriented teaching.

Specific uses of LLMs by educators include:

- Adapting education to diverse student needs: This remains a challenge, particularly in multilingual environments. LLMs are significant aids in creating differentiated exercises and learning examples, aimed at reaching students from different cultural backgrounds and varying levels of proficiency in the language of instruction. Even for primary-level mathematics or language teaching, LLMs have been developed (primarily in the Anglophone world and often via subscription) to provide assistant services for differentiated instruction. They allow for the creation of personalised exercises for students struggling with specific concepts. Research by Wang et al. (2025) explored how LLMs can improve personalised learning experiences to enhance overall educational quality. They propose the design of personalisation guidelines to direct LLMs in creating bespoke learning plans. Systems such as LearnMate, based on LLMs, provide real-time support and tailored plans.
- Differentiation and material production: LLMs allow for the creation of materials at varying levels of complexity or linguistic difficulty. Povey (2024) investigated LLMs in educational material design, focusing on how tailored content can meet diverse linguistic, academic, and cultural needs. Case studies

indicate that AI-based tools can enhance the relevance and adaptability of educational resources.

- Lesson planning and feedback: Hu et al. (2025) concluded that LLMs can assist in pre-lesson preparation. While they can be used for grading and feedback, tests have shown that numerical scores provided by LLMs can be inconsistent and lack a scientific basis. LLMs tended to provide positive evaluations regardless of quality, potentially because language models are less sensitive to numerical values. Therefore, the focus should remain on the model's linguistic comprehension, role-play capabilities, and self-reflection. Self-reflection is a metacognitive process involving the critical examination of beliefs and experiences to better guide actions. Inexperienced teachers often require such reflection to revise their materials (Smith, 1996). Due to a lack of experience, these teachers may struggle to predict student difficulties (Hill et al., 2008). Utilising LLMs to enhance lesson plans before teaching provides novice educators with higher-quality content and ideas, reducing risks associated with inadequate preparation (Hu et al., 2025). However, continuous adaptation to specific classroom dynamics and teacher skills remains necessary.
- Assessment of student submissions: As text generation has become effortless for students, educators must develop new strategies for assignment design. Tasks should require critical thinking, analysis, and personal experience—elements LLMs cannot convincingly replicate. For example: *"Evaluate how the use of Twitter would change the way citizens are informed about a specific event, using three specific sources."* Furthermore, clear rules regarding LLM use should be established, such as prohibiting them for final deliverables. Assessment should be used to foster the development of critical thinking, teamwork, and problem-solving skills (Martínez-Peláez et al. 2025).

Since AI technology seems to be very important Yan et al. (2023) suggest that the tools used in education settings should improve with the newest AI technology. The results should be shared openly to the public, and make sure everything that is build is designed with people's needs in mind.

Concerns

Purpose-built AI tools can save time and help create engaging, accessible, and personalised learning environments. However, concerns persist regarding data protection. Piri (2024) emphasises the importance of continuous education for both students and teachers, alongside guidelines for responsible use. Service design must comply with data protection legislation and prioritise privacy. As Generative AI continues to evolve, its impact on privacy will remain a significant issue, necessitating robust regulations.

Ethical Considerations: AI tools do not typically cite their sources and may produce biased results based on their training data. If student data is entered, users must be aware of how it is collected and used. These challenges can be used as teaching moments to help students critically evaluate information for bias or inaccuracies. The effective use of LLMs in education requires careful navigation of associated ethical and practical challenges, including data privacy, content bias, sustainability, regulatory compliance, and other critical considerations (Guizani et al. 2025).

Human Interaction: Even the best LLM applications cannot replace face-to-face interaction with peers and teachers, which is vital for developing social-emotional skills. A balance between LLM-assisted learning and traditional methods is recommended to maintain student motivation and engagement.

Technological Dependency: Despite the benefits, over-reliance on technology may negatively impact students' critical thinking and problem-solving skills.

Conclusion

As AI is an evolving field with an uncertain future, it is essential to harness its potential for the benefit of humanity within an ethical framework. Professional development for educators is crucial, as it can significantly aid their work. Teachers should understand what LLMs are, what they offer, and how they can be used, while also being aware of potential pitfalls. Training should include the use of AI detectors to identify AI-generated content, many of which are free and designed for educators. Finally, it is vital that students learn to use and cite their sources correctly, ensuring every resource used in their work is properly documented.

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Artificial Intelligence and Music in French as a Foreign Language Teaching: A Multimodal Pedagogical Approach

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Abstract—The rapid integration of Artificial Intelligence (AI) into educational contexts has reshaped teaching and learning practices, particularly in foreign language education. This paper explores the pedagogical potential of combining AI technologies with music as a multimodal resource for teaching French as a Foreign Language (FFL), proposing an applied, learner-centred instructional approach grounded in multimodality, creativity, and experiential learning.

Drawing on research from cognitive neuroscience and applied linguistics, which highlights the strong interconnection between music and language processing, the study situates music as a powerful facilitator of phonological awareness, memory retention, pronunciation accuracy, and emotional engagement. These effects are further amplified through the use of generative AI tools that enable learners to actively produce, transform, and reinterpret linguistic input across multiple semiotic modes, including text, sound, image, and voice.

The paper presents a classroom-based didactic scenario entitled *L'auteur des rêves*, in which learners collaborate with AI tools to create a coherent multimodal artefact. Specifically, students generate song lyrics in French with the support of large language models, compose music using AI-driven composition tools, design visual narratives through image-generation applications, and integrate synthetic voice technologies for oral narration. This process promotes intersemiotic translation, encouraging learners to move meaningfully between linguistic, musical, and visual representations.

From a pedagogical perspective, the approach supports personalised learning pathways, learner autonomy, and active engagement, aligning with communicative and task-based language teaching principles. AI functions not as a substitute for the teacher, but as a cognitive and creative partner that enriches instructional design and enables differentiated learning experiences within limited classroom time. At the same time, the paper emphasises the importance of developing AI literacy, enabling learners to critically evaluate AI-generated outputs, recognise system limitations, and address issues related to authorship, originality, and data ethics.

The study also addresses the evolving role of the teacher in AI-enhanced environments, highlighting the need for educators to act as learning designers, facilitators, and ethical

mediators. Teacher expertise remains central in setting linguistic objectives, scaffolding learning processes, and fostering reflective and responsible AI use.

Overall, this contribution positions AI-supported musical multimodality as an innovative and transferable pedagogical approach for foreign language education. It contributes to current discussions on practical applications of AI in teaching and learning, teacher professional development, and ethical integration of emerging technologies, offering a concrete example of how AI can support creative, inclusive, and human-centred language learning in the 21st century.

Keywords— Artificial Intelligence, Multimodality, Music-Based Language Learning, French as a Foreign Language (FLE), Creative Pedagogy

Introduction

In recent years, the rapid development of Artificial Intelligence (AI) has significantly influenced educational practices, reshaping teaching methodologies and redefining the roles of educators and learners alike (Holmes et al., 2019; Luckin et al., 2016). In foreign language education, AI technologies have opened new perspectives for personalised learning, creative engagement, and multimodal interaction, moving beyond traditional text-centred approaches (Godwin-Jones, 2018).

At the same time, research in language pedagogy increasingly highlights the pedagogical value of the arts, and particularly music, as a powerful mediator of linguistic, cognitive, and affective processes in language learning (Murphey, 1992; Fonseca-Mora, 2000). Music facilitates pronunciation, rhythm, intonation, and lexical retention, while fostering emotional involvement and learner motivation. When combined with visual and narrative elements, music contributes to the creation of multimodal learning environments that promote deeper comprehension and long-term language acquisition (Paivio, 2006; Mayer, 2009).

Within this context, the integration of AI technologies offers new possibilities for the creative exploitation of musical material in the foreign language classroom. Rather than positioning AI as a replacement for the teacher, this paper conceptualises AI as a pedagogical partner that extends established didactic practices and supports learner autonomy, creativity, and experiential learning (Holmes & Tuomi, 2022).

This study explores the pedagogical potential of combining music and Artificial Intelligence in the teaching of French as a Foreign Language (FFL). The proposed approach is illustrated through a small-scale didactic scenario entitled *L'auteur des rêves*, in which learners collaborate with AI tools to create a multimodal artefact integrating written text, music, images, and oral narration. By situating music-based pedagogy within an AI-enhanced framework, the paper contributes to current discussions on innovation in foreign language education and highlights the conditions under which AI-supported artistic practices can foster meaningful and transformative learning experiences.

2. Pedagogical and Theoretical Framework

2.1 Multimodality in Foreign Language Learning

Multimodality refers to the use of multiple semiotic modes—such as language, image, sound, gesture, and movement—in the construction of meaning (Kress, 2010). According to social semiotic theory, learning is enhanced when learners engage with content through diverse modes that activate complementary cognitive and sensory channels (Jewitt, 2008).

In foreign language education, multimodal environments facilitate comprehension and memory retention by allowing learners to process linguistic input through combined verbal, visual, and auditory representations (Paivio, 2006). Research indicates that multimodal instruction supports learner engagement and motivation while fostering the development of multiple literacies, including visual, media, and digital literacies, which are essential in contemporary educational contexts (New London Group, 1996; Cope & Kalantzis, 2015).

2.2 Music as a Cognitive and Affective Resource in Language Learning

Music occupies a central place within multimodal pedagogy due to its strong cognitive and affective dimensions. Neurocognitive studies suggest that music and language share overlapping neural mechanisms, particularly in the processing of rhythm, intonation, and prosody (Patel, 2008). These shared pathways explain the positive impact of musical activities on pronunciation accuracy, fluency, and phonological awareness in foreign language learning (Besson et al.,2011)
In addition to its cognitive benefits, music plays a significant affective role by reducing learner anxiety and creating emotionally engaging learning environments (Krashen, 1982; Fonseca-Mora, 2015). Songs provide authentic linguistic input embedded in meaningful cultural contexts, thereby supporting intercultural awareness and learner motivation. The repetitive and rhythmic nature of music further enhances lexical acquisition and long-term retention (Murphey, 1992).

2.3 Pedagogical Exploitation of Song in the Foreign Language Classroom

The didactic use of songs in foreign language teaching has been extensively explored within communicative and action-oriented approaches (Boiron, 2018). Songs are not merely motivational tools, but structured pedagogical resources that can support listening comprehension, phonological awareness, vocabulary development, and creative language use (Boiron, 2018).

Effective pedagogical exploitation of songs requires a systematic progression of activities that guide learners from global comprehension to linguistic analysis and creative production (Krashen, 1982). Principles and practice in second language acquisition. Oxford: Pergamon.. This process is commonly organised into three main phases: pre-listening, while-listening, and post-listening activities (Boiron, 2018).

Phase	Didactic Objectives	Sample Activities
Pre-listening	Activation of prior knowledge, prediction, emotional engagement	Discussing themes, visual prompts, key vocabulary
While-listening	Global and selective comprehension, phonological awareness	Identifying keywords, rhythm and intonation tasks
Post-listening	Linguistic reuse, creativity, production	Rewriting lyrics, composing new verses, role-play

Table 1. Pedagogical phases in song-based language teaching

Song-based pedagogy also promotes learner creativity and autonomy by encouraging students to transform and reinterpret musical material. Learners may rewrite lyrics, compose alternative endings, or create visual and narrative representations of songs, thereby engaging in higher-order cognitive processes such as interpretation, synthesis, and creation (Kress, 2010).

Dimension	Pedagogical Contribution
Linguistic	Pronunciation, vocabulary retention, syntactic awareness
Cognitive	Memory, pattern recognition, inferencing

Dimension	Pedagogical Contribution
Affective	Motivation, emotional engagement, reduced anxiety
Cultural	Intercultural awareness, authentic language exposure
Creative	Imagination, narrative construction, artistic expression

Table 2. Didactic benefits of song exploitation in the foreign language classroom

Through these practices, songs function as mediators between language, emotion, and culture, supporting experiential and learner-centred approaches to foreign language education (Littlewood, 1981).

2.4 Artificial Intelligence as an Extension of Music-Based and Multimodal Pedagogy

Within the pedagogical framework outlined above, Artificial Intelligence can be understood as an extension of established multimodal and music-based practices rather than a disruptive innovation. AI tools enable the creation, transformation, and personalisation of multimodal content, allowing learners to engage actively with language through the integrated production of text, sound, image, and voice.

Generative AI technologies, in particular, support creative language use by enabling learners to co-construct songs, narratives, and visual artefacts in the target language. This shift from consumption to production aligns with constructivist and action-oriented approaches, reinforcing learner agency and student empowerment.

When embedded within a sound pedagogical framework, AI functions as a mediating tool that amplifies the educational potential of music and multimodality, while maintaining the central role of the educator as designer, facilitator, and critical guide of the learning process.

3. Intervention Methodology and Didactic Scenario: L'auteur des rêves

This chapter presents the methodological framework and the didactic scenario *L'auteur des rêves*, which illustrates a multimodal approach to teaching French as a Foreign Language (FFL) through the integrated use of Artificial Intelligence (AI) tools. The proposed scenario is grounded in multimodal pedagogy and music-based language teaching, aiming to create a learning environment where text, sound, image, and voice interact dynamically (Jewitt, 2008).

Within this framework, AI is conceptualised as a pedagogical mediator that supports creativity, differentiation, and learner engagement. Students are guided to collaboratively produce a complete multimodal artefact—song lyrics, music, visual representations, and oral narration—using a sequence of AI tools that correspond to specific linguistic and pedagogical objectives.

3.1 ChatGPT: Personalisation and Linguistic Production

ChatGPT, as a Large Language Model (LLM), offers significant pedagogical affordances for foreign language teaching, particularly in the areas of written production, interaction, and personalised feedback. Recent studies indicate that the use

of ChatGPT can enhance learners' writing skills and conversational competence by providing immediate, adaptive support tailored to individual proficiency levels (Kohnke et al., 2023; Çobanogullari, 2024).

In the proposed scenario, ChatGPT is primarily employed for the guided production of song lyrics in French. The teacher designs prompts that include explicit grammatical, syntactic, and thematic constraints, aligned with curricular objectives. For example, learners may be asked to generate lyrics incorporating specific subjunctive structures (*il faut que, bien que, je doute que*) at a B1 level, within a meaningful thematic context.

Example prompt:
"Écris une chanson sur un rêve à Paris, destinée à des apprenants de niveau B1, en utilisant au moins trois phrases avec le subjonctif."
Such prompt design ensures that the generated output is pedagogically relevant while remaining creative. Learners subsequently analyse, revise, and enrich the AI-generated text, transforming ChatGPT into a tool for formative feedback and metalinguistic reflection (Halliday, 2004). This process supports differentiated instruction, particularly in heterogeneous classrooms, where learners progress at different paces.

3.2 Suno AI: Music Production as a Pedagogical Act

Suno AI is a text-to-song platform that enables users without formal musical training to generate complete musical compositions, including melody, harmony, and instrumentation. Within the didactic scenario, Suno AI allows learners to transform their French lyrics into fully realised songs, thereby integrating language learning with musical creation (Chang, 2025).

Research suggests that the use of AI-generated music in educational contexts can lead to improved engagement and content retention compared to traditional instructional methods (Amal & Shofiyuddin, 2025). By removing technical barriers related to musical expertise, Suno AI transforms the classroom into a creative laboratory where all learners can participate equally.

A critical pedagogical component of Suno AI use is **musical prompt engineering**. Learners and teachers must consciously define musical parameters—such as genre, tempo, instrumentation, and emotional tone—to ensure coherence between linguistic meaning and musical expression.

Parameter	**Pedagogical Function**	**Example Prompt**
Lyrics	Linguistic production and structure	[Verse 1] Dans un café à Paris...
Style	Genre and atmosphere	*French pop, jazz manouche, tempo 120 bpm*
Instrumentation	Cultural and aesthetic coherence	*accordion, violin*
Effects	Expressive nuance	*(second voice, echo)*

Table 3. Pedagogical Parameters for Using Suno AI

Through this process, learners assume the dual role of lyricists and composers, reinforcing the connection between linguistic intention and musical expression (Jäncke, 2012).

3.3 Gemini (Imagen & Storybook) and Grok: Visual and Kinetic Representation

Following the linguistic and musical phases, visual representation plays a central role in completing the multimodal artefact. Gemini (Imagen/NanoBanana and Storybook) and Grok are employed to support image creation, narrative development, and short video generation.

Gemini Imagen allows learners to generate and edit images based on detailed textual prompts, such as album covers or visual scenes inspired by song lyrics. Storybook supports the creation of short multimodal narratives that combine text, voice, and music. Grok complements these tools by enabling the transformation of static images into short animated sequences, enhancing narrative dynamism.

The pedagogical value of these tools lies in the development of visual literacy, as learners learn to select and design visual elements that reinforce linguistic meaning (Kress, 2010). Teachers play a crucial role in guiding learners toward precise and meaningful prompt formulation in French, ensuring that visual production remains aligned with learning objectives.

3.4 ElevenLabs: Voice, Pronunciation, and Oral Interaction

ElevenLabs is a text-to-speech platform that produces highly realistic synthetic voices in multiple languages, including French. In the proposed scenario, it is used to support pronunciation practice, oral comprehension, and role-play activities.

The tool allows learners to convert written texts into spoken language, create narrated videos, and engage in simulated dialogues with historical or fictional characters. Such applications provide opportunities for repeated listening, phonological awareness, and oral rehearsal in a low-anxiety environment (Mavropoulou & Arvanitis, 2024).

For example, learners may interact with a simulated monologue by Jules Verne, practising comprehension and response production at an A2–B1 level. This role-play dimension transforms oral practice into an immersive and motivating experience.

3.5 Summary of the Didactic Scenario

AI Tool	Mode	Pedagogical Objective
ChatGPT	Text	Writing, grammar, interaction
Suno AI	Music	Rhythm, memory, emotional engagement
Gemini / Grok	Image & Video	Visual literacy, narrative coherence
ElevenLabs	Voice	Pronunciation, oral fluency

Table 4. Multimodal Mapping of AI Tools and Pedagogical Objectives

Overall, the *L'auteur des rêves* scenario demonstrates how AI tools can be orchestrated within a coherent pedagogical design to support multimodal, creative, and learner-centred foreign language learning. AI does not replace the teacher but extends instructional possibilities, reinforcing the educator's role as designer, facilitator, and critical mediator of learning.

4. Pedagogical and Ethical Implications

Artificial Intelligence (AI) has emerged as a transformative force in contemporary education, reshaping teaching and learning practices through applications that range from personalised learning environments to innovative instructional designs. In the field of foreign language education, and particularly in French as a Foreign Language (FFL), the integration of AI offers significant pedagogical opportunities while simultaneously raising important ethical and professional considerations that must be addressed with transparency and responsibility.

The pedagogical use of AI tools does not constitute a neutral technological intervention. Rather, it redefines classroom interactions, redistributes agency between teachers, learners, and digital systems, and calls for a critical reflection on issues related to authorship, data protection, and educational equity.

4.1 Redefining the Pedagogical Relationship and the Role of the Teacher

The introduction of AI into the language classroom reshapes the role of the teacher, shifting it from that of a primary transmitter of knowledge to that of a learning designer, facilitator, and ethical mediator. AI-supported environments enable differentiated and personalised learning paths, allowing learners to progress at their own pace and to engage with content that reflects their individual interests and needs (Klimova et al., 2024).

Despite these affordances, AI does not replace the teacher. On the contrary, the teacher remains the central pedagogical agent responsible for setting clear linguistic objectives, scaffolding learning processes, and fostering critical reflection on AI-generated content. Teachers guide learners in evaluating, revising, and contextualising AI outputs, ensuring that language learning remains meaningful and goal-oriented.

Moreover, the educator assumes a crucial ethical role by raising learners' awareness of issues related to data privacy, algorithmic bias, and responsible AI use. As Reiss (2021) argues, ethical reflection must be embedded within pedagogical practice, particularly when digital tools influence learners' cognitive and creative processes. In this sense, AI-enhanced instruction reinforces—rather than diminishes—the professional responsibility of the teacher.

4.2 The Need for AI Literacy

The increasing accessibility of generative AI tools, such as ChatGPT and Suno AI, highlights the urgent need to develop AI literacy among learners (Liu & Wang, 2025). AI literacy extends beyond the technical ability to operate digital tools; it encompasses an understanding of how AI systems function, their limitations, and the potential inaccuracies they may produce, particularly in less widely represented languages.

Learners must be explicitly trained to critically assess AI-generated content, identify linguistic or semantic errors, and actively revise outputs rather than accepting them uncritically. Additionally, issues related to originality, authorship, and intellectual property require careful pedagogical attention. Students need to be informed about licensing conditions, the differences between free and paid versions of AI applications, and the extent to which generated content can be reused or modified (Wang, 2024).

By integrating AI literacy into language education, teachers empower learners to engage with AI tools responsibly and reflexively, transforming them from passive users into informed and critical participants in digital learning environments.

Conclusion

The proposed multimodal teaching approach, integrating AI tools and music into the teaching of French as a Foreign Language, was designed to enhance linguistic production, foster creativity, promote collaboration, and develop learners' AI literacy. While the didactic scenario was developed specifically for French, its pedagogical principles are transferable to the teaching of foreign languages more broadly.

Through the combined use of AI-generated text, music, image, and voice, language learning is repositioned as a dynamic process of creative meaning-making rather than the acquisition of a static system of rules. AI tools contribute to the creation of learning environments where learners actively experiment with language, negotiate meaning, and express themselves through multiple semiotic modes.

The pedagogical benefits of this approach are multifaceted. Creative experimentation enables learners—regardless of prior musical or artistic experience—to produce complex multimodal artefacts, thereby enhancing motivation and self-confidence. Furthermore, the neurocognitive interaction between language and music, amplified through AI-supported tools, facilitates memory retention and phonological accuracy, offering learners a deeply engaging and experiential learning process.

Equally important is the emphasis on intersemiotic translation, understood as the transfer of meaning across modes—from text to sound and image—which cultivates higher-order cognitive skills and critical literacy. Learners do not merely acquire communicative competence in French; they develop the ability to navigate, connect, and critically evaluate knowledge within complex digital ecosystems.

In conclusion, the effective implementation of this pedagogical approach presupposes a teacher who acts as an orchestrator of learning, balancing technological innovation with ethical responsibility. AI-enhanced multimodality offers a powerful framework for language teaching practices that respond to the educational challenges of the 21st century, rendering the learning of French—and foreign languages in general—a deeply human, creative, and pedagogically meaningful endeavour.

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Factors and Ethical Issues in Integrating Artificial Intelligence in Education: A Scoping Review Through the Lens of General Systems Theory

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Artificial Intelligence and Innovation in Education:
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Abstract—This paper examines the factors influencing the integration of Artificial Intelligence (AI) in Education (AIED), as well as the ethical issues and challenges that emerge, as mapped through a scoping review. The review focuses on the international literature on AIED integration through the lens of General Systems Theory (GST). GST is adopted as a theoretical framework aligned with related approaches, such as Dynamic Systems Theory and Socio-Technical Systems Theory, because it enables a holistic understanding of the complex, dynamic relationships among people, pedagogical processes, and technologies that constitute educational practice, and it conceptualizes education as a system of interdependent parts.

The review was conducted in the Scopus and ERIC databases and was complemented with backward and forward snowballing in IEEE Xplore, Semantic Scholar, and Google Scholar. Eligibility criteria included peer-reviewed publications in English, with no time restrictions, addressing AIED integration, with a direct or indirect connection to GST or a related derivative theory. The review followed the stages proposed by Arksey and O'Malley, and database searching was guided by the PRISMA-ScR protocol, resulting in the retrieval of 12 articles. A thematic analysis of the included studies was conducted following Braun and Clarke's framework. Hybrid coding, combining inductive and deductive approaches, was implemented using ®MAXQDA Analytics Pro, a qualitative data analysis software. Findings indicate that AI should not be approached as an isolated tool but as a transformative element of the educational process. Five categories of interdependent factors were identified as shaping large-scale, smooth integration of AIED: policy factors, human factors, pedagogical factors, technological factors, and systemic factors. In addition, a broad range of ethical issues and challenges associated with the use and adoption of AIED is documented, in full alignment with the international literature.

Overall, the findings suggest that integrating AIED requires a holistic approach and a deep understanding of relationships and interactions among educational components and the factors that influence responsible adoption, alongside the recognition and management of the ethical issues and challenges that such integration entails.
Keywords - Artificial Intelligence in Education (AIED), General Systems Theory (GST), scoping review, AIED integration factors, ethical issues and challenges.

Introduction

Artificial Intelligence (AI) is rapidly reshaping educational practice, not only by adding new tools to existing workflows but also by reconfiguring how teaching, learning, and assessment are designed, implemented, and evaluated (Holmes et al., 2019). As AI tools are embedded in everyday educational activity, questions about "effective integration" extend beyond technical adoption. They increasingly involve the alignment of pedagogical goals with technological affordances, the readiness and adaptability of educators and learners, institutional governance and policy, and the ethical conditions in which AI tools are introduced and used (Chassignol et al., 2018; Zawacki-Richter et al., 2019; Chen et al., 2020, 2022; Wang et al., 2024). At the same time, the integration of AI in Education (AIED) has surfaced a wide range of ethical issues and practical challenges. These issues usually relate to responsible use, transparency, accountability, privacy and data protection, fairness and bias, autonomy, and the broader implications of automation within learning environments. Ethical concerns do not emerge in isolation: they are shaped by context (e.g., governance arrangements, institutional capacity, and pedagogical design), and they can, in turn, influence stakeholders' trust, acceptance, and patterns of use. Consequently, understanding the conditions for responsible AIED integration requires a perspective that can capture both what the key factors are and how they interact as a part of a wider educational system (Xu & Ouyang, 2022).

General Systems Theory, introduced by Bertalanffy (1968), provides a comprehensive framework for analyzing complex systems across disciplines. Systems are conceptualized as sets of interacting elements that continuously exchange information, feedback, and adaptive responses, thereby generating emergent properties absent in isolated components. GST conceptualizes education as a system, composed of interdependent parts (students, educators, learning content, technological tools, educational policies, etc.) and emphasizes relationships, feedback, and dynamic interaction among system components. In this framework, AIED integration can be examined as a systemic change process rather than a sterile implementation of new technological tools. GST is also conceptually aligned with related approaches, such as Dynamic Systems Theory and Socio-Technical Systems Theory, which similarly highlight complexity, emergence, and the co-evolution of human activity and technological infrastructures (Chen & Stroup, 1993; Banathy & Jenlink, 2004). By adopting a GST oriented view, AIED can be approached as a sociotechnical and pedagogical transformation that extends throughout multiple levels (classroom, institution, policy), involving multiple stakeholders and interacting integration factors.

Although the literature on AIED has grown substantially, research findings remain scattered across different disciplines and educational levels. Many studies focus either on particular tools and applications, or on single dimensions of adoption, (e.g., usability, attitudes, or learning outcomes) (Chen et al., 2020; Ng et al., 2025). This fragmentation can make it difficult to build an integrative understanding of how policies, human factors, pedagogical choices, technological characteristics, and systemic conditions co-determine the quality and effectiveness of AIED integration. Therefore, a systemic approach that synthesizes this landscape is valuable, especially one that makes interdependencies visible and supports more coherent decision-making for large-scale, sustainable, and ethical integration. To address this need, this paper presents a scoping review of the international literature on AIED integration through

the lens of GST. The review follows the stages proposed by Arksey and O'Malley and is guided by the PRISMA-ScR protocol. The review was conducted in the Scopus and ERIC databases and was complemented with backward and forward snowballing in IEEE Xplore, Semantic Scholar, and Google Scholar. Eligible studies are peer-reviewed publications in English, without time restrictions, focusing on AIED integration with a direct or an indirect connection to GST or a derivative systemic theory. 12 studies were retrieved and thematically analyzed, following Braun and Clarke's framework, using a hybrid (inductive–deductive) coding strategy implemented in MAXQDA Analytics Pro.

Guided by this approach, the study aims to: identify and organize the main factors that influence AIED integration, map the ethical issues and challenges associated with AIED adoption and use, and interpret these findings in a way that highlights systemic interdependencies and supports a holistic understanding of responsible integration. In line with this aim, the review is oriented around the following research questions (RQ):

- **RQ1:** What categories of factors are reported to influence the integration of AI in Education when examined through a GST oriented perspective?
- **RQ2:** What ethical issues and challenges are documented in relation to AIED adoption and use?
- **RQ3:** How do these factors and ethical considerations relate to one another as interdependent components of the educational system?

The contribution of this paper is threefold. First, it provides a structured mapping of the AIED integration landscape under a systemic lens, emphasizing relationships and interactions rather than isolated factors and issues. Second, it synthesizes evidence into five interdependent categories of factors, policy, human, pedagogical, technological, and systemic, which shape the prospects for a large-scale integration. Third, it highlights the range of ethical issues and challenges reported in the literature and positions them as important considerations in the design of AIED integration efforts.

The next section describes the methodology of the scoping review, including search strategy, eligibility criteria, and analytic procedures. The Results section presents descriptive characteristics of the included studies and the thematic synthesis of integration factors and ethical issues. The Discussion interprets the findings through a GST oriented view and outlines implications for stakeholders and future research. Finally, the Conclusion summarizes the key insights, limitations, and directions for further work.

Methods

This study employed a scoping review design to map and synthesize the literature on the integration of AIED through the lens of GST and related derivative systems perspectives. The review process followed the methodological stages proposed by Arksey and O'Malley, and the reporting of the search and selection process was guided by the PRISMA-ScR framework. A structured database search was conducted in Scopus and ERIC. To capture additional relevant studies that may not be indexed consistently across those two databases, the review was complemented with backward and forward snowballing using IEEE Xplore, Semantic Scholar, and Google Scholar. Search terms were designed to capture three core elements:

- Artificial Intelligence in Education (e.g., artificial intelligence, AI, machine learning, intelligent systems, generative AI where applicable),
- Education context and integration/adoption (e.g., education, teaching, learning, classroom, higher education, integration, adoption, implementation), and
- Systems-theory framing (e.g., general systems theory, systems thinking, socio-technical systems, dynamic systems).

An example of the search query that was used, is presented in Figure 1.

```
TITLE-ABS-KEY ( ( "Artificial Intelligence" OR "AI" ) AND ( "Education" OR "Educational" OR "Education* System*" ) AND ( "Systems Theory" OR "General Systems Theory" OR "Complex Systems" OR "System Dynamics" OR "Complex Dynamic System*" OR "Ecosystem" ) ) AND PUBYEAR > 1997 AND PUBYEAR < 2026 AND ( LIMIT-TO ( PUBSTAGE , "final" ) ) AND ( LIMIT-TO ( DOCTYPE , "ar" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) )
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Figure 1. Scopus search query

The final search strategy was adapted to the syntax and indexing conventions of each database. The snowballing procedure was applied iteratively by scanning reference lists of included studies (backward) and examining papers that cited them (forward), adding records that met the eligibility criteria. Studies were included if they met all of the following criteria, as presented at table 1.

Table 1. Inclusion and exclusion criteria

N	Criteria	Inclusion	Exclusion
1	Period	Any period (no restrictions)	-
2	Language	English	Non-English
3	Thematic Relevance	AIEd, GST, and derivative theoretical frameworks such as ST, DST, Educational Ecosystems, etc.	Articles that do not explicitly or implicitly incorporate ST concepts in education; articles related to GST/ST without reference to education
4	Educational Level and Context	Any (no restrictions)	-
5	Country of Origin	Any (no geographical restrictions)	-
6	Access	Full Access	Limited access (abstracts only) or unavailable versions
7	Type of Publication	Peer Reviewed Articles	Preprints, unpublished, non-peer-reviewed articles, “grey” literature.

Records that did not focus on AIED integration (e.g., purely technical AI papers without educational integration implications), did not involve an educational context or lacked a meaningful systems-theory connection, were excluded. The research, held on June 2025, followed the PRISMA-ScR flow diagram (Page et al., 2021) and returned 453 articles. After the removal of duplicates, 428 records were title and abstract screened. Studies without a concrete theoretical framework or unrelated to education (e.g., diagnostic uses of Large Language Models, LLMs), chatbot performance, medical training, or engineering courses on AI/ST) were excluded. In total, 401 articles were discarded and four articles were inaccessible. In total, 17 articles proceeded to full-text review, during which thematic familiarization and data charting were initiated (Braun

& Clarke, 2006; Arksey & O'Malley, 2005). Five were subsequently excluded, resulting in a final sample of 12 studies, as presented in Figure 2 (PRISMA-ScR 2020; Tricco et al., 2018).

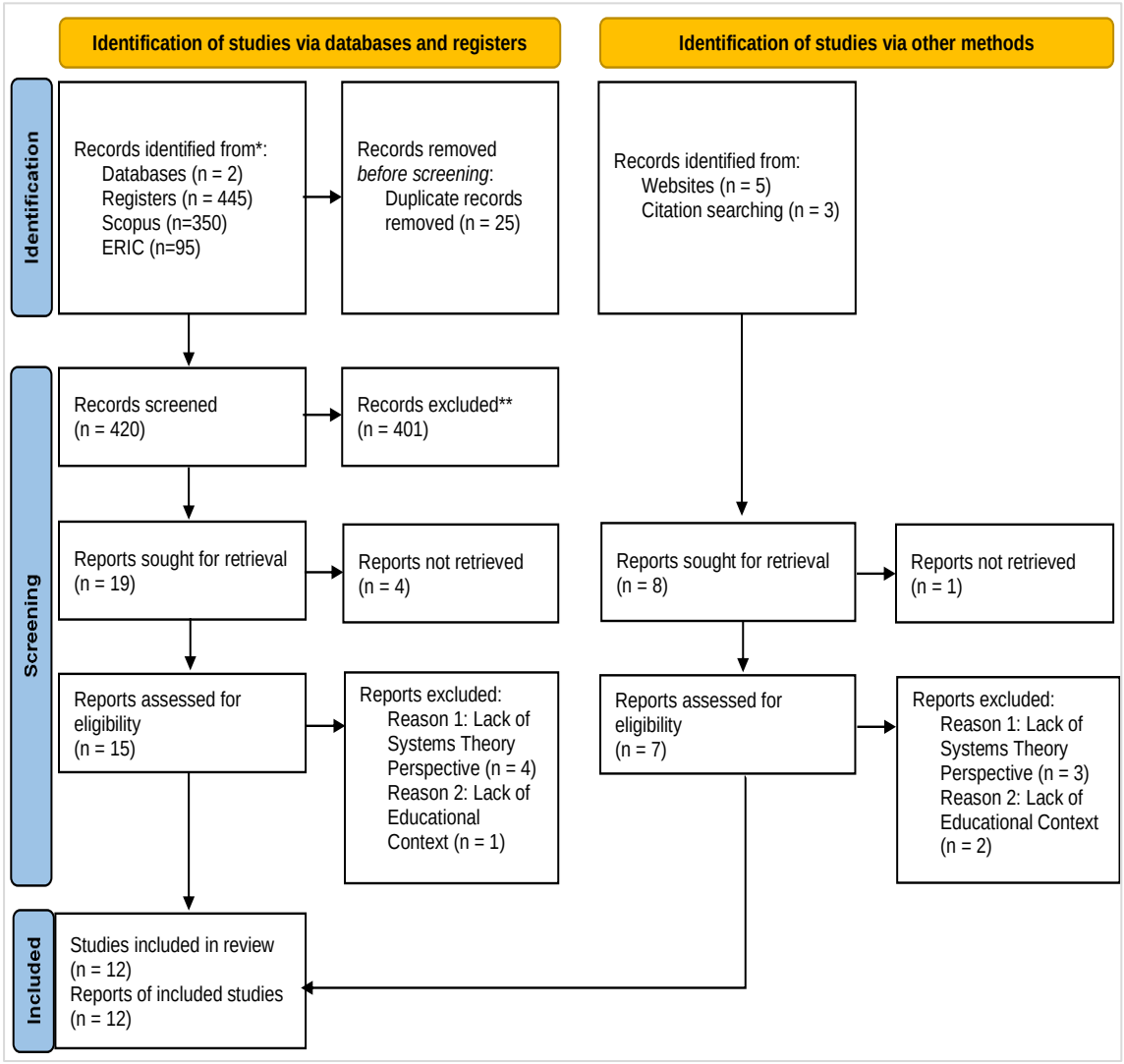


Figure 2. PRISMA-ScR flow diagram (Page et al., 2021)

To synthesize evidence across heterogeneous study designs and contexts, the review used thematic analysis following Braun and Clarke's (2006) framework. A hybrid coding strategy was applied, combining deductive coding informed by the review's systemic lens (GST and related approaches), and inductive coding to allow themes to emerge directly from the included studies (Braun & Clarke, 2012).

Coding and theme development were supported using MAXQDA Analytics Pro. Themes were repetitively refined by reviewing coded segments, merging overlapping concepts, and organizing findings to make interdependencies visible. Validity was strengthened through transparent inclusion criteria, a structured charting approach, and the consultative involvement of a second reviewer to discuss ambiguous cases and improve consistency of decisions. Throughout analysis, themes were checked against source data to ensure that interpretations remained aligned with the included studies.

Results

As summarized in the PRISMA-ScR flow diagram (Figure 2), the search and selection process resulted in a final corpus of 12 included studies. The list of the 12 articles is presented in Table 2.

Table 2. List of included studies

N	Year	Authors	Title	Journal
A1	2008	Moise G.	*A Formal Description of the Systemic Theory based e-Learning*	*International Journal of Computers, Communications & Control*
A2	2020	Guleva V., Shikov E., Bochenina K., Kovalchuk S., Alodjants A., Boukhanovsky A.	Emerging Complexity in Distributed Intelligent Systems	Entropy
A3	2022	Jing L., Gao X., Song X., Xu L.	System Dynamics-Based Analysis on Factors Influencing Artificial Intelligence Talents Training	IEEE Journal of Radio Frequency Identification
A4	2022	Xu W., Ouyang F.	The Application of Artificial Intelligence Technologies in STEM Education: A Systematic Review From 2011 to 2021	International Journal of STEM Education
A5	2023	Gibson D., Kovanovic V., Ifenthaler D., Dexter S., Feng S.	Learning theories for artificial intelligence: Promoting learning processes	British Journal of Educational Technology
A6	2024	Katsamakas E, Pavlov O. V., Saklad R.	Artificial Intelligence and the Transformation of Higher Education Institutions: A Systems Approach	Sustainability
A7	2024	Watson S, Romic J.	ChatGPT and the entangled evolution of society, education and technology: A systems theory perspective	European Educational Research Journal, Advance online publication
A8	2024	Zhang Y, Dong C.	Exploring the Digital Transformation of Generative AI-Assisted Foreign Language Education: A Socio-Technical Systems Perspective Based on Mixed-Methods	Systems
A9	2024	Zhang Y, Dong C.	Unveiling the Dynamic Mechanisms of Generative AI in English Language Learning: A Hybrid Study Based on fsQCA and System Dynamics	Behavioral Sciences
A10	2025	Memarian B., Doleck T.	Education with a systems theory and control perspective	Education and Information Technologies
A11	2025	Wang J., Zhang X.	Exploring the Role of AI Technology in Shaping College Students' English Writing Development: Insights from the Complex Dynamic Systems Theory	Journal of Azerbaijan Language and Education Studies
A12	2025	Zha H., Li W., Wang W., Xiao J.	The paradox of AI empowerment in primary school physical education: Why technology may hinder, not help, teaching efficiency	Behavioral Sciences

Descriptive Characteristics of the Articles

As illustrated in Figure 3, research activity in the field of the integration of AIEd from a systemic perspective was largely inactive from 2008 to 2019, with only a single publication in 2008. A noticeable increase is observed after 2020, culminating in a peak of four publications in 2024, followed by three publications in 2025.

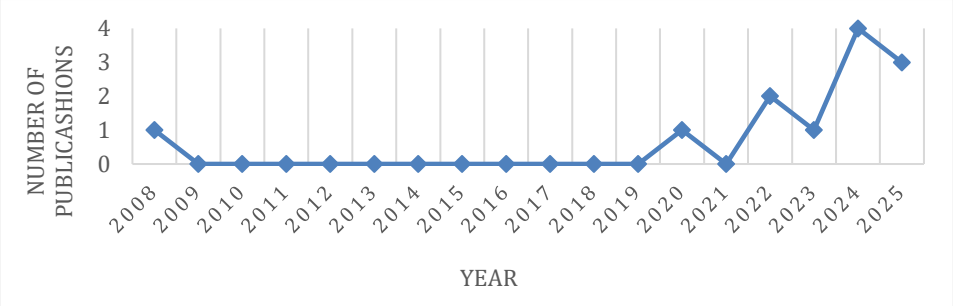


Figure 3. Number of publications per year

The articles cover the following geographical range: six studies were conducted by research teams in China, two by researchers in the United States of America (USA), two in Europe (United Kingdom and Romania), one in Russia, and one through international collaboration among researchers from Australia, the United States, Germany, and China. Concerning educational levels and fields of application, most articles focus on higher education (A2, A3, A6, A8, A9, and A11), with specific emphasis on foreign language instruction (A8, A9, and A11) and STEM education (A4). One article examines primary education, specifically physical education (A12). Two articles address distance or online education (A1 and A2). The remaining articles do not target a specific educational level or subject area (A5, A7, and A10).

The theoretical frameworks and approaches used to study the integration of AIEd from a systemic perspective, the analysis revealed that the dominant frameworks are CDS Theory and the systemic approach. A list of the theoretical frameworks is presented in Table 3.

Table 3. Theoretical frameworks in studies of AI integration in education

Systemic Theoretical Background	Number	Article
General Systems Theory (GST)	2	A4, A10
Systems Theory (ST)	1	A7
Socio-Technical Systems Theory (STST)	2	A8, A12
Complex Dynamic/Adaptive Systems Theory (CDS/CAD)	2	A1, A11
Systemic Approach (without explicit reference)	5	A2, A3, A5, A6, A9

As shown in Table 3, most studies adopted a systemic perspective without explicit reference to a single framework, followed by GST, STST, and CDS/CAD. The category "Other Theories and Frameworks" (e.g., TAM, UTAUT, TPACK) was not treated separately, as these models serve as supporting tools rather than interpretive frameworks and appeared in only two studies. Overall, the systemic approach, understood as a perspective conceptualizing education as a system, emerged as the dominant orientation.

Regarding methodological approaches, five studies were empirical (A3, A8, A9, A11, A12), five theoretical without a defined methodological framework (A1, A2, A5, A6, A7), and two systematic reviews (A4, A10). Among the empirical studies, three used mixed methods, one quantitative (test scores), and one qualitative. Of the theoretical works, two were purely conceptual, while three employed system modeling through mathematical equations or causal loop diagrams.

Results of Thematic Analysis

The thematic analysis showed two main themes: “Integration Factors” and “Ethical Issues and Challenges”.

Regarding the theme “Integration Factors,” five categories of factors were identified: policy factors, human factors, technological factors, pedagogical factors, and systemic factors. The latter constitute the novel finding highlighted by the present mapping. The categories are outlined in Table 4.

Table 4: Integration Factors

Code	Subcode	Discription	Example
Factors (RQ1)	Policy Factors	References to factors related to governance, educational policy, regulatory frameworks, and related issues.	“Unclear School Policies: Ambiguous or frequently changing guidelines for AI implementation.” (Zha et al., 2025, p. 15).
	Human Factors	References to factors related to attitudes, skills, concerns, and acceptance-related issues, among others.	“For instance, teachers’ technology beliefs, innovation orientations, and professional competencies significantly influence their adoption and adaptation of AI-based tools in pedagogical practices [30].” (Zhang & Dong, 2024a, p. 4).
	Technological Factors	References to technological factors such as accessibility, compatibility, infrastructure, etc.	“Device and System Incompatibility: Technical conflicts between AI tools and existing school infrastructure.” (Zha et al., 2025, p. 11).
	Pedagogical Factors	References to pedagogical factors such as instructional approaches, the role of the teacher/educator, and related aspects.	“In this approach, all factors that affect the learning - motivation, goals, previous knowledge, interest, teaching styles, learning styles, classroom climate, parents, preoccupations, hobbies, etc. - represent the perturbations.” (Moise, 2008, p. 5).
	Systemic Factors	References related to overall systemic behaviour and the role of AI as an input to educational environments, including the emergence of system properties, links to ethical issues, and related considerations.	“Performance outcomes can be damaging if transparency, open discussion, and contribution from all interested parties in the process are absent.” (Memarian & Doleck, 2025, p. 11).

Policy factors relate to issues of governance, educational policy, regulatory frameworks, and related institutional arrangements. Human factors involve stakeholders’ attitudes, skills, concerns, and issues of technology or AI acceptance, among others. The included studies also referred to technological factors, such as the compatibility of AI tools, the availability and adequacy of technical infrastructure, internet connectivity, and cost considerations. In addition, the literature included references to pedagogical factors, including the selection of appropriate pedagogical practices, the transformation of the teacher’s role, adjustments to instructional goals or teaching methods, learning styles, and the management of cognitive load, among other aspects. Finally, several references were classified under systemic factors, which relate to overall system behavior and to the role of AI as an input within educational

environments. These references primarily emphasized the interconnection of multiple factors, their links to ethical issues, and the need for continuous feedback and system adaptation in response to new data and emerging conditions. For example, the statement "Performance outcomes can be damaging if transparency, open discussion, and contribution from all interested parties in the process are absent." was coded as a systemic factor because it does not pertain exclusively to any single category; rather, it foregrounds the interaction among all actors involved in the educational process and its connection to the ethical issue of transparency.

Based on the frequency distribution chart, a total of 69 references relate to policy factors were identified across the literature (approximately 27% of all references), and 68 references are associated with human factors (also approximately 27%). Technological factors account for about 20% of the references, while approximately 19% relate to pedagogical factors. The systemic factors identified represent 7% of the total.

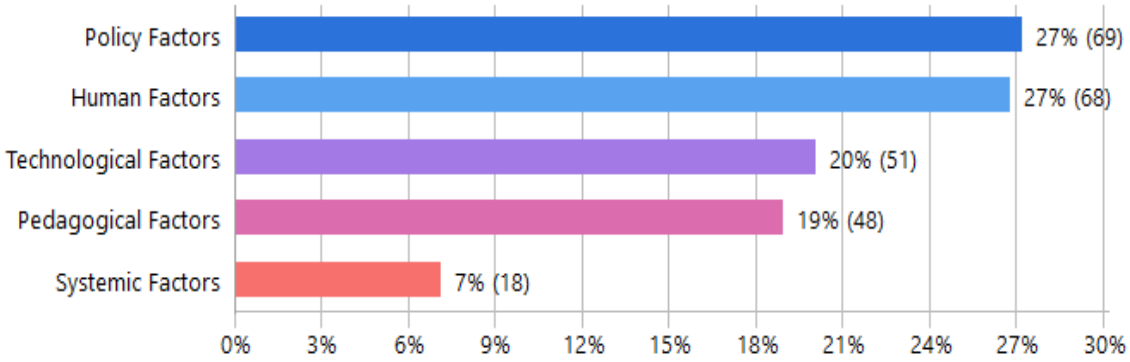


Figure 4: Frequency percentage of code occurrences for Integration Factors

A broad range of ethical issues and practical challenges is documented across the included studies, broadly consistent with the international discourse on responsible AIED. Rather than appearing as standalone concerns, these issues are repeatedly connected to the conditions of integration and to the interactions among system components. These issues are academic integrity, consent and transparency, specifically regarding data and algorithms, as well as algorithmic bias and trust. To avoid unnecessary elaboration, given that the ethical issues cited have already been identified across numerous publications, we focus briefly on the category of general ethical issues, which consists of small clusters of references. In other words, topics represented by only one, two, or three to four references, and therefore not forming a standalone category, were grouped under this broader category. This category includes references related to accessibility and exclusion, as well as other, less obvious concerns. For example, the statement "The environmental impacts, carbon and water footprints, and energy consumption of AI data centers are also concerning" highlights the environmental impact of AI use, an issue that also constitutes an ethical concern. Table 5 presents the ethical issues in five categories.

Table 5: Ethical Issues

Code	Subcode	Discription	Example

Ethical Issues (RQ2)	Academic Integrity	References related to academic integrity and the use of AI tools for cheating and plagiarism.	"In higher education, the rapid adoption of ChatGPT brings excitement about opportunities for learning as well as concerns about challenges, such as students cheating on their assignments [6], for instance, by asking ChatGPT to write an essay about any topic [7]." (Katsamakas et al., 2024, p. 1)
	Consent and Transparency	References to issues of consent and transparency regarding algorithms, data, and information.	"Transparency and explainability are hot topics, especially with the 'black box' nature of many algorithms." (Watson & Romic, 2024, p. 219).
	Algorithmic Bias	References to algorithmic bias.	"Algorithmic bias is another significant concern [71]. Algorithms may reinforce decision biases when evaluating student work, admissions, job placements, etc." (Katsamakas et al., 2024, p. 5).
	Trust	References related to trust in AI, the provision of information lacking accuracy or validity, and the generation of false content.	"Learners' self-regulated learning strategies, metacognitive skills, and trust in AI systems also play a crucial role in determining the effectiveness and sustainability of AI-assisted language learning [25]." (Zhang & Dong, 2024a, p. 3).
	General Ethical Issues	General references to ethical concerns, such as access to AI, the exclusion of social groups, and related issues.	"The environmental impacts, carbon and water footprints, and energy consumption of AI data centers are also concerning [78]." (Katsamakas et al., 2024, p. 6).

Figure 5 presents the frequency of references related to ethical issues. Specifically, 28% concern general ethical issues, 22% relate to privacy and security, and 22% also relate to trust. 13% of the references concern academic integrity, 9% relate to algorithmic bias, and, finally, 8% concern consent and transparency. Notably, general ethical issues account for the largest share, simply because they are aggregated (i.e., they combine multiple low-frequency issues into a single broader category).

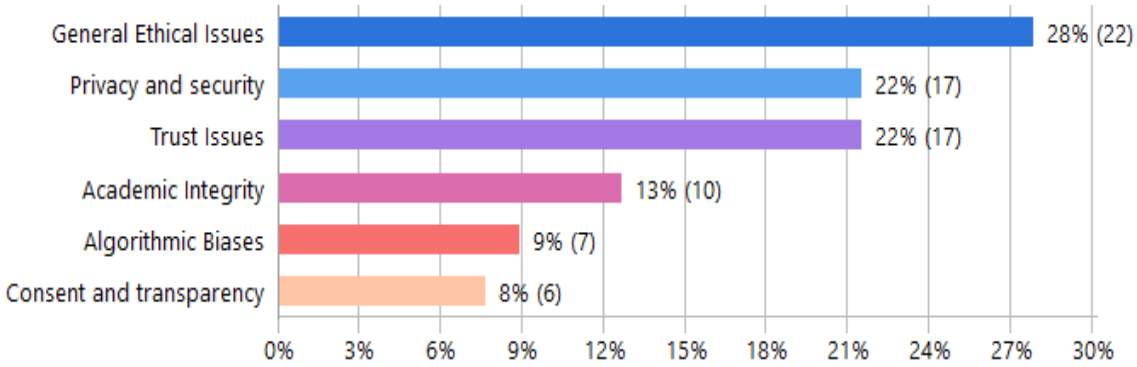


Figure 5: Frequency percentage of code occurrences for Ethical Issues

The identification of these factors and the ethical issues that arise highlights the interaction of different elements within the pedagogical, organizational, and social environment, elements that operate in combination and can either facilitate or hinder the integration of AI into the educational process.

All data from the scope of the reviewed literature concerning the factors and ethical issues associated with the smooth integration of AIED through a systems approach are presented in Figure 6 in the form of a brief Causal Loop Diagram (CLD). The CLD summarizes the most important interrelations among the key factors[57] identified in the literature review. Specifically, it depicts relationships among the main policy, pedagogical, technological, human, and systemic factors influencing AIED integration, where the "+" symbol indicates a positive causal relationship and "–" indicates a negative causal relationship.

What is particularly noteworthy is the linkage and interaction among all the reported factors. In the diagram, policy factors are shown in red, human factors in orange, pedagogical factors in blue, technological factors in green, and systemic factors in purple. Several examples of causal relations are illustrated. The presence of long-term planning and a clear institutional framework strengthens technological and AI-related literacy and, at the same time, creates the conditions for educators' professional development and training. This, in turn, increases the likelihood of appropriate instructional design and the selection of learner-centered and collaborative methods by the educators, which subsequently support the effective management of cognitive load required for wide-scale and smooth AIED integration. Conversely, the absence of long-term planning, combined with mandatory implementation and administrative pressure, reduces the presence of a supportive environment while increasing negative attitudes and distrust. A supportive environment can enhance positive attitudes and trust, whereas negative attitudes and distrust diminish them. Finally, the provision of resources and infrastructure can reduce both AI tool incompatibility and usage costs, factors that tend to increase negative attitudes and distrust and to decrease positive attitudes and trust.

[57] Only a subset of factors that appeared frequently in the thematic analysis was included. Unfortunately, it was not possible to represent all factors and all causal relationships among them because the diagram would become overly complex.

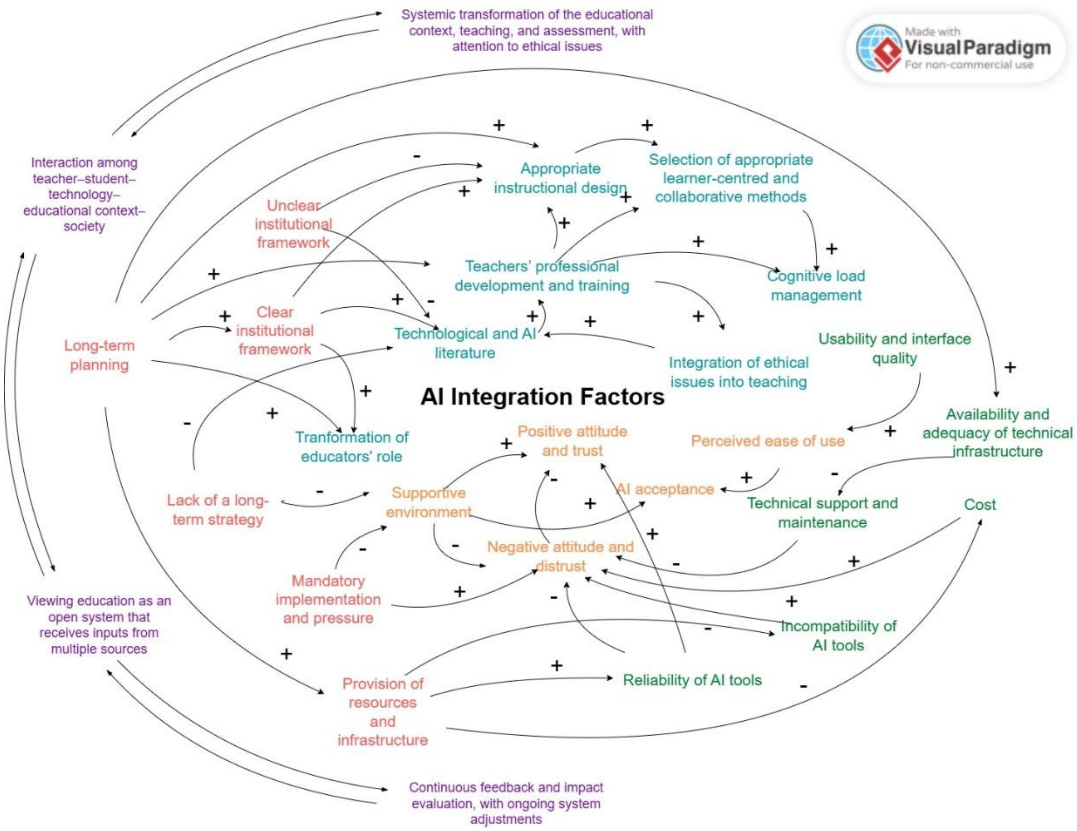


Figure 6: Causal loop diagram AI integration factors

In the following section, these findings are interpreted and situated in relation to the existing literature.

Discussion

Despite the fact that important AIED integration reviews do not explicitly adopt a systems-theory lens (Zawacki-Richter et al., 2019; Chen et al., 2022; Wang et al., 2024), a clear pattern emerges: while AI is widely recognized as influencing multiple interdependent educational dimensions, explicit Systems Theory oriented studies remain relatively limited. This aligns with literature noting the limited use of systemic perspectives in AI integration research (Xu & Ouyang, 2022; Gibson et al., 2023; Zhang & Dong, 2024b; Memarian & Doleck, 2025). Notably, Wang et al. (2024) found that more than half of 125 AIED integration studies used no theoretical framework, and that the remainder drew on diverse theories, yet without explicit reference to GST/Systems Theory or derivative theories.

Most of the studies identified in the present mapping were published within the last five years (Figure 3), suggesting emerging interest in systemic framings. Half of the included papers emphasize the relevance of a systems approach particularly in Higher Education, consistent with broader AIED review evidence that university contexts dominate the field (Zawacki-Richter et al., 2019; Wang et al., 2024; Xu & Ouyang, 2022). Several studies also justify systemic framings by treating specific subject domains, (e.g., foreign language education, STEM, physical education, etc.), as complex systems. Finally, the diversity, and occasional mismatch, between methodological approaches and tools may reflect the absence of a unified educational theory base; however, within systems-oriented research, the proliferation of closely

related theories can also challenge conceptual clarity, methodological coherence, and cumulative knowledge building (Wang et al., 2024).

The thematic synthesis indicates that systems-oriented AIED research conceptualizes AI as a dynamic, complex systemic phenomenon, not as an isolated instructional tool, consistent with General Systems Theory (Bertalanffy, 1968) and later systemic conceptions of education (Banathy, 1991; Senge, 2006). Across the included studies, AIED integration is portrayed as non-linear, multifactorial, and adaptive, requiring attention to interdependencies among pedagogical practice and educational governance (Holmes et al., 2019). The dense interlinking of codes further suggests that key concepts are rarely meaningful in isolation but must be interpreted through their relationships to other system elements.

More broadly, the reviewed literature frames AI as a transformative and potentially disruptive force within educational ecosystems, reinforcing a holistic view that integrates human attitudes and interactions, organizational support structures, policy conditions, and wider societal context, an orientation that resonates with sociotechnical systems thinking (Trist & Bamforth, 1951, as cited in Abbas & Michel, 2025; Luckin et al., 2016; Holmes et al., 2019). The interdependence of integration factors also aligns with calls for institutional leadership support and sustained professional development for educators (Holmes et al., 2019; Xu & Ouyang, 2022; Yim et al., 2024). Finally, recurring concerns around privacy, trust, and transparency underline that AI is not value-neutral; rather, it embeds ethical and social implications, strengthening the case for responsible and ethically grounded integration frameworks (UNESCO, 2019, 2021; Ng et al., 2021; European Commission, 2022; Memarian & Doleck, 2023).

Based on the results and the discussion sections of this paper, the research questions are answered as followed:

- RQ1: The GST-informed synthesis identified five interdependent categories of factors shaping AIED integration: policy, human, technological, pedagogical, and systemic factors (the systemic category emerging as the key additional contribution of this mapping).
- RQ2: The review documented ethical issues and challenges related to academic integrity, consent and transparency, algorithmic bias, trust (e.g., inaccurate/invalid or false content, data privacy, etc.), and a broader set of general ethical concerns (e.g., access, exclusion, environmental impact), alongside frequent references to privacy and security.
- RQ3: Factors and ethics function as tightly coupled system components: policy and governance shape acceptable use and accountability; human readiness and trust condition adoption; pedagogical design mediates how AI is used; and technological affordances/constraints influence both practice and risk—while ethical issues (e.g., privacy, transparency, fairness) emerge from, and feed back into, these interactions, requiring continuous feedback and system adaptation.

Limitations and directions for future research

This review has several limitations. The small number of included articles and the exclusion of grey literature (e.g., reports, dissertations, conference proceedings) may have led to the omission of relevant studies. Restricting the search to English-language

publications may also have excluded significant contributions in other languages. The limited corpus constrained the use of advanced statistical tools in ®MAXQDA, restricting the analysis to qualitative thematic exploration. Consequently, while the findings identify clear research trends and categories, they cannot be generalized quantitatively.

Future research can build on these results in several ways. Expanding searches to additional databases and languages could improve coverage and capture context-specific perspectives. Empirical work that explicitly operationalizes GST constructs, such as feedback loops, system boundaries, and cross-level alignment, could strengthen explanatory power and translate systemic insights into measurable implementation indicators.

Conclusion

This scoping review mapped the relevant international literature on the integration of Artificial Intelligence in Education (AIED) through the lens of General Systems Theory (GST). Searches in Scopus and ERIC, complemented by backward and forward snowballing in IEEE Xplore, Semantic Scholar, and Google Scholar, yielded 12 eligible studies, which were analyzed using thematic analysis (Braun & Clarke) with a hybrid inductive–deductive coding strategy in MAXQDA. The synthesis indicates that AIED should not be approached as an isolated tool, but as a transformative element within educational ecosystems. Five interdependent categories of factors shaping smooth, large-scale integration were identified: policy, human, technological, pedagogical, and, emerging as a distinct contribution of this mapping, systemic factors, which capture cross-level interconnections, feedback mechanisms, and the need for continuous system adaptation. In parallel, the review documented a range of ethical issues and challenges associated with AIED adoption and use, including academic integrity, privacy and security, consent and transparency, algorithmic bias, trust, and broader "general" ethical concerns such as access/exclusion and environmental impacts. Overall, the findings underscore that responsible AIED integration requires a holistic, system-level approach that aligns governance and institutional support with pedagogical design and technological choices, while proactively addressing ethical risks.

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BioFit_AI: An Innovative Teaching Model Integrating Artificial Intelligence and Exercise Biology in Upper Secondary Biology Education

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract —This paper presents BioFit_AI, an innovative educational intervention that integrates Artificial Intelligence (AI) into the teaching of secondary education Biology, in conjunction with the fundamental principles of Exercise Biology. The initiative aims to enhance students' understanding of core biological concepts through interactive digital tools, effectively linking the theoretical knowledge of the curriculum with students' lived experiences.

AI-based applications support personalized learning, provide real-time feedback, and foster the development of critical thinking skills. Interactive simulations representing physiological systems—such as blood circulation, nervous system function, and musculoskeletal activity—enable students to explore biological processes in an active, inquiry-based, and scientifically grounded manner. The program also addresses the reproductive system through the use of an intelligent digital assistant and customized educational videos.

Furthermore, students can manipulate variables including exercise intensity, nutrition, and environmental conditions, directly observing the body's corresponding physiological responses. The integration of Exercise Biology enriches the learning experience by allowing students to investigate cardiovascular, respiratory, and musculoskeletal function during physical activity using real-time biometric data. Measurements such as heart rate, oxygen saturation, and respiratory rate are recorded instantly and connected to empirical data, thereby strengthening experiential learning and deepening understanding of concepts such as homeostasis, metabolism, and physiological adaptations to exercise.

Through this process, students transition from passive observers to active researchers. The initiative contributes to the development of essential 21st-century skills: familiarity with AI tools promotes digital literacy, while the analysis and interpretation of biological data enhance critical thinking and creativity. Moreover, the interdisciplinary approach connects Biology with Mathematics (statistical analysis), Physical Education, Physics, and Informatics, broadening students' understanding of knowledge across domains.

On a social level, the intervention promotes healthy habits and well-being by highlighting physical exercise as a key component of a healthy lifestyle.

Simultaneously, engagement with modern technologies and scientific practices strengthens students' career orientation and cultivates active, informed citizenship.

Overall, the findings underscore the pedagogical potential of experiential learning supported by AI in the teaching of natural sciences in secondary education. Specifically, Biology instruction is transformed into an engaging, multimodal, and applied learning process, fully aligned with the demands of contemporary education.

Keywords—Artificial Intelligence, Biology Education, Secondary Education, Digital Simulations, Experiential Learning

Introduction

In the modern digital age, concerns are often raised about the shortening of learners' attention spans. There is also the perception that the human attention span has declined to levels below that of even a goldfish (Microsoft Canada, 2015) — a claim that, while lacking rigorous scientific foundation, underscores the intense concern about our declining attention span. In general, such claims are often oversimplified, lack strong empirical foundation, and reflect a broader concern about the shifting nature of attention in media-saturated environments. However, empirical evidence suggests that constant exposure to digital information reshapes cognitive processing, promoting multitasking and fragmented attention (Firth et al., 2019). In fact, recent research demonstrates an acceleration of the dynamics of "collective attention," which is driven by constant exposure to large amounts of information, with the result that this enormous amount of information forces the individual — and especially children/adolescents — into persistent multitasking, i.e., constant multitasking (Lorenz-Spreen, Monsted, Hovel, & Lehmann, 2019). This change is not simply a quantitative reduction in attention span, but a structural change in cognitive processing, i.e., in the way the "online brain" processes stimuli, prioritizing speed over depth (Firth et al., 2019).

This structural shift is supported by clinical evidence, such as the study by Ra et al. (2018) published in JAMA, which found that adolescents with high levels of digital media use were twice as likely (9.5% vs. 4.6%) to exhibit symptoms of attention deficit. Within this context, traditional teaching approaches that rely exclusively on oral instruction often struggle to engage and adequately motivate students. It is increasingly evident that this transformation challenges conventional lecture-based pedagogy, particularly in science education.

In contrast, cognitive theories of multimedia learning propose that meaningful learning is enhanced when verbal and visual representations are integrated, thereby reducing extraneous cognitive load and facilitating deeper understanding (Mayer, 2009; Sweller, Ayres, & Kalyuga, 2011). More specifically, Mayer and Moreno (2003) argue that multimedia learning provides an effective pathway for deeper knowledge acquisition, as students learn more efficiently from the combined presentation of words and images; this "dual coding" process optimizes cognitive resources and supports comprehension.The effectiveness of this approach is further reinforced by meta-analytic evidence indicating that interactive learning environments and the use of educational videos significantly improve learning outcomes (Noetel et al., 2021). Consequently, the rapid evolution of digital technological innovation is reshaping the landscape of lifelong learning and professional skills at both local and global levels. The integration of intelligent technologies into education represents not merely a technical advancement but also a pedagogical and ethical challenge. In this context, Artificial Intelligence (AI) emerges as a critical factor in the transformation of learning, enabling personalized pathways and providing intelligent feedback that supports student development (Kasneci et al., 2023; Russell & Norvig, 2021).

In the context of this necessary pedagogical adaptation, we designed and implemented an innovative teaching model, BioFit_AI (Figure 1), within the framework of the Greek Lyceum Biology curriculum. It is a teaching model designed for the teaching of Biology in the A' Lyceum, combining Artificial Intelligence (AI) technologies with Exercise Biology to promote meaningful learning experiences. Through interactive simulations

of key physiological systems—including the circulatory, reproductive, neuromuscular, and musculoskeletal systems—students actively explored biological processes within a scientifically documented learning environment. Essentially, this project promotes experiential, exploratory and personalized learning, because it bridges the gap between theoretical biological concepts and practical application, by integrating Artificial Intelligence (AI) tools with Exercise Biology. As depicted in Figure 1, the conceptual identity of the project reflects precisely this synergy.



Figure 8: The BioFit_AI Project Logo. The visual identity symbolizes the integration of computational intelligence (brain core circuit) with life sciences (DNA helix), emphasizing a data-driven approach to physical health and education.

The basic structure and interactive narrative were created with the Genially platform (Figure 2). To address limitations in URL management and content hosting, a solution was implemented through the Firebase Hosting service in combination with the Node.js environment and the firebase-admin library (via npm), ensuring reliable and autonomous access to the project resources and ensuring a public URL mapped to point directly to the public directory of the local system, with a startup file index.html. In other words, in this way, stable access to the content was ensured, independent of the limitations of the Genially platform, while maintaining its integration with it.



Figure 9: Central interface of the BioFit_AI platform on Genially, which serves as the interactive navigation guide for students through the action modules.

The audiovisual content was integrated through the Vimeo platform, which allowed the insertion of videos via embed links within Genially, providing high quality playback on all devices. In addition, educational videos in English were linguistically adapted and subtitled in Greek using the HandBrake software, ensuring the pedagogical accessibility of the material.

The interactive activities were developed using HTML, CSS and JavaScript, including applications for recording heart rate, systolic and diastolic blood pressure (Figure 3), as well as educational memory games (Figure 4). Such data-driven learning approaches have been shown to enhance conceptual understanding and student engagement in science education (Papamitsiou & Economides, 2014). The visual material was partially created using generative AI tools, while additional educational images were drawn from open access repositories and adapted for teaching purposes.



Figure 10: Digital environment for recording and visualizing biometric data, where pulse, systolic and diastolic pressure measurements are displayed during exercise.

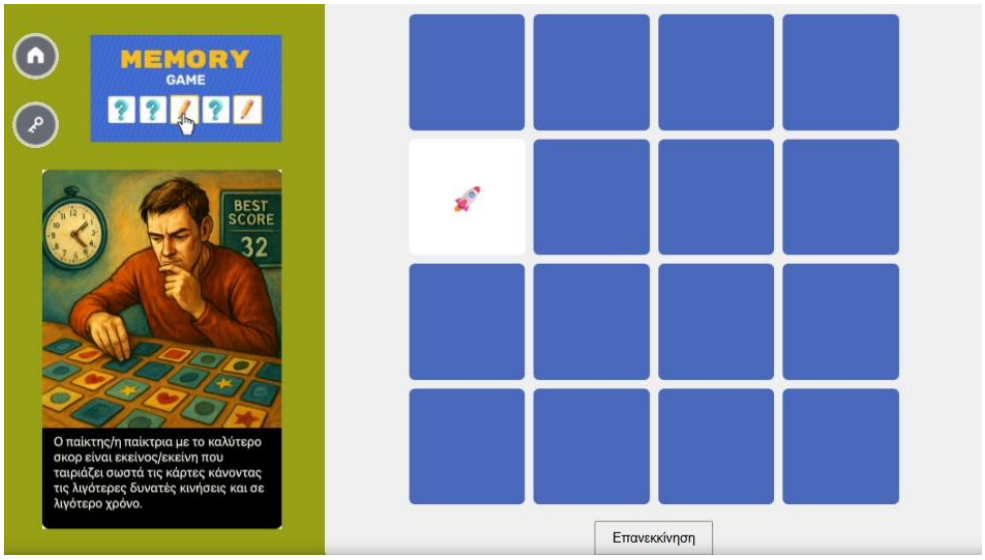


Figure 11: Screenshot of the educational memory game for assessing memory as an indicator of nervous system wellness.

AI-powered chatbots were developed using the Chatbase platform and trained on curriculum-aligned content, including textbooks and assessment materials. The integration of AI tutors is consistent with research demonstrating their potential to support student-centered learning and adaptive teaching (Woolf, 2010). In addition, three-dimensional (3D) anatomical models from Sketchfab enabled the exploration of musculoskeletal structures in real time (Figure 5), while formative assessment and feedback were implemented using the Wayground platform.

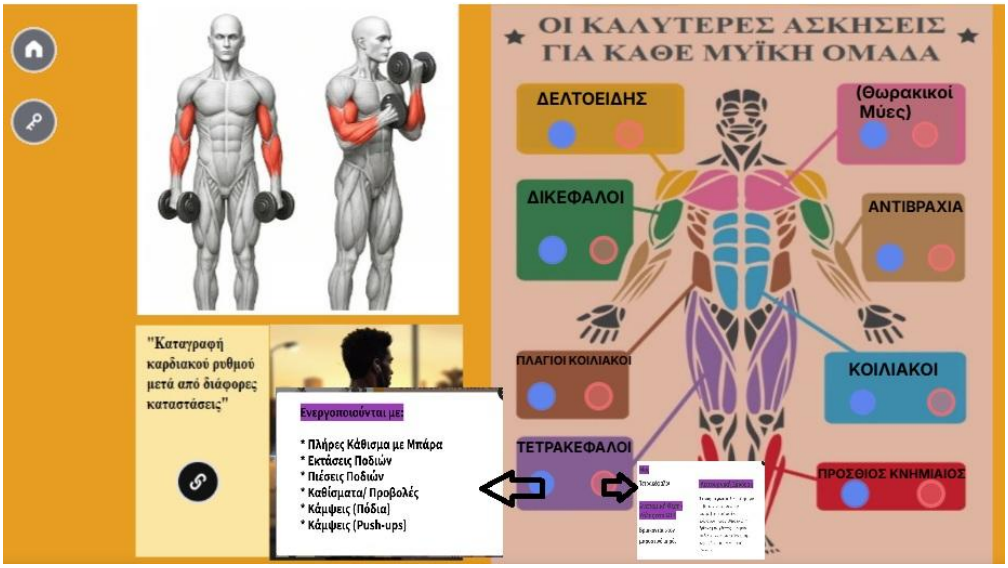


Figure 12: Interactive representation of the musculoskeletal system for identifying active muscle groups based on the selected type of physical exercise.

Conclusion

The findings of the BioFit_AI intervention demonstrate that the integration of Artificial Intelligence and Exercise Biology can effectively mitigate students' attentional decline, transforming learning into an active, data-driven, and personally meaningful process. Multimodal instructional tools and dual-coding strategies enabled students to engage

more deeply with complex biological concepts through direct interaction with their own physiological data. These results underscore the need for a pedagogical reorientation that aligns educational practices with the cognitive characteristics of the contemporary digital learner. The findings are consistent with existing literature highlighting the educational value of AI-enhanced, multimedia-supported learning environments (Luckin, Holmes, Griffiths, & Forcier, 2016; Mayer, 2009). Although challenges remain—particularly regarding technological infrastructure and teacher training—the proposed model offers a scalable and innovative framework for Biology instruction supported by Artificial Intelligence.

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Exploring Cognitive Styles: Differentiating Students as Field-Independent and Field-Dependent Learners

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Abstract— Cognitive style refers to an individual's preferred way of processing information, which is manifested in perception, attention, thinking, memory, and problem-solving methods. Learning style is shaped by an individual's neural structure and function and is influenced by family, education, and social culture. Learning styles have a significant impact on the quality and effectiveness of learning. The concepts of field independence and field dependence originate from H. Witkin's research on perception. Individuals who are field-independent tend to use their internal references when making objective judgments; they are less influenced or hindered by external factors and are cognitively independent from their environment. They tend to process information at a more abstract and analytical level, making independent judgments. On the other hand, field-dependent individuals tend to rely on external references when processing information and perceiving objects, which makes it more difficult for them to escape the influence of environmental factors. Their attitudes and self-perception are more easily influenced or disturbed by those around them, especially by authority figures. They are skilled at reading between the lines and pay attention to and remember the social content of verbal information. Field independence and dependence are closely related to students' learning. Research shows that field-independent students generally prefer the natural sciences and mathematics, and their grades in these subjects are significantly positively correlated. Their learning motivation is often primarily intrinsic. Field-dependent students, however, generally prefer the social sciences; their learning relies more on external feedback, and they are more interested in people than in things. Field-independent individuals are skilled in using analytical perceptual methods, while field-dependent individuals prefer non-analytical, general, or holistic perceptual methods. They find it difficult to distinguish the components or elements of things in complex situations. Furthermore, field-independent students find it easier to provide structure to unstructured material and adapt more easily to less rigid teaching methods. In contrast, field-dependent students prefer highly structured teaching, as they require external structure from the teacher and need clear guidance and explanations.

In the survey conducted, 330 students aged 12–16 participated. The assessment of learning styles revealed a remarkable imbalance in the distribution between field-independent and field-dependent students. Field-dependent students constituted the majority, accounting for 72.1% (n = 238), while field-independent students represented

27.9% (n = 92) of the sample. Data analysis showed that the Field Dependent (FD) learning style was dominant, with nearly 3 out of 4 students (72%) exhibiting this characteristic. It also appeared that there was no statistically significant relationship between the FI/FD learning style and the students' gender, age group, or computer usage hours. These findings suggest that the FI/FD learning style is independent of demographic characteristics and technology use habits in this particular sample. The high proportion of FD students compared to FI students may have important implications for the design of educational interventions and the adaptation of teaching methods.

Keywords— (cognitive style, field dependent, field independent)

Introduction

Learning is defined as the way people acquire new knowledge, skills, attitudes, or behaviors through experience, study, and practice, leading to relatively permanent changes in behavior or understanding. Learning is a phenomenon that has occupied scientists from various specialties for decades, such as psychologists, educators/teachers, biologists, neuroscientists, sociologists, and others, frequently bringing the issue to numerous studies and discussions, yet it continues to remain open and burning with researchers' views showing variety, since it is a multidimensional phenomenon that depends on numerous factors.

The definition of learning, as originally given by Gagné (1970), describes learning in a comprehensive way as "a process that leads to behavior change through practice." Additionally, Kimble (1981) states that learning is a stable change in behavior that results from experience and practice, but not from physical maturation, which is not considered learning since it is based on genetic factors. Furthermore, Falk and Adelman (2003) define learning as a multidimensional process that includes not only knowledge and skills but also emotions, values, and attitudes, emphasizing its uniqueness for each individual, due to external and internal factors such as mental maturity, family and socioeconomic environment, the student's interests and motivations, which play a catalytic role in the learning process. In summary, learning refers to a personal and dynamic process influenced by various factors and cannot be limited to a single teaching practice.

Cognitive learning style constitutes an important part of the learning style and is defined as a psychological approach to the organization and representation of information, as well as the way in which the student seeks solutions to their problems (Riding & Al-Sanabani, 1998; Saracho, 1998). Many cognitive scientists have given their own definitions over time. However, the largest experimental research was conducted by Witkin (1954), wanting to examine students' perceptual skills in relation to their personality, as a result of different ways of adapting to the world. According to Witkin (1971), cognitive style is a form of mental function that appears in an individual's mental and perceptual activities. In short, cognitive learning styles relate to the student's internal cognitive characteristics in information processing and are connected to students' reactions to the broader environment.

An important classification in cognitive learning style that includes an intuitive and analytical dimension of the concept of learning is Field-Dependent and Field-Independent learning, introduced by Witkin and Fellows in 1977. The theory was developed by Herman Witkin and his colleagues and relates to cognitive styles, that is, the way different people perceive, process, and organize information. These are two basic fields of cognitive learning that reflect how pattern recognition is processed and maintained in memory. According to Witkin's scientific interpretation of field-dependent and field-independent learning, the ability of an individual to identify a simple figure within a larger, more complex figure is considered to belong to the independent field; conversely, an individual who has difficulty identifying these details belongs to the dependent field (Grigorenko & Sternberg, 1997). More specifically, in field-dependent learning in pattern recognition, the parts of a whole are perceived as "fused," while in the independent field there is a difference in the way of perception, and the individual is likely to see the parts of the whole differentiated from the

organized background (Witkin et al., 1971). Messick, in turn, found that field-dependent learning exists when a student's perception depends strongly on the environment in which they dominate, and field-independent learning when the student perceives more or less, independently of their environment.

State of the art

The distinction between Field-Dependent (FD) and Field-Independent (FI) cognitive styles constitutes one of the most established schemes for describing individual differences in information processing and is particularly relevant to the design of learning environments and the understanding of learners' behavior. Witkin's work (Witkin et al., 1971, 1977) introduced this typology based on perceptual tests, such as the Group Embedded Figures Test (GEFT), and documented systematic differentiation in how individuals recognize, organize, and use information from their environment.

Contemporary literature continues to examine the implications of this distinction in various contexts, with particular emphasis on hypermedia environments, distance learning, and digital educational tools. A significant body of research documents that FD individuals face greater difficulty in unstructured navigation environments, as they rely more on external cues, clarity of structure, and instructor or system guidance (Tsoni, 2017). Conversely, FI students demonstrate greater ease in autonomous exploration, identifying essential information in complex environments, and self-directed learning, relying less on external structure.

In technological contexts, such as the use of adaptive platforms, learning management systems, and multimedia tools, differentiation in cognitive style can determine the effectiveness of the learning experience. For example, in environments where linear navigation dominates or information hierarchy is unclear, FD learners may experience frustration and cognitive overload, while in environments offering multiple pathways, personalized support, and visual assistance, performance and engagement can be significantly improved (Tzelepis et al., 2023). Similarly, research into distance education shows that FD learners benefit from structured organization of content, systematic monitoring, and frequent feedback, while FI learners prefer greater autonomy, opportunities for exploration, and fewer constraints.

It is worth noting, however, that the literature does not support absolute alignment of teaching with a single cognitive style, nor does it suggest predetermined individualization based solely on FI/FD. On the contrary, modern approaches emphasize universal design with differentiation options, so that the same learning environment offers flexibility according to learners' needs. This means that educational material should be structured with clear objectives, navigation aids, and progress indicators, but should also allow the option for deeper exploration, autonomous work, and alternative paths of approach.

From a pedagogical perspective, significant attention is given to self-regulation, metacognition, and the ability to adjust learning strategies according to the task. FD students can be helped to develop analytical strategies, self-monitoring skills, and independence from the environment, while FI learners can utilize their abilities in structured environments that require collaboration, integration of perspectives, and

holistic processing (Baghestani, 2018). The goal is not to reinforce a pre-existing profile but to expand the learners' adaptive repertoire.

Furthermore, research data link learning style to the type of task, content, and objectives. For example, tasks requiring synthesis of information, collaborative work, and integration of social or contextual elements may be easier for FD students, while tasks requiring analysis, abstraction, and detailed distinction favor FI students. However, this does not mean that one category is generally superior to the other. On the contrary, the literature emphasizes that the concept of "better" or "worse" cognitive style is misleading; what exists is compatibility or incompatibility between the learning environment and the individual's profile.

Additionally, studies on online and distance learning environments reveal that the absence of face-to-face interaction can intensify the needs of FD learners for external structure, social support, and clear guidance, so that motivation and active participation are maintained (Aisopou, 2024). Although these studies do not always directly examine the FD/FI dimension, references to autonomy and the importance of structure confirm that the application of a single design does not ensure coverage of the differentiated needs of learners.

Beyond navigation, the literature links FD/FI with performance and learning strategies, with findings often depending on the subject, type of task, and environmental requirements. In language contexts, FI individuals often appear to use more analytical and metacognitive strategies, while FD individuals utilize more social strategies or strategies based on external feedback (Baghestani, 2018). In other contexts (e.g., problem-solving, spatial tasks), the ability to isolate critical elements may offer an advantage, but this does not mean that FD individuals are overall inferior: they may excel in tasks requiring holistic perception and social collaboration.

The FD/FI distinction has also been examined in relation to psychoeducational dimensions, such as counseling support, adaptation to the school environment, and provision of learning guidance. Research shows that students who exhibit greater field dependence may benefit from clearer goal structure, enhancement of their social integration, and external reference points, while those who exhibit greater independence respond positively to opportunities for autonomous work and self-direction. These approaches do not aim at different educational models per category but at forms of support that facilitate the learning process for all students.

At the same time, contemporary research approaches relate individual differences to broader psychological parameters, such as personality, cognitive flexibility, and performance anxiety. Findings indicate that cognitive style is embedded in a complex network of factors, and its interpretation requires a multi-factorial approach (Matthews, Deary, & Whiteman, 2003). Consequently, the pedagogical utilization of the FD/FI distinction primarily concerns the design of multiple ways of accessing knowledge rather than predicting learners' capabilities.

An issue constantly raised in contemporary literature is the need to avoid uncritical transfer of cognitive styles to pedagogical practices. The concept of cognitive style has been the subject of criticism in various forms, especially when confused with learning styles or used for matching teaching approaches without sufficient empirical

documentation. Particularly for the FD/FI distinction, its research value is mainly found in investigating the interaction between student, learning environment, and task, and how, under what conditions, field dependence affects understanding, strategies, and performance (Witkin et al., 1977; Khatib, 2015).

Regarding methodology, three basic points emerge. First, the use of GEFT is useful when accompanied by behavioral indicators and learning outcomes, so that interpretations based exclusively on test scores are avoided (Tzelepis et al., 2023). Second, generalization of findings requires special attention, as factors such as experience, context, and learning subject may affect results. Finally, it is important to distinguish cognitive style from ability, as FD/FI concerns ways of processing information and not level of intelligence.

Closing this review, research reports confirm that the Field-Dependent/Field-Independent distinction constitutes a useful framework for understanding differences in learning methods, particularly in environments requiring navigation and self-regulation. GEFT can be utilized as a valid research tool when integrated into a broader assessment and not used as the sole criterion (Witkin et al., 1971; Khatib, 2015). Additionally, research findings from hypermedia learning environments show that providing alternative navigation options contributes to supporting different learner profiles (Tzelepis et al., 2023).

For applications such as digital educational material and blended or distance learning, the literature supports universal design with differentiation capabilities. This includes clear structure, progress indicators, and supportive material for those who need it, as well as options for autonomous exploration and advanced study for learners with greater autonomy. In this way, the FD/FI distinction is utilized not as a classification tool but as a basis for a more inclusive and effective pedagogical design.

Methodology

Research Objective

The main objective of this research is to evaluate the usability of digital and robotic learning tools from the perspective of students, while simultaneously investigating their cognitive styles (Field-Independent/Field-Dependent). The research seeks to understand how different learning styles interact with innovative educational methodologies that incorporate educational robotics, new technologies, and gamification elements.

Sample and Data Collection

The sample was formed using purposive sampling. A total of 330 secondary education students aged 12-16 participated in the study. The questionnaires were distributed during educational seminars from March 2025 to October 2025 in various secondary education structures. The research involved students from different types of schools including junior high schools (Gymnasiums), general high schools (Lyceums), vocational high schools, and model/experimental schools.

Research Instruments

The research utilized a comprehensive questionnaire adapted from the SUMI (Software Usability Measurement Inventory) tool, specifically modified for student assessment. Additionally, a section for detecting learning style was added using the adapted GEFT (Group Embedded Figures Test) questionnaire as standardized and used by Khatib and Hosseinpur (2011). The questionnaire was organized into three distinct sections:

- Demographic Information: Seven questions recording basic demographic data and characteristics of students' family and social environment, including gender, age, residence location, parents' educational level, availability of tablet or computer at home, and weekly hours spent playing video games.

- Learning Style Classification: Fifteen questions designed to classify students into two categories – field-dependent and field-independent learners – based on their social characteristics and preferences. These questions explored aspects such as preference for group vs. individual work, social interaction patterns, comfort with autonomy, and collaborative tendencies.

- Usability Assessment: Forty-seven questions evaluating the usability of the methodology through the SUMI model, adapted for the student audience with simplified language and appropriate formulations. These questions were grouped into five dimensions: Effectiveness, Satisfaction, Usefulness, Ease of Use, and Ease of Learning.

Reliability and Validity

Several measures were taken to ensure the reliability and validity of the research instrument. A pilot study was conducted with an initial group of five students who completed the questionnaire using their names. This process led to the addition of some extra options to certain questions and the rephrasing of others to make them more comprehensible. Content validity was examined through evaluation by a panel of experts with knowledge in the subject matter, including two secondary education teachers and one tertiary education professor. They assessed the appropriateness, representativeness, and clarity of formulations. The reliability was assessed using Cronbach's alpha coefficient for internal consistency. The overall scale showed acceptable levels of internal consistency ($\alpha = 0.876$). The questionnaire completion time was set at approximately fifteen minutes to ensure participants would not become fatigued.

Data Analysis

Data were analyzed using the SPSS statistical package. Given that all variables failed to meet the requirements of normal distribution, non-parametric tests were used for group comparisons. Specifically, Mann-Whitney U tests were employed to assess differences in effectiveness, satisfaction, usefulness, ease of use, and ease of learning between students with field-independent (FI) and field-dependent (FD) learning styles. Descriptive statistics were calculated for all main variables, including means, medians, standard deviations, and interquartile ranges.

Results

Demographic Characteristics

The study involved 330 secondary education students. Regarding gender distribution, the sample showed relative balance with 49.4% (n=163) boys and 50.6% (n=167) girls. The age distribution showed that the largest group consisted of students aged 14-15 years, representing 51.8% (n=171) of the sample, followed by students under 14 years at 35.8% (n=118), and students over 15 years at 12.4% (n=41).

Regarding residence location, students from urban areas constituted 43.0% (n=142), semi-urban areas represented 23.0% (n=76), rural areas 21.2% (n=70), island areas 3.9% (n=13), and border areas 3.9% (n=13) of the sample. The educational level of parents varied, with the majority of mothers having completed high school (39.7%, n=131) and fathers also predominantly having high school education (40.0%, n=132).

A significant finding was that 83.7% (n=273) of students reported having access to a tablet or computer at home. Regarding weekly hours spent playing video games, 42.9% (n=139) reported 0-10 hours, 29.3% (n=95) reported 11-20 hours, 19.1% (n=62) reported 21-30 hours, and 8.6% (n=28) reported more than 31 hours per week.

Learning Style Distribution

The assessment of learning styles revealed a remarkable imbalance in the distribution between field-independent and field-dependent students. Field-dependent (FD) students constituted the majority, accounting for 72.1% (n=238), while field-independent (FI) students represented 27.9% (n=92) of the sample. This finding indicates that the FD learning style was dominant, with nearly 3 out of 4 students (72%) exhibiting this characteristic.

Descriptive Statistics of Main Variables

Descriptive statistics were applied to the five main variables of the study: effectiveness, satisfaction, usefulness, ease of use, and ease of learning. The mean score for effectiveness was 3.82 (SD = 0.51), with a median of 3.88 and observed scores ranging from 1.00 to 5.00. The satisfaction scale had a mean score of 3.80 (SD = 0.62) and a median of 3.79. For the usefulness dimension, the mean score was 3.68 (SD = 0.52), and scores ranged from 1.00 to 5.00. The ease of use variable showed a mean of 3.86 (SD = 0.50) and a median of 3.89. Finally, the ease of learning variable had a mean value of 3.86 (SD = 0.51) and a median of 3.86. All variables showed moderate to high mean scores, indicating generally positive user perceptions.

Differences in Usability Perceptions by Learning Style

A Mann-Whitney U test was conducted to assess differences in effectiveness, satisfaction, usefulness, ease of use, and ease of learning between students with field-independent (FI) and field-dependent (FD) learning styles.

For effectiveness, FI students (Median = 3.875, Mean Rank = 171.24) and FD students (Median = 3.875, Mean Rank = 163.28) showed similar scores. The difference was not statistically significant, U = 10420.000, Z = -0.683, p = .494.

For satisfaction, the mean ranks were 160.59 for FI students and 167.40 for FD students. The Mann-Whitney U test did not show a significant difference between groups, U = 10496.000, Z = -0.585, p = .559, indicating comparable levels of satisfaction.

For usefulness, FI students had a mean rank of 165.18, while FD students had a mean rank of 165.62. The test did not reveal a significant difference, U = 10919.000, Z = -0.037, p = .970.
For ease of use, FI students (Mean Rank = 166.79) and FD students (Mean Rank = 165.00) also did not differ significantly, U = 10829.000, Z = -0.154, p = .878.

For ease of learning, FI students (Mean Rank = 162.93) and FD students (Mean Rank = 166.49) showed similar scores, with no statistically significant difference, U = 10712.000, Z = -0.305, p = .760.

These results indicate that there were no statistically significant differences in any of the five usability dimensions between field-independent and field-dependent students. Both groups showed comparable positive evaluations of the educational methodology.

Summary of Findings

The data were analyzed based on 330 secondary education students to determine variation in usability perceptions regarding demographic, technological, and learning factors. Descriptive analysis findings showed moderate to high mean scores across all usability dimensions, including effectiveness, satisfaction, usefulness, ease of use, and ease of learning, indicating positive user perceptions.

The inferential findings showed that gender, parental education, and learning styles did not play a significant role in usability perceptions. However, some variations were found between age groups and residence locations. Students aged 14-15 years were more likely to rate effectiveness and usefulness higher than other age groups, and those residing in semi-urban areas gave higher ratings for effectiveness and ease of use than those in urban and border areas. Additionally, students who had access to a tablet or computer had significantly higher usability scores.

Overall, the findings show that demographic and cognitive factors had relatively little influence. However, age, residence location, and access to technology had moderate but significant effects on students' development of usability perceptions. Most importantly, the FI/FD learning style appeared to be independent of gender, age group, and computer usage hours, suggesting that this cognitive characteristic transcends basic demographic variables.

Discussion and Conclusions

The present study investigated the cognitive styles of secondary education students, specifically examining the distribution and characteristics of field-independent (FI) and field-dependent (FD) learners in the context of educational technology use. The

findings provide valuable insights into how these cognitive styles manifest in a contemporary educational setting and their relationship with various demographic and technological factors.

The most striking finding was the significant imbalance in the distribution of learning styles, with field-dependent students comprising 72.1% of the sample compared to only 27.9% field-independent students. This substantial predominance of the FD style challenges some traditional assumptions about cognitive style distribution and raises important questions for educational practice. The high proportion of field-dependent learners suggests that educational interventions, particularly those involving technology, should be designed with this majority in mind while still accommodating the needs of field-independent learners.

Contrary to expectations, the study found no statistically significant differences between FI and FD students across all five dimensions of usability assessment (effectiveness, satisfaction, usefulness, ease of use, and ease of learning). This finding is particularly important as it suggests that the educational methodology employed - incorporating educational robotics, new technologies, and gamification elements - was sufficiently flexible and well-designed to meet the needs of students with different cognitive styles. This aligns with contemporary pedagogical approaches that emphasize universal design with differentiation options rather than creating entirely separate learning pathways for different learner profiles.

The absence of significant differences between FI and FD students in their usability perceptions indicates that the methodology successfully provided multiple entry points for learning. Field-dependent students likely benefited from structured guidance, group work opportunities, and visual presentations inherent in the robotic and gamification elements, while field-independent students found space for autonomous exploration and analytical problem-solving within the same framework. This supports the notion that effective educational design should not aim to match instruction to a single cognitive style but rather to create environments rich in varied learning opportunities.

The finding that FI/FD learning style was independent of gender, age group, and computer usage hours is also significant. This suggests that cognitive style represents a stable individual characteristic that transcends basic demographic variables and technology exposure. This has important implications for educational assessment and intervention, indicating that cognitive style should be considered as a distinct factor in pedagogical planning, separate from demographic characteristics.

However, the study did reveal that certain demographic and contextual factors influenced usability perceptions. Students aged 14-15 years showed higher ratings for effectiveness and usefulness, possibly reflecting optimal developmental readiness for technology-enhanced learning at this age. The positive influence of access to technology at home underscores the importance of digital equity in education. The variation by residence location, with semi-urban students rating effectiveness and ease of use higher, may reflect differences in prior technology exposure and infrastructure quality.

The predominance of field-dependent learners in this sample has important pedagogical implications. While the current methodology successfully accommodated both learning

styles, the high proportion of FD students suggests that educational interventions should prioritize clear structure, social learning opportunities, frequent feedback, and explicit guidance while still maintaining options for autonomous exploration. This is particularly relevant for technology-enhanced learning environments, which can sometimes assume a level of self-direction more natural to field-independent learners.

From a methodological perspective, this study demonstrates the value of combining learning style assessment with usability evaluation. The use of the adapted GEFT instrument alongside the SUMI-based questionnaire provided a comprehensive picture of how students with different cognitive profiles experience educational technology. The high reliability of the instruments (Cronbach's alpha = 0.876) supports their continued use in educational research.

The study also contributes to the ongoing discussion about the practical utility of cognitive style constructs in education. While some critics have questioned the value of learning style categorizations, the present findings suggest that understanding cognitive style distribution in a student population can inform educational design decisions. The key is not to use these categories to limit or label students but rather to ensure that learning environments are sufficiently varied and flexible to support different approaches to information processing.
Several limitations should be acknowledged. The study was conducted with a specific age group (12-16 years) in secondary education settings, which may limit generalizability to other age groups or educational levels. The predominance of field-dependent students in this sample, while interesting, may not represent all student populations and could be influenced by cultural, educational, or regional factors not fully explored in this study. Future research should investigate whether this distribution pattern holds across different contexts and populations.

Additionally, while the study assessed students' perceptions of usability, it did not directly measure learning outcomes. Future research should examine whether students with different cognitive styles show variations in actual learning achievement when using technology-enhanced methodologies, even if their perceptions of usability are similar. Longitudinal studies could also explore whether cognitive style profiles remain stable over time and whether prolonged exposure to certain types of educational technology influences cognitive style development.

In conclusion, this study provides evidence that field-dependent and field-independent learners can be equally well-served by carefully designed educational methodologies that incorporate multiple modalities and support structures. The predominance of field-dependent learners in the sample highlights the importance of ensuring that educational technologies provide adequate structure, social learning opportunities, and clear guidance. At the same time, the successful accommodation of both learning styles in the present study demonstrates that it is possible to create inclusive learning environments that do not require separate instructional pathways for students with different cognitive profiles.

The findings support a pedagogical approach that emphasizes universal design principles, differentiated support, and flexibility rather than rigid matching of instruction to predetermined learner categories. As educational technology continues to evolve, understanding the distribution and characteristics of cognitive styles in student

populations can help educators and designers create more effective, inclusive, and accessible learning experiences for all students.

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Educators' Digital Competencies: From Theory to Practice

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Abstract —Living in the 21st century, digital skills constitute a fundamental prerequisite for educators to create a learning environment that meets their students' educational needs. In a world overwhelmed by technological challenges, teachers are called upon to apply ICT (Information and Communication Technologies) in practice during the learning process, becoming creators of digital content, facilitators of learning, and guides for their students. However, for teachers to be able to effectively implement educational technology in practice, continuous training, collaboration, experimentation, and time are factors that are all required. The result, nevertheless, is impressive, as the use of digital tools transforms teaching into a flexible, meaningful, and more participatory process with new perspectives that foster learning motivation. Technology thus becomes a valuable ally for the teacher, and theory finds its application in practice.

The sample was formed using purposive sampling. The questionnaire was completed by teachers from primary and secondary education, regardless of specialty, who were participating in four different postgraduate programs delivered through distance learning. Structurally, the questionnaire is divided into two parts. The first part includes the demographic characteristics of the participants, which also define the independent variables of the study. These include gender, age, years of service, subject specialization, educational level, school structure, school location, level of studies, ICT training, and pedagogical education. The second part of the questionnaire consists of two main categories. The first category investigates participants' accessibility to digital resources, while the second examines the obstacles to the effective integration of new technologies in education. Based on these dependent variables, the study initially explores and evaluates the academic and instructional background of teachers in relation to their level of access to digital resources and the barriers to the effective integration of new technologies in education. The questionnaire includes five Likert-scale subscales, with total scores calculated based on the mean responses for each category. The "Accessibility to Digital Resources" scale yielded an average score of 3.76 (SD = 0.882), while the "Barriers to the Effective Integration of New Technologies in Education" scale showed a mean score of 3.43 (SD = 0.578).

Overall, the analyses indicate that accessibility to digital resources and perceptions of barriers to technology integration vary according to teachers' demographic and

professional characteristics. Regarding specialization, teachers in the Humanities and Technological Studies reported higher accessibility to digital resources compared to teachers in the Natural Sciences, though the differences were not statistically significant. A similar trend was observed for the barriers, as there were no statistically significant differences between teachers of different specialties. In terms of workplace location, teachers working in island and rural areas reported higher accessibility to digital resources, whereas teachers in urban areas displayed lower values, showing a statistically significant difference. Years of experience and educational level were also correlated with digital accessibility, with mid-career teachers and doctoral degree holders presenting higher scores. Finally, pedagogical training and ICT education were strongly associated with greater accessibility, particularly among SELETE/ASPETE-trained teachers and those holding Level B ICT certification. However, perceived barriers showed less variability and did not reach statistical significance.

In conclusion, the study demonstrates that specialized education and professional experience enhance the use of digital resources in education, while barriers to successful integration appear to be less affected by demographic and professional factors.

Keywords— educator, educational technology, familiarization, ICT

Introduction

The rapid pace of development of digital technologies has led to substantial changes in all areas of social life, with a direct impact on the way the educational process is organized and implemented. Modern education must adapt to the demands of a knowledge and information society, in which access to knowledge, critical processing of information, and the cultivation of complex skills constitute fundamental prerequisites for the active participation of citizens. In this specific context, Information and Communication Technologies (ICT) cease to be considered merely as auxiliary tools, but are treated as means capable of transforming the way teaching and learning occur, redefining the roles of educators and students (Pangé & Kyriazi, 2022).

To improve the educational process, educators can use a wide range of online tools and thus shape modern teaching methods characterized by originality and innovation. The way in which these tools will be applied in educational practice depends exclusively on educators' attitudes toward ICT and the degree of their integration into educational practice. At the same time, the creation of a modern pedagogical and educational framework and the validity and reliability of a positive outcome constitute a fundamental element for the utilization of New Technologies in education.

Greek educational reality has been substantially affected by these developments, especially during the last decade. The integration of Information and Communication Technologies into the school context has been strengthened both through institutional policies and interventions as well as due to the need for distance education that emerged during the pandemic period. Despite the expansion of access to digital infrastructure and platforms, the use of technology in daily teaching practice remains uneven and is often limited to presentation, communication, and classroom management functions (Rapti, 2026; Kolyda, 2025). The literature documents that technology, when not integrated into a clear pedagogical framework, rarely leads to substantial changes in the learning process.

Perceptions, attitudes, and the emotional disposition of educators play a decisive role in the integration of digital technology into educational practice. According to research data, educators largely recognize the importance of Information and Communication Technologies and generally adopt a positive attitude toward their use in the school classroom context. At the same time, the emotional dimension of teaching in digital and hybrid learning environments emerges as a decisive factor in shaping the pedagogical climate.

State of the art

The possibilities offered by digital technologies, the Internet, and Social Media are numerous. The use of the Internet continues to evolve, improve, and continues to create new tools that are difficult to categorize. Some of the most modern tools applied in the field of education include social networks, (micro)blogs, personal learning environments, videoconferencing and real-time lectures, multimedia sharing and distribution, task management, bulletin boards, data collection and presentation, wikis, social calendars and social bookmarking, image, video, and audio editing, recording and broadcasting of audio content, story creation, online games, virtual reality

environments, sketch design, collaborative writing and reading programs, tag clouds, and concept maps and mind maps.

A series of independent studies show that both teachers' personal theories and perceptions of teaching and learning processes and their level of competence in using ICT play a significant role in the way they apply them and in how they are motivated to use the tools offered to them in the classroom. Educators generally agree that computer systems constitute valuable tools for education and are positive about the development of students' knowledge and skills through the use of ICT. However, a positive attitude toward the use of technology does not always entail systematic and pedagogically documented utilization in educational practice. The divergence between intention and implementation emerges as one of the central findings of the relevant literature. Many educators declare competence in the use of basic digital tools, yet struggle to integrate technology in a way that supports collaborative, inquiry-based, and student-centered learning (Nikolopoulou & Kousloglou, 2020). Technology often functions as a supplement to traditional teaching rather than as a means of substantial transformation.

The discussion on the utilization of digital technology in education cannot be studied independently of the pedagogical climate of the classroom and the emotional engagement of students and educators. Technology does not operate in a neutral framework but complements a complex network of relationships, attitudes, and emotions that shape the learning process. Research shows that emotions manifested during teaching, such as challenge, pride, frustration, and boredom, directly affect students' participation, concentration, and willingness to learn.

Both in face-to-face and digital classrooms, the emotions of students and educators determine the learning climate and shape the course of interaction. It is noted that in the digital classroom, the absence of physical proximity may intensify feelings of detachment or insecurity if appropriate pedagogical management is not applied. Conversely, when the educator utilizes technology in a supportive manner, they can enhance the sense of challenge and student engagement. According to Trikkaliotis and Dogoulis (2022), emotions such as challenge, pride, as well as frustration or boredom are experienced by both students and educators and directly affect participation and the effectiveness of the learning process, particularly in the digital classroom.

In the context of technology-supported teaching, the emotional dimension of learning makes the educator's role decisive in shaping the overall learning experience. The educator's role is not merely to handle digital tools but to create a safe and supportive environment in which students feel free to experiment, collaborate, and freely express their ideas. The pedagogically documented utilization of digital technology is inextricably linked to the educator's pedagogical and emotional skills.

Research data confirm the above and identify factors that hinder the integration of ICT. Difficulties are connected on the one hand with external factors, such as insufficient material and technical infrastructure and limited institutional support, and on the other hand with internal factors related to educators' beliefs and self-confidence. Similar findings are recorded in Schismenou's (2025) study, which highlights the essential importance of continuous training and professional development for the effective utilization of digital technologies in the educational process.

Didactic transposition offers a frame of reference that helps in understanding the way technology is utilized in the modern classroom. Technology can contribute to the reconstruction of teaching practice only when accompanied by a comprehensive revision of pedagogical goals, teaching strategies, and assessment methods. The educator changes roles: from transmitter of knowledge they become coordinator and facilitator of the learning process, thus creating conditions that favor active and discovery learning.

Research data confirm that digital technology can produce significant learning benefits provided it is utilized with the correct method. Studies at various educational levels record improvement in academic performance, enhancement of concept comprehension, and increase in student engagement through applications such as educational robotics, virtual and augmented reality, and digital games (Papazooglou et al., 2020; Paxinou, 2020). Digital games in particular, when integrated into appropriate pedagogical design, can function as powerful tools for learning and motivation.

Simultaneously, the utilization of digital tools is connected with the enhancement of 21st-century skills, such as critical thinking, creativity, collaboration, and problem-solving. Approaches such as educational robotics and STEAM enhance computational thinking and collaborative learning; however, the literature emphasizes that these skills do not develop automatically through technology but require clear pedagogical design and an active role by the educator (Topoliati, 2020).
A decisive factor for the effective integration of digital technology is teacher training. Participation in ICT training programs is positively correlated with self-confidence and the frequency of digital tool use in the classroom (Vakalis et al., 2025; Rapti, 2026). However, it is noted that training often remains techno-centric and less pedagogically oriented, a fact that limits its transformative role.

Furthermore, material and technical infrastructure and institutional support significantly affect educators' intention and ability to utilize technology. Deficiencies in equipment, technical problems, and limitations of the institutional framework function as deterrents, particularly in secondary education (Kostaki et al., 2024). Indicative is also the limited utilization of the national repository Photodentro, despite the abundance of available material, a fact attributed to lack of time and training (Kostaki & Kalogiannakis, 2019).

In contemporary literature, digital games present particular interest as learning tools. When integrated into a defined pedagogical framework, they can function as powerful learning incentives, strengthening student participation and substantial understanding of teaching subjects. The gamification of learning contributes to the creation of a more attractive learning environment in which students actively participate and take initiatives (Zeimbekis & Theofanellis, 2015).

Studies show that primary education teachers generally adopt a positive attitude toward the use of digital games, recognizing how they contribute to the improvement of school performance and the enhancement of student motivation (Kokolakis, Vasiou, & Gerakopoulou, 2023). At the same time, however, significant obstacles are mentioned, such as limited training and insufficient material and technical infrastructure, which function as inhibitors to their broader integration into daily teaching practice.

Digital games are also connected with the development of 21st-century skills, such as problem-solving, collaboration, and decision-making. More specifically, the literature presents a broad set of fundamental skills that include critical thinking, creativity, communication, collaboration, digital literacy, flexibility and adaptability, as well as the ability for autonomous learning. Through playful and interactive activities, students can assume an active role in the learning process, manage information, reflect, and develop strategies. Thus, their metacognitive ability is also enhanced. Overall, the literature confirms that the learning benefits attributed to the use of digital games cannot arise exclusively from the digital medium itself, independent of the educator. They are inextricably connected with pedagogical design and the way they are integrated into teaching practice (Zeimbekis & Theofanellis, 2015). The educator's role as guide of the learning process emerges as decisive, as they are called upon to organize, support, and set the framework for the learning experience so that digital tools can deliver results and be pedagogically effective.

In summary, Greek literature depicts a complex picture of digital technology in the educational classroom. Although educators maintain positive attitudes and recognize the significant benefits of technology, its utilization remains fragmented. The substantial integration of digital technology in the school classroom requires a holistic approach that includes pedagogical redesign, continuous teacher training, adequacy of material and technical infrastructure, and institutional support. Under these conditions, technology can become a catalyst for educational quality and contribute to the formation of a modern, student-centered, and inclusive school.

Research Methodology

The present research focuses on the evaluation of the usability of digital and robotic learning tools from the perspective of educators, methodologically utilizing the questionnaire tool. The central instrument is the adapted SUMI (Software Usability Measurement Inventory) questionnaire, an internationally recognized usability measurement tool, which was modified to meet the needs of this specific educational research. The questionnaire uses a five-point scale from "strongly disagree" to "strongly agree," thus allowing detailed recording of opinions. The development and implementation of the questionnaire was based on pilot tests, initially on a small sample and subsequently on 27 educators of different specializations and levels, with the aim of improving clarity, reducing ambiguity in formulation, and ensuring its functionality.

Particular emphasis was placed on ensuring the reliability and validity of the research instrument through pilot implementation, internal consistency testing (Cronbach's alpha), as well as adherence to ethical principles such as anonymity and confidentiality of participants. Data analysis was conducted using the SPSS statistical package, while data collection was done through the QuestionPro electronic platform. The questionnaire is structured in two parts: the first concerns demographic characteristics (independent variables) and the second thematic sections that investigate accessibility to digital media and barriers to the integration of new technologies in educational practice.

Specifically, this particular section not only captures the material and technical infrastructure but attempts to outline comprehensively the ecosystem within which

educators are called upon to integrate new technologies. Technological readiness is not limited to the existence of equipment but is influenced by the degree of training, the school's culture of innovation, support from administration, and the sense of self-efficacy of the educators themselves. Through the responses, an attempt is made to highlight the extent to which conditions are ripe for the implementation of modern digital methodologies or whether interventions are required at the level of training, infrastructure upgrading, and organizational reinforcement. Thus, this section functions as a critical indicator of the readiness of the educational framework, allowing interpretation of the research findings in relation to the actual conditions of implementation.

The sample was formed using purposive sampling. The questionnaire was completed by educators participating in 4 different postgraduate programs implemented remotely. The questionnaires were distributed during classes, during the hours of the educational programs. The research concerns primary and secondary education teachers regardless of specialization. The group of individuals participating in the research comes from educators of primary and secondary education school units of the following types of schools: (a) Primary Schools, (b) Junior High Schools (Gymnasiums), (c) General High Schools (Lyceums), (d) Vocational High Schools, (e) Model and Experimental Schools.

A total of 302 educators participated in the study. Regarding gender distribution, the sample showed notable imbalance, with women constituting the majority at 72.2% (n = 218), while male participants represented 27.8% (n = 84) of the total sample.

The age distribution of participants showed relatively balanced representation in the primary education working-age categories. The largest group consisted of educators aged 31-40 years, representing 34.4% (n = 104) of the sample, followed by those aged 21-30 years at 29.5% (n = 89). Participants in the 41-50 age group constituted 28.5% (n = 86) of the sample. Representation of older educators was significantly lower, with those aged 51-60 years representing 7.0% (n = 21) and only 0.7% (n = 2) of participants being over 61 years old.

Regarding academic specialization, participants from the field of Humanities constituted the largest group at 59.6% (n = 180), indicating strong representation from language arts, social sciences, and related fields. Specialists in Technological Studies constituted 25.2% (n = 76) of the sample, while Natural Sciences educators represented 15.2% (n = 46).

The education level at which participants teach revealed interesting information about the sample composition. Primary Education teachers constituted the largest group at 48.3% (n = 146), indicating significant participation of primary education teachers. Secondary education was represented in multiple categories: Secondary education teachers constituted 36.8% (n = 111) of the sample, of whom those serving in General Lyceum constituted 13.6% (n = 41), Vocational Lyceum (EPAL) teachers represented 16.6% (n = 50), while Gymnasium teachers represented 6.6% (n = 20). Tertiary Education teachers constituted 14.9% (n = 45) of the sample, providing valuable perspectives from higher education contexts.

The geographical distribution of participants' workplaces showed that the majority taught in urban environments, representing 58.6% (n = 177) of the sample. Semi-urban

areas represented 22.2% (n = 67) of participants, while rural area educators constituted 10.9% (n = 33). Island-based educators represented 7.9% (n = 24) and only one participant (0.3%) worked in a border area (Figure 5). Of course, it is worth noting that the educators' work school concerns their status, that is, the status at the time of the research implementation. This is clarified because most educators do not serve each year in either the same type of school or the same area.

Analysis of data regarding participants' professional experience revealed that the sample showed significant concentration of educators with limited years of service. Specifically, 71.2% (n = 215) of educators stated they have 1 to 10 years of teaching experience. 17.9% (n = 54) reported 11 to 20 years, while 10.3% (n = 31) stated 21 to 30 years of service. Finally, only 0.7% (n = 2) of participants reported experience exceeding 30 years.
Regarding academic qualifications, master's degree holders constituted the largest group at 54.6% (n = 165), followed by university degree holders at 44.4% (n = 134). Doctoral degree holders represented only 1.0% (n = 3) of the sample.

The pedagogical training background differed significantly among participants. The majority, 67.5% (n = 204), received training based on their appointment degree, while 23.5% (n = 71) had SELETE/ASPETE certification. A smaller percentage, 8.9% (n = 27), reported having no formal pedagogical training.

Information and Communication Technology (ICT) training levels presented interesting patterns in the sample. Almost half of the participants, 47.7% (n = 144), held private certificates such as ECDL. ICT training based on degree was reported by 28.8% (n = 87) of participants, while 11.9% (n = 36) had Level B certification. Minimal representation was found for Level A training, at 3.0% (n = 9), and 8.6% (n = 26) reported having no ICT training (Table 1).

Table 1 - Demographic characteristics of participants

Variable	Category	Frequency (n)	Percentage (%)
Gender	Men	84	27.80%
	Women	218	72.20%
Age	21-30	89	29.50%
	31-40	104	34.40%
	41-50	86	28.50%
	51-60	21	7.00%
	>61	2	0.70%
Specialization	Humanities	180	59.60%
	Technological Studies	76	25.20%
	Natural Sciences	46	15.20%
Educational Level	Primary Education	146	48.30%
	Secondary – Lower Secondary (Gymnasium)	20	6.60%

	Secondary – General Upper Secondary (Lyceum)	41	13.60%
	Secondary – Vocational Upper Secondary (EPAL)	50	16.60%
	Tertiary Education	45	14.90%
Geographical Distribution	Urban	177	58.60%
	Suburban	67	22.20%
	Rural	33	10.90%
	Island	24	7.90%
	Border Area	1	0.30%
Years of Experience	0-10	215	71.20%
	11-20	54	17.90%
	21-30	31	10.30%
	>30	2	0.70%
Academic Qualifications	Bachelor's Degree	134	44.40%
	Master's Degree	165	54.60%
	PhD	3	1.00%
Pedagogical Training	None	27	8.90%

Statistical Data Analysis

The questionnaire included five Likert-based scales (1 = Strongly Disagree to 5 = Strongly Agree), with total scores calculated based on the mean responses per category. Descriptive statistics for the five scales of the questionnaire revealed varying response patterns among participants. The Information on Technology Use (Accessibility to digital media) scale demonstrated a mean score of 3.76 (SD = 0.882), while the Barriers to the Effective Integration of New Technologies in Education scale showed a mean of 3.43 (SD = 0.578).

Reliability Analysis

Internal consistency was assessed using Cronbach's alpha coefficient (a) for each scale. The "Accessibility to Digital Media" scale (a = 0.724) showed acceptable reliability, exceeding the recommended threshold of 0.70. However, the "Barriers to Effective Integration" scale (a = 0.670) demonstrated slightly lower internal consistency.

Table 2 - Reliability analysis for questionnaire scales

Scale	Cronbach's Alpha (α)	Number of Items	Mean	Standard Deviation (SD)
Accessibility to digital media	724	5	3.76	882
Barriers to the effective integration of ICT in education	670	5	3.43	578

Normality Testing

To assess the suitability of parametric tests, the distribution of scale scores was examined using both the Kolmogorov-Smirnov and Shapiro-Wilk tests. As shown in the results, all questionnaire scales significantly violated the assumption of normality ($p < .05$) in both tests, most notably in the "Accessibility to digital media" scale (Shapiro-Wilk = 0.957, $p < 0.001$). These findings suggest that the data are not normally distributed and, therefore, non-parametric statistical methods may be more appropriate for subsequent analyses.

Table 3 - Normality tests for questionnaire scales

Scale	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	p-value	Statistic	df	p-value
Accessibility to digital media	89	301	< 0.001	957	301	< 0.001
Barriers to the effective integration of ICT in education	107	301	< 0.001	980	301	< 0.001

Conclusion

The study involved 302 teachers, presenting significant demographic diversity in terms of gender, age, specialization, educational level, workplace, professional experience, qualifications, pedagogical training, and digital proficiency in ICT. The majority of participants were female (72.2%), while most were under 50 years old, with a strong presence of educators from the Humanities. Descriptive statistics showed generally favorable perceptions toward the use of technology. Internal consistency was evaluated using Cronbach's Alpha to assess the reliability of the grouped items. Normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) indicated that none of the composite variables met the assumption of normality, leading to the use of non-parametric tests for group comparisons. These included the Mann-Whitney U test for gender comparisons and Kruskal-Wallis tests for other demographic categories. Additionally, Pearson correlation coefficients were calculated to assess the relationships between the seven dependent variables. Descriptive results revealed a high mean score for the "Accessibility to digital media" parameter ($M = 3.76$, $SD = 0.82$), suggesting that most participants had access to basic technological tools in their teaching environment. The concept of barriers had a low mean, indicating that while certain obstacles to implementation exist, they generally have a limited or moderate impact. Gender differences were tested using the Mann-Whitney U test, and results showed no significant differences between genders; this finding suggests that while general perceptions were comparable between men and women, emotional engagement with the methodology appears to be slightly more intense among female participants. Age-related differences emerged for the "Barriers to Integration" and "Ease of Learning" parameters, with younger teachers reporting greater ease in learning new technologies. Academic specialization did not significantly influence technology adoption. The workplace affected perceptions of "Accessibility to digital media," particularly among rural teachers. Teaching experience showed potential trends but no significant differences. Notably, degree type influenced perceptions of "Accessibility to digital

media," with doctoral holders consistently scoring higher. Pedagogical training also influenced "Accessibility to digital media," where those with SELETE/ASPAITE training outperformed others. The level of ICT education significantly impacted Information Use, especially among those with Level B training. Collectively, these results highlight that individual background characteristics, particularly education and training, shape how teachers perceive and adopt educational technologies. In summary, the research results indicate that participants overall evaluated the methodology positively, showing high values across all examined dimensions. The most significant influences on their perceptions stemmed from personal and professional background variables, such as age, educational level, and pedagogical or professional training. In particular, perceptions related to Access to Technology appeared to be especially sensitive to these factors.

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Literacies, Multiliteracies, New Literacies and Literacies in the AI Era. The Society in the Post-Digital Age

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Abstract — The historical evolution of *literacy* reflects a gradual move away from a narrowly functional definition-literacy as a technical skill (e.g., reading, writing, arithmetic)-toward a concept that is socially situated and ideologically charged (Tuominen et al., 2005; Sperling et al., 2024). As D. Barton, M. Hamilton, and R. Ivanič (2000) argue, there are multiple literacies connected to different domains of life, and these are shaped by social institutions and relations of power. *Multiliteracies* brought into sharper focus the role of cultural and linguistic diversity, multimodal forms of expression, otherness, and social contexts in shaping communication and the ways people make sense of-and ultimately experience-their world (Cope & Kalantzis, 2000; New London Group, 1996). *New literacies* extended this perspective into digital, online, and collaborative modes of communication, suggesting that a literate citizen is defined through the social practices, values, and identities (both offline and online) that accompany them (Jenkins et al., 2009; Lankshear & Knobel, 2011). In today's social landscape, the ongoing expansion of what counts as *AI literacy* brings an old question back with renewed urgency: what does it mean to be "literate" in a society where knowledge, judgment, and decision-making are increasingly permeated by big data, statistical inference, and algorithmic systems (Chiu et al., 2025)? From this vantage point, sociocritical analyses of contemporary literacies increasingly attend to three interrelated shifts: (i) a movement from the dominance of discourse to the mediation of data; (ii) a movement from citizen participation in content production-across both physical and digital worlds-to the co-production of meaning with machines; and (iii) a movement from critically reading social structures to critically reading algorithmic structures (Rapanta et al., 2025; Ruiz et al., 2025; Williamson & Eynon, 2024). The evolution of literacies in the age of AI creates significant opportunities, but it also introduces complex challenges. Societies do not always manage to absorb these ongoing shifts in an even or coherent way, partly because changes in communication and knowledge practices are rapid, multi-layered, and often asymmetric. The result is a set of educational, social, and digital divides-serious, but not inevitable or insurmountable. What becomes necessary, then, is the development of new capacities and skills: not only so that citizens can use emerging tools effectively, but also so that they can understand them in depth, question them, and help shape the norms that govern their use. As C. Rapanta and colleagues (2025) emphasise, literacies such as *critical GenAI literacy* should be understood "*as a constellation of situated literacies, shaped by disciplinary perspectives, socio-political contexts, and technological affordances*". In a post-digital era-where AI technologies and digital tools are organically intertwined with everyday material and social practices-the challenge goes beyond simply reading

the world of AI. It is also about rewriting it, and redesigning it critically and collectively.

Keywords- Literacies, Artificial Intelligence, Post-Digital Society

1. Introduction and Brief Theoretical Framework

The evolution of *literacy* points to a gradual shift from a functional definition (reading - writing - arithmetic) toward a multidimensional concept -one that better captures contemporary demands (Sperling et al., 2022; Tuominen et al., 2005). *Literacy* is now understood as a tapestry of multiple literacies, shaped by social institutions and enacted in specific contexts, with the literate citizen(s) defined by skills as well as practices, values, and identities (Barton et. al, 2000). A pivotal contribution comes from critical literacy, rooted in Freire's emancipatory pedagogy: literacy is not only about "reading the word" abut also about "reading the world", recognising ideological meanings and power relations running through texts and images (Freire, 1970; Luke & Freebody, 1997). Street's (1984) sociocultural perspective further reframed literacy as social practice: participation in communities of meaning and identity.

Building on the New London Group's manifesto (1996), *multiliteracies* reshaped the field by foregrounding multimodality and treating learning as "the design of meaning," with learners positioned as active co-creators (Cope & Kalantzis, 2000; 2009). The *new literacies* perspective extends this discussion into digital culture, where practices are co-formed through online communities and collaborative frameworks for understanding (Jenkins et al., 2009; Lankshear & Knobel, 2011, Papailia & Petridis, 2015). In this view, literacy includes the capacity to participate in-and critically reflect on-the ecosystems of the Web and platforms.

In today's algorithmically mediated environment, *AI literacy* (AIL) does not replace earlier literacies; it absorbs and reconfigures them. Citizens are asked to "read" not only texts and multimodal media but also algorithmic processes, in order to understand data practices and to develop the capacity for critical and ethical evaluation of AI systems (including transparency/explainability, accountability, and social impacts). This sociocritical reading extends critical literacy into the algorithmic infrastructures of knowledge, linking also AIL to questions of democracy, equity and justice.

This discussion points to a specific theoretical framework that draws on four complementary strands: (i) the move from functional literacy to critical and sociocultural literacy, (ii) the emergence of multiliteracies and multimodality, (iii) the expansion toward digital literacies, and (iv) the consolidation of AIL as an intersection of critical and ethical capacities within algorithmically mediated societies.

2. Reading, Writing, Arithmetic and Functional Literacy

Functional literacy shaped the dominant understanding of literacy as a set of basic reading, writing, and arithmetic skills (the 3Rs), oriented toward the demands of everyday life and work and closely linked to literacy policy and social inclusion agendas. Conceptually, it treated literacy primarily as a "technical skill": the ability to decode text and produce basic written language (OECD/PIAAC, 2025a; Tuominen et al., 2005; New London Group, 1996; Cope & Kalantzis, 2000).

A critical perspective does not dismiss the importance of the 3Rs. It argues, rather, that they are necessary but not sufficient for meaningful participation in public life and equitable access to knowledge, particularly given their tight entanglement with socioeconomic inequality. The turn toward sociocultural and critical lenses reframed

literacy as a socially constructed practice: "reading" involves understanding and using discourse, "writing" becomes an act of negotiating meaning, and "numeracy" extends to interpreting quantitative representations (Barton et al., 2000; Freire, 1970; Luke & Freebody, 1997; Street, 1984/1995; New London Group, 1996).

From this standpoint, a twofold position is proposed: (i) strengthening the 3Rs remains an "infrastructure of equity" against social exclusion and (ii) this infrastructure must be expanded into practices of comprehension, critique, and creation aligned with learners' cultural and technological ecosystems (Ball et al., 2014; Cope & Kalantzis, 2012/2015; Hepp & Laval, 2003; OECD/PIAAC, 2025a). This avoids the reductionism of a purely functional model while supporting transfer across multimodal contexts, responding more directly to the demands of an algorithmically mediated society (Cope & Kalantzis, 2012/2015; Jenkins et al., 2009; Lankshear & Knobel, 2011; New London Group, 1996; OECD/PIAAC, 2025a).

3. The Social Context of Literacies: Critical Literacy and Multiliteracies

Critical literacy transformed the "narrow" functional definition of literacy into an understanding of literacy as a sociopolitical practice: meaning-making in which power, ideology, and hegemony are always at stake-so we read not only words, but also the world that produces them (Freire, 1970/1972; Luke & Freebody, 1997). In parallel, the sociocultural tradition rejected "autonomous" *literacy* and advanced *literacy* as social practice embedded in specific social, cultural, and historical contexts. The literate citizen is defined by participation in communities of meaning and identity, not by isolated technical skills (Street, 1984/1995). On this foundation, *multiliteracies* reframed learning through (i) recognising cultural and linguistic diversity as a resource and (ii) foregrounding multimodality, where meaning is "designed" through language, image, sound, movement, space, and digital technologies, with students positioned as active co-creators (New London Group, 1996; Cope & Kalantzis, 2000/2015). At the same time, the field highlights that "different literacies" operate across institutions and domains with unequal visibility and power-an insight that calls for more just and participatory educational arrangements (Barton, Hamilton, & Ivanič, 2000).

Overall, *critical literacy* provides the conceptual lens, while *multiliteracies* offer the pedagogical architecture for learning as "the design of meaning" in multimodal, multilingual, and culturally heterogeneous settings. Together, they lay important groundwork for "new literacies" and the demands of the post-digital condition (Cope & Kalantzis, 2000/2009; New London Group, 1996).

3.1 The Economic Impact of Literacy Gaps

Gaps in foundational reading - writing - numeracy (the 3Rs). Insufficient proficiency in the 3Rs can reinforce cycles of poverty and restrict employment opportunities. The cost of illiteracy has been estimated at up to USD 1.19 trillion (PwC, 2018; Rothwell, 2020; Lal, 2015; World Literacy Foundation, 2015). Early investment in emergent/early literacy shows strong effects on improving reading outcomes (Kim et al., 2020), yet in many developing regions large proportions of students still fail to reach adequate levels in reading and mathematics (Gaskell, 2018). Functional literacy remains a critical benchmark, but a narrow focus on the 3Rs can obscure broader reforms and sociocultural determinants of literacy (Gaskell, 2018).

Gaps in functional literacy. Low performance in the 3Rs remains widespread: approximately 26% of adults in OECD countries score at Level 1 or below in literacy proficiency, with difficulties understanding basic texts (OECD, 2025a,b). Cross-national PIAAC analyses also indicate that a one standard deviation increase in numeracy is associated with roughly 18% higher wages (Hanushek et al., 2015). Let us emphasise that, the COVID-19 pandemic triggered widespread disruptions to schooling and compounded learning losses, with long-run implications for human capital and productivity. At the macroeconomic level, these losses have been estimated to translate into very large lifetime earnings and growth costs for today's student cohorts (World Bank, 2020), while the Global Education Monitoring Report cautions that pandemic shocks have increased the cost of achieving SDG 4 by 2030, widening the financing gap and underscoring the need for sustained investment in learning recovery and foundational skills (GEMRT, 2020).

Gaps in multiliteracies. Today's economy demands capabilities beyond "reading and writing": digital and information competences, critical evaluation of sources, collaborative problem-solving, and adaptability (Fuster Rabella, 2025; Mann et al., 2025). In PIAAC, problem-solving skills in technology-rich environments and "computer skills" are positively associated with wages and employment beyond formal education-highlighting an "opportunity cost" when such skills are absent (Lane & Conlon, 2016). DESI indicators likewise link underperformance in "Human Capital - Digital skills" to lower productivity and slower digital transformation, particularly for SMEs (EC, 2022). Evidence also suggests that well-designed uses of digital technologies can disproportionately benefit less advantaged students, implying that gaps in digital and information skills may reproduce income inequalities (Di Pietro & Castaño Muñoz, 2025). Multiliteracies therefore function as foundational human capital and call for coherent lifelong learning policies linking schooling, adult education, and labour-market needs (EC, 2022; Elzir & Morgandi, 2024).

4. New Literacies

New literacies shift the emphasis from individual possession of skills to participatory meaning-making practices. This shift has two dimensions: (i) from a print-centred view of discourse to multimodality and the "design of meaning," and (ii) from the passive reader to the active participant who co-produces content within communities of practice (Cope & Kalantzis, 2000/2015; New London Group, 1996). C. Lankshear and M. Knobel (2007/2011) connect *new literacies* to a "new ethos" of digital culture - openness, collaboration, networking, participation, and remix - and define the literate citizen through participation in online communities and the management of digital identity. A sociocritical reading underscores that digital environments are institutionally and technologically mediated ecosystems, where visibility, information flows, and opportunities for participation are governed by platform architectures. *New literacies* therefore require participatory skills alongside critical awareness of power structures, data politics, and the terms of access and inclusion (Cope & Kalantzis, 2015; Jenkins et al., 2009). Against this backdrop, *data* and *AI literacies* extend "reading" beyond texts and media to algorithmic processes and automated classifications and, morover, *critical data literacy* asks who decides what is collected, who benefits or is harmed, and how data can reproduce unequal power relations (Louie, 2022; Louie et al., 2023.). *AI literacy* is commonly framed as a blend of knowledge, skills, and

dispositions for responsible engagement with AI systems - often summarised as understanding, evaluation (accuracy/validity/bias), and use for creation and problem-solving (Biagini, 2025; Lo, 2025; Nerantzis, 2025). And these three pillars are operationalised across five complementary dimensions: technical knowledge (how AI systems work and what they can and cannot do), ethical awareness (fairness, transparency, accountability, privacy, and harm), critical thinking (questioning outputs, detecting bias and misinformation, and judging validity), practical use (effective, context-sensitive application for learning and problem-solving), and social impact (understanding how AI reshapes participation, power relations, and social outcomes (Biagini, 2025; Lo, 2025; Nerantzis, 2025).

In summary, *new literacies*: (i) consolidate multimodality and participation as central to learning (New London Group, 1996; Jenkins et al., 2009), (ii) shift the focus from "having" skills to participating in communities and networks (Lankshear & Knobel, 2007/2011), and (iii) presuppose critical awareness of institutional and technological mediation, preparing learners for a post-digital society where reading extends to data and algorithms (Cope & Kalantzis, 2015; D'Ignazio & Bhargava., 2020; Louie et al., 2023; Mills et al., 2024; WEF, 2025).

4.1 The Economic Impact of Gaps in New Literacies

Lagging behind in *new literacies* carries a tangible and measurable socioeconomic cost. For example, at the individual level, *financial literacy* is associated with stronger financial behaviors and resilience. A meta-analysis of 126 evaluation studies reports a positive overall effect (mean effect size = 0.148), with a stronger impact on financial knowledge (0.26) and a measurable effect on financial behaviour (0.09) (Kaiser & Menkhoff, 2017). At the European level, around 20% of the citizens shows low financial literacy, and many households report no emergency savings-patterns that weaken both micro-level resilience and macroeconomic stability (EC, 2024). From a labour-market and productivity perspective, comparative PIAAC analyses document positive returns not only to classic skills (literacy/numeracy) but also to ICT related competences. In wage estimates that, one standard deviation increase in ICT task skills corresponds to roughly +8.7% higher wages, while the corresponding "return" to numeracy is around +4.1% (Grundke et al., 2018). In short, gaps in *new literacies* translate into foregone returns for individuals and firms, and into greater vulnerability in periods of disruption (EC, 2024/2025; Grundke et al., 2018; Lane & Conlon, 2016). International evidence also links performance in technology-rich problem-solving (PSTRE) to wages and labour-market outcomes, and sectoral "digital intensity" tends to reward higher-level numeracy and skill bundles (Grundke et al., 2018; Nwakasi et al., 2019). A recent World Bank synthesis underscores that aligning digital skills with labour-market needs is a key lever for employability and skills resilience (Elzir & Morgandi, 2024).

4.2 The Economic Impact of Gaps in AI Literacy

Across the international literature, there is growing convergence around a clear point regarding *AI literacy.* Insufficient *AI literacy* has a clear and expected measurable costs for work, productivity, equity, and compliance. Where *AI literacy* is weak, the reconfiguration of roles and skill requirements increases the risk of occupational downgrading and reduced employability (WEF, 2023). The OECD highlights a

persistent “AI skills gap” that constrains AI adoption: demand is rising, while training supply remains limited. In an analysis across four countries, only 0.3% - 5.5% of courses included AI-related content (OECD, 2025a,b). At the macro level, IMF estimates suggest that roughly 40% of the global workforce is in occupations with “high exposure” to AI, intensifying pressures on wages, job transitions, and inequality (IMF, 2024). In education and governance, the costs of low *AI literacy* extend beyond economic returns to sociocultural and ethical risks: exposure to bias, misinformation, privacy and security threats, and automation bias in critical decision-making-strengthening the case for a critical *AI literac*y orientation focused on understanding, evaluation, and responsible use (Miao & Cukurova, 2024; Vuorikari et al., 2022; Veldhuis et al., 2025). Evidence also suggests that over-reliance on conversational AI may weaken critical evaluation and increase exposure to inaccuracies, generating educational and organisational costs (Zhai et al., 2024). Under post-digital conditions, a sociocritical approach-attentive to datafication and algorithmic power-becomes a prerequisite for equitable participation in algorithmically mediated societies (OECD, 2025a,b; Rapanta et al., 2025; UNESCO, 2024; Vuorikari et al., 2022; WEF, 2023).

5. The Post-Digital Society and the Need for a Sociocritical Reading of Literacies

In post-digital society, the digital dimension of our worlds and actions is no longer treated as a separate “other sphere” of immaterial virtual reality. It is interwoven into everyday human activity and onto every human expression (Rapanta et al., 2025). Platforms, networks and algorithms now sit at the core of contemporary societies, shaping institutions, economic transactions, and social practices (Filgueiras et al., 2022; Pradip Ninan, 2023; Van Dijck et al., 2018). Major technology corporations have accumulated substantial power over social life and its infrastructures (Tambini & Moore, 2018; The Economist, 2025a,b; Van Dijck et al., 2018). This reality of digitalisation is accompanied by digital surveillance (Nur et al., 2024; Гавриленко, 2024), platform hegemony (Prey & Lee, 2024; Ming, 2023; van Dijck & Lin, 2022), algorithmic bias (Celiktutan et al., 2024; Jain & Menon, 2023; Jha, 2024), socio-algorithmic dynamics in social media (Acheampong & Taden, 2024; van Dijck & Poell, 2013), and the growing penetration of AI into education through EdTech solutions, datafication, learning analytics, and adaptive learning systems (Holmes et al., 2019). For citizens to navigate and critically engage with this landscape, what is needed is a sociocritical reading of *literacies*. We need an approach that frames digital skills and knowledge through social critique, making visible power relations and ideologies embedded in technological practices.

A. *Digital Surveillance.* In the post-digital landscape, online services extract, aggregate, and monetise user data, a dynamic at the heart of “Surveillance Capitalism,” reinforcing datafication in which lived experience becomes “raw material” for prediction and behavioral influence (Pradip Ninan, 2023; Zuboff, 2019).. The knowledge asymmetry between largely invisible “watchers” and highly visible users creates power imbalances, with implications for democracy, accountability, and transparency (Zuboff, 2019; Andrejevic, 2019; Couldry & Mejias, 2019). Dispelling the myth of the “free” ecosystem requires sociocritical literacy: citizens who understand data cycles, recognise surveillance/commodification risks, and claim privacy rights (Andrejevic, 2019). In the age of AI, this expands into critical AI literacy-analysing

algorithmic processes, identifying opacity and bias, and anticipating social consequences (Lee & Cai, 2024; Rapanta et al., 2025).

B. *Platform Dominance and Sociocritical Reading.* In a "platform society," platforms act as core infrastructures, shaping institutional life and information flows (van Dijck, Poell, & de Waal, 2018; Van Dijck, 2018). Large firms operate as gatekeepers, leveraging network effects and data accumulation to set terms of access and interaction, influencing public-interest values such as access to knowledge and citizens' rights (Prey & Lee, 2024; van Dijck & Lin, 2022). A sociocritical reading treats platforms as political economies rather than neutral infrastructures, and foregrounds civic demands for transparency, accountability, and democratic participation in defining the digital public sphere (Cohen, 2019; Hildebrandt, 2018; O'Neil, 2016; van Dijck & Lin, 2022).

C. *Algorithmic Bias and the Opacity of Systems.* In the "age of algorithms," search engines, news feeds, and AI systems shape consequential decisions, and cases of bias and unequal treatment are well documented (Celiktutan et al., 2024; Jain & Menon, 2023; Jha, 2024). Bias is often structurally embedded, reflecting historical inequality and commercial incentives (Noble, 2018), while "black-box" opacity undermines scrutiny and accountability (D'Ignazio & Klein, 2020; Raji et al., 2020). Algorithmic literacy therefore, asks who designed systems, with what data and assumptions, and to whose benefit-supporting demands for transparency, accountability, and democratic oversight (D'Ignazio & Klein, 2020; Raji et al., 2020; Selbst et al., 2019).

D. *Social Media, "Affective Publics," and Echo Chambers.* Social media reshapes information, expression, and participation, fostering "affective publics"-networked communities mobilised through emotion (Papacharissi, 2014). Engagement-optimised ranking can privilege polarising content and reinforce echo chambers and filter bubbles, narrowing exposure to dissenting perspectives (Bail et al., 2018). A sociocritical social media literacy recognises news feeds as algorithmic constructions, supports active source diversification, and promotes dialogue beyond like-minded networks-an educational priority for democratic resilience (Bail et al., 2018; Papacharissi, 2014; boyd, 2019).

E. *Education, EdTech, and Artificial Intelligence.* In education, the post-digital condition is visible in the rapid penetration of EdTech and AI systems. Adaptive platforms, personalised learning, automated assessment, "smart" classroom management, and real-time analytics promise tailored learning, reduced workload, and continuous support (Selwyn, 2022). At the same time, datafication can reorganise schooling around what is easiest to measure, aligning practice with platform metrics and drawing schools into the logics of digital/platform capitalism (Lewis et al., 2022; Thorpe & Sellar, 2023). The documented risks include the de-professionalisation of teaching, new inequalities, the privatisation of critical functions, and the need for renewed regulatory tools (Lewis et al., 2022; Thorpe & Sellar, 2023).

Against the backdrop of "AI hype", the conversation needs to move from "how do we bring in more AI?" to "why, under what conditions, and what kind of education do we actually want?" (Selwyn, 2022). A sociocritical reading insists on realism about AI's capabilities, attention to limits (context, judgement, emotion), explicit risk assessment (privacy, bias, unequal access), clarity about value assumptions behind "efficiency/personalisation," and an appraisal of environmental costs (Selwyn, 2022).

Practically, this implies public oversight of AI solutions, strengthening teachers and students through critical digital and AI literacies to counter "teaching to the algorithm", and restoring political and ethical dimensions to educational design (Selwyn & Jandrić, 2020; Lewis et al., 2022; Thorpe & Sellar, 2023). The aim is not more technology per se, but pedagogies serving critical thinking, creativity, inclusion, and democratic accountability.

In the first quarter of the twenty-first century, *literacy* requires the capacity to critically read the ecosystem of data, algorithms, and platforms mediating knowledge and public discourse. Critical consciousness shifts from interpreting texts to interpreting the models produced by algorithmic processes (Williamson & Eynon), making critical literacy a form of resistance to algorithmic hegemony (Couldry & Hepp, 2017). *Sociocritical literacy* therefore integrates technical and critical capacities, and *AI literacy* includes interrogating who designs and trains systems, with what data and exclusions, while *digital* and *information literacy* includes recognising manipulation by understanding platform logics and incentives (Williamson & Eynon; Couldry & Hepp, 2017). Overall, *sociocritical literacy* helps bridge the gap between rapid technological change and social understanding. Without it, citizens risk becoming spectators-or casualties-of big data, automated decision-making, and platformisation. With it, technology can be oriented toward democratic and just transformation (Couldry & Hepp, 2017).

6. The Social and Critical Dimension of Literacies

Sociocultural approaches emphasise that *literacy* is situated in cultural and social contexts: it is not a neutral set of skills, but a way of participating in communities and power relations (Street, 1984). *Multiliteracies* treat otherness as a learning resource and shift from a single "standard norm" to participatory communities of meaning, especially in digital and multilingual environments (Kalantzis & Cope, 2012; New London Group, 1996; Cope & Kalantzis, 2015). Today, *AI literacy* develop within a datafied society, where automated processes shape consequential decisions (Picasso et al., 2024). The critical dimension focuses on recognising bias in data and outputs and on insisting on transparency, explainability, and rights-based oversight. Citizens are called to "read the world through data", to examine how information is produced, which inequalities it reproduces, and how to act toward fairer outcomes (Elzir & Morgandi, 2024). *AI literacy* are thus a necessary 21st century capability, and not only as a tool to use, but to gain judgement about consequences, for accountability, and participation in fair (Elzir & Morgandi, 2024; EC, 2025). Education with a sociocritical orientation-combining technical preparation with dialogue about values, rights, and democratic participation, is central to preventing exclusion and strengthening equitable participation (Picasso et al., 2024).

6.1 Adoption Gaps in New Literacies

The emergence of *digital*, *information*, *critical*, and *AI literacy* does not imply automatic or uniform integration. Instead, we see temporal, spatial, and generational/age-related gaps (Petrovčič et al., 2024; Selwyn, 2022).

A. *Temporal gap.* Policy and school practice often lag behind technological change. A global UNESCO survey reported that fewer than 10% of 450+ institutions had an

official policy for the use of generative tools (UNESCO, 2023), while the rapid release cycles of GenAI tools outpace national regulatory frameworks, leaving privacy and institutional readiness insufficiently addressed (Miao & Holmes, 2023).

B. *Geographic and socioeconomic gaps.* In 2024, 2.6 billion people remained offline-fueling not only a digital divide, but also a potential "AI divide" (ITU, 2024; UNESCO, 2025b). Women and girls are 25% less likely to use digital technology, with direct implications for digital and AI literacy; UNESCO therefore calls for a human-centred, rights-based approach with safeguards (UNESCO, n.d.; UNESCO, 2025b).

C. *Generational and age-related gaps.* "Digital natives" may adapt quickly to platforms, but informal familiarity is not the same as critical awareness of algorithms, bias, and ethics. Meanwhile many teachers and adults report feeling unprepared, producing pedagogical asymmetries (Selwyn, 2022). By 2022, only 15 countries had incorporated AI learning objectives into national curricula, highlighting the distance between diffusion and systemic integration (Miao et al., 2024).

International organisations therefore call for capacity-building through *AI literacy*/competency frameworks supported by clear policy guidance (Miao et al., 2024; Miao & Holmes, 2023; UNESCO, 2025a). Overall, updated AI use frameworks, investments in connectivity/equipment for vulnerable groups, and national upskilling plans are needed so that digital and AI literacy function as levers of equity (UNESCO, 2025b; Miao et al., 2024).

7. Discussion

One reason these gaps keep widening is the acceleration of technological change. Each innovation spreads faster than the previous one, and the era of generative AI has intensified pressures on education systems and society. Drawing on Z. Bauman's account of "liquid modernity", we can also speak of "liquid (or fluid) knowledge" - since knowledge is increasingly provisional, mobile, and continuously reworked, and therefore demands ongoing learning (Bauman, 2000/2007; Barnett, 2012; Ribolzi, 2009). B. Cope and M. Kalantzis (2020) describe contemporary literacy as designing meanings: learners and citizens co-create and re-interpret reality rather than merely memorising it. From this perspective, technological change can be treated as an opportunity for empowerment-learning how to learn, adapt, and become co-creators of knowledge. International research and policy organisations propose strategies to close these gaps and ensure that *AI literacy* serves the public interest. These strategies converge around a critical orientation to *AI literacy*.

A. *A human-centered and critical approach.* UNESCO argues that AI in education must be guided by inclusion and equity so that it narrows rather than widens inequalities (Miao & Holmes, 2023; UNESCO, 2025a, 2025b). This aligns with the notion of *critical AI literacy* because technical competence is insufficient without a critical understanding of AI in its social and cognitive contexts (Rapanta et al., 2025). Learners and students are invited to examine AI's role in knowledge production, recognise biases and limits, and align practice with social justice and democratic participation.

B. *Empowerment and participation in education.* In Freirean terms, literacy-including AI literacy-is empowerment rather than mere training. "Reading the world to transform

it" today implies that citizens should not use AI passively, but participate in shaping how it is governed and used (Freire; Miao & Holmes, 2023; UNESCO, 2025a, 2025b). UNESCO's AI Competency Framework for Students positions learners as responsible citizens, foregrounding critical thinking, responsibility for their digital world, and foundational AI knowledge (Miao et al., 2024; UNESCO, 2025b).

C. *Curriculum adaptation and teacher professional development.* As skill requirements shift, curricula must become more flexible and forward-looking, with computational thinking and basic AI concepts increasingly introduced in schooling (Guidry, 2024; Nerantzis, 2025). UNESCO recommends updated AI curricula across levels and targeted adult upskilling (Miao & Holmes, 2023; UNESCO, 2025a). Teacher development is central: educators need sustained support to use AI pedagogically and to keep generative AI "in the service of teachers and students," oriented to autonomy and well-being (Miao & Holmes, 2023; UNESCO, 2025a, 2025b).

D. *Investment in infrastructure and open resources.* Equitable AI literacy presupposes adequate infrastructures: connectivity and access to suitable devices remain basic conditions of participation (UNESCO, 2025a, 2025b). UNESCO and the OECD call for national strategies to close access gaps (UNESCO, 2025a, 2025b). In parallel, open educational resources and multilingual AI content are essential so that AI does not become monopolised by English-speaking or economically advantaged communities. UNESCO also highlights the need to enrich systems with data from underrepresented languages and cultures (Miao & Holmes, 2023; UNESCO, 2025a, 2025b).

Bringing these strands together, literacies in the age of AI offer major opportunities alongside complex challenges. Rapid, multi-layered, and often asymmetric changes create educational and social divides, but these are not inevitable. *Critical AI literacy* becomes a necessity, not only for effective use, but for deep understanding, creative questioning, and shared governance of norms and rules. Importantly, there is no single, monolithic "AI literacy" that applies uniformly. Rather, it is a "constellation" of skills and orientations that must remain sensitive to contexts and values (Rapanta et al., 2025). The challenge is not only to read the world of AI, but to rewrite it: to redesign it critically and collectively so that technological progress aligns with democracy, equality, and human dignity (Rapanta et al., 2025). As C. Rapanta and colleagues (2025) argue, *literacies* - such as *critical GenAI literacy* - should be understood "*as a constellation of situated literacies, shaped by disciplinary perspectives, socio-political contexts, and technological affordances*". In a post-digital era, where AI and digital tools are interwoven with social practice, the task goes beyond reading the world of AI. It is about rewriting and redesigning the world critically and collectively, while remaining open to what is yet to come (Axelos, 2009/2011).

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From Theory to Practice: Implementing Participatory Pedagogical Approaches to Support Students' Understanding of Artificial Intelligence

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Abstract—The rapid development of Artificial Intelligence (AI) and its increasing presence in educational contexts call for pedagogically grounded and critically informed approaches to its integration in schools. This paper presents a participatory, school-based research project conducted with upper secondary students, aiming to explore their perceptions, attitudes, and concerns regarding the role of AI in learning and everyday life. The study was designed not only as an empirical investigation but also as a pedagogical intervention that foregrounds student agency and inquiry-based learning. Students participated actively as co-researchers in the formulation of research questions, the design of an anonymous questionnaire, data collection, and the interpretation of findings. The theoretical framework draws on inquiry-based pedagogy, critical digital literacy, and sociocultural theories of learning, emphasizing the role of human mediation and ethical reflection in AI-enhanced educational environments. The findings indicate that students adopt a nuanced and critical stance toward AI. While they recognize its potential to support understanding, organization, and efficiency in learning, they also express concerns related to dependency, data privacy, creativity, and the erosion of personal effort. AI is predominantly perceived as a supplementary cognitive tool rather than a substitute for learning or teaching. Students further emphasize the irreplaceable role of teachers as guides, mentors, and ethical mediators in AI-mediated learning contexts. Beyond the empirical results, the study highlights the pedagogical value of participatory research. Through their involvement in the research process and the public presentation of findings at a student conference, students developed critical thinking, research literacy, communication skills, and ethical awareness. The paper argues that engaging students as active producers of knowledge offers a meaningful pathway for fostering responsible, reflective, and pedagogically sound engagement with AI in secondary education.

Keywords: Artificial Intelligence (AI), education, experiential learning, participatory research

Introduction

The rapid development of Artificial Intelligence (AI) and its increasing integration into everyday life have profoundly transformed not only technological practices but also the ways in which knowledge is produced, accessed, evaluated, and legitimized Pamuk et al., 2015). In educational contexts, AI-driven tools - such as intelligent tutoring systems, recommendation algorithms, and generative models - are reshaping learning environments, study habits, and assessment practices (Haleem, Javaid, Qadri & Suman, 2022). As a result, education systems are confronted with challenges that go far beyond technical implementation, raising fundamental pedagogical, epistemological, and ethical questions about learning, agency, creativity, responsibility, and the role of human judgment (Banjade, Patel & Pokhrel, 2024).

Within this evolving landscape, a growing body of research emphasizes that AI in education should not be approached merely as a neutral or efficiency-enhancing technology. Rather, it constitutes a socio-technical phenomenon that actively mediates cognition, reorganizes access to information, and influences how learners interpret, trust, and use knowledge (Mittal, Sai, Chamola & Sangwan, 2024). Consequently, there is an urgent need for pedagogical approaches that do not limit themselves to introducing students to AI tools or functionalities but instead foster critical understanding of how such technologies shape thinking, learning, and decision-making processes.

At the same time, despite the increasing presence of AI in schools, students' perspectives, experiences, and concerns often remain underrepresented in academic research and educational policy discussions. While students are among the primary users and subjects of AI-mediated educational practices, their voices are frequently absent from debates about how AI should be integrated into teaching and learning. This gap is particularly significant in secondary education, where students are developing academic identities, learning strategies, and ethical orientations that will shape their future engagement with technology and knowledge (Pedro, Subosa, Rivas, & Valverde, 2019).

The present study addresses this gap by presenting a participatory, school-based research project designed and implemented with upper secondary school students. The project aimed to explore students' perceptions, attitudes, and concerns regarding the role of AI in their everyday lives and educational practices, while simultaneously engaging them in an authentic research process. Rather than positioning students as passive respondents or consumers of ready-made knowledge, the project deliberately involved them as active co-researchers who contributed to the formulation of research questions, the design of data collection tools, the analysis of findings, and the interpretation of results.

This approach is grounded in the assumption that meaningful education about AI requires students' active participation in knowledge construction. From a pedagogical perspective, involving students in inquiry-based and participatory research can enhance critical thinking, metacognitive awareness, collaboration, and ethical reflection (Konieczny, 2024; Wang, Gao, Chen, 2023). From an epistemological standpoint, such involvement allows students to experience knowledge not as fixed or authoritative, but as provisional, contested, and socially constructed (Hyytinen, Holma, Toom, Shavelson & Lindblom-Ylänne, 2014). especially in contexts where algorithmic systems

increasingly participate in generating and organizing information (Timotheou et al., 2023).

Rational, Purpose and Research Objectives

The present study was primarily designed as a pedagogical intervention aimed at exploring how participatory, inquiry-based teaching approaches can support students' critical understanding of Artificial Intelligence (AI) within secondary education. The research positions AI not merely as a technological innovation to be adopted in classrooms, but as a pedagogically significant phenomenon that reshapes learning processes, knowledge construction, and students' cognitive and ethical engagement with information.

At its core, the study sought to examine the educational value of involving students actively in the investigation of AI through structured research practices. By engaging students as co-researchers (Smit, 2013), the intervention aimed to cultivate critical digital literacy (Ilomäki et al., 2023), ethical awareness (Biagini, 2025), collaborative skills (Lin et al., 2015), and reflective thinking (Titus & Muttungal, 2024; Saritepeci & Durak, 2024) - competencies considered essential in technology-mediated learning environments. The exploration of students' perceptions, attitudes, and experiences with AI functioned as a vehicle for assessing the effectiveness of this pedagogical approach.

Within this framework, the study pursued a dual purpose. First, it aimed to evaluate how participatory and inquiry-based pedagogical methods enable students to develop a deeper, more critical understanding of AI and its role in learning and knowledge production. Second, it sought to document students' perspectives on AI use in education and everyday life, using these perspectives as empirical evidence to inform pedagogical reflection and instructional design.

A central premise of the study is that meaningful AI education requires positioning students as active agents rather than passive users of AI-generated content. Through their direct involvement in literature review, question formulation, data collection, and analysis, students were encouraged to examine AI as an object of inquiry, recognizing both its educational affordances and its cognitive, ethical, and social implications.

More specifically, the study addressed the following research objectives:

- To investigate the pedagogical impact of participatory, inquiry-based approaches on students' understanding of AI and their engagement with complex technological issues.
- To examine how students conceptualize the role of AI in learning, including its influence on understanding, effort, creativity, and autonomy.
- To explore students' ethical reflections related to AI use, particularly concerning data privacy, reliability of information, algorithmic bias, and dependency.
- To analyze students' perceptions of the teacher's role in AI-mediated learning environments, with emphasis on guidance, mediation, and evaluation.
- To develop students' research literacy by involving them in an authentic research process as an integral pedagogical objective.

By foregrounding pedagogy and situating students' views on AI within an educational design perspective, the study contributes to ongoing discussions on how AI can be

meaningfully integrated into secondary education. It highlights the value of participatory research methodologies as a pedagogical strategy for fostering critical engagement, ethical awareness, and reflective knowledge construction in AI-enhanced learning contexts.

Methodology

The present study employed a qualitative–quantitative mixed-methods design embedded within a participatory, school-based research framework. The methodological choices were intentionally aligned with the pedagogical objectives of the project, as the research process itself functioned as an educational intervention. Rather than positioning students solely as research participants, the study actively involved them as co-researchers throughout multiple stages of the research cycle, including literature review, formulation of research questions, data collection, data analysis, and interpretation of findings.

This approach draws on principles of inquiry-based and participatory research, which emphasize learner agency, authenticity, and reflective engagement with processes of knowledge construction (Kuhn, 2011; Cook-Sather, 2016). At the same time, it enabled the systematic collection of empirical data concerning students' perceptions, attitudes, and concerns regarding the use of Artificial Intelligence (AI) in educational contexts.

The research was conducted in an urban Lyceum during regular instructional activities. A total of 112 (out of 154) students participated by completing an anonymous online questionnaire. The participants represented diverse academic orientations and varying levels of familiarity with digital technologies, allowing for the collection of a broad range of perspectives on AI use in learning and everyday life. Participation was voluntary, and students were informed in advance about the educational purpose of the study and the anonymous nature of their responses. Ethical principles of confidentiality, informed participation, and responsible data handling were observed throughout the research process.

A distinctive methodological feature of the study was the structured pedagogical integration of students into the research design. Under the guidance of the teachers, students engaged in a systematic review of academic literature on AI in education, digital literacy, ethical implications of AI, and knowledge construction, using sources in both Greek and English accessed through platforms such as Google Scholar and open-access academic databases and the school library. Based on this theoretical grounding and classroom discussions, students collaboratively formulated the research questions and contributed to the design of the data collection instrument.

Data was collected through an anonymous online questionnaire developed using Google Forms, selected for its accessibility, ease of distribution, and automated data organization capabilities. The questionnaire included both closed-ended and open-ended items and addressed four main thematic areas: frequency and purposes of AI use, perceived benefits and challenges of AI-supported learning, ethical concerns related to AI (including data privacy, reliability, and dependency), and perceptions of the role of teachers in AI-mediated learning environments. While students played a central role in drafting the questionnaire items, teachers provided methodological support to ensure clarity, neutrality of wording, and alignment with the research objectives.

The questionnaire was distributed digitally within the school community, resulting in 112 valid responses. The distribution process was managed by the students themselves, reinforcing their sense of ownership and responsibility within the research process. No personally identifiable information was collected, and the data was used exclusively for educational and research purposes.

Following data collection, students—supported by the teachers—participated in the initial stages of data analysis. Quantitative data from closed-ended questions were organized into frequency tables and basic graphical representations to identify patterns and trends, while qualitative responses were grouped thematically to highlight recurring ideas, concerns, and reflections. The interpretive process was explicitly connected to theoretical concepts explored during the literature review and classroom sessions, such as algorithmic bias, reliability of information, digital dependency, creativity, and ethical responsibility. This integration enabled students to understand how empirical findings acquire meaning through theoretical frameworks and social contexts.

Ethical considerations were central not only to the research design but also to its pedagogical implementation. In addition to ensuring anonymity and voluntary participation, the study incorporated explicit discussions with students about research ethics, data protection, and the responsible use of digital tools, reinforcing ethical awareness as a core learning outcome.

Finally, certain methodological limitations should be acknowledged. The study was conducted within a single school context, which limits the generalizability of the findings. Moreover, the reliance on self-reported data may reflect students' subjective interpretations and varying levels of familiarity with AI technologies. Nevertheless, the study offers valuable insights into students' perspectives and demonstrates the pedagogical potential of participatory research methodologies for fostering critical engagement, ethical reflection, and deeper understanding of Artificial Intelligence in secondary education.

Findings: Pedagogical Insights from Students' Engagement with AI

The findings of the study portray students' relationship with Artificial Intelligence (AI) as pedagogically reflective, differentiated, and marked by a clear awareness of both learning opportunities and educational risks. Rather than approaching AI through extremes of enthusiasm or rejection, students articulate positions that reveal developing critical judgment, concern for learning quality, and sensitivity to issues of effort, creativity, ethics, and teacher–student relationships. From a pedagogical perspective, the results highlight how students interpret AI primarily as a learning tool whose educational value depends on context, guidance, and purposeful use.

Students' reported patterns of AI use suggest that AI has entered learning practices in a selective and non-dominant manner. Only a small proportion of students reported never using AI for school-related purposes (12.6%), while an even smaller group indicated daily use (4.6%). Most students positioned themselves between these two extremes: approximately 22.5% reported using AI several times per week, and over half described sporadic use—either rarely (32.4%) or a few times per month (27.9%). From a pedagogical standpoint, this distribution indicates that AI has not become an

automatic or habitual substitute for learning activities. Instead, students appear to engage with AI situationally, using it in response to specific learning demands, perceived difficulty, or time constraints. This pattern suggests emerging discernment in tool use and aligns with a view of AI as a supplementary cognitive resource rather than a foundational element of study routines.

Students identified several pedagogical benefits associated with AI, particularly in relation to comprehension and learning support. AI was frequently described as helpful for clarifying complex concepts, providing alternative explanations, supporting idea organization, and assisting with task initiation. These functions position AI as a form of scaffolding that can support learning beyond classroom time. Importantly, students framed these benefits as conditional. AI was valued when it supported understanding and efficiency but was not perceived as legitimate when it replaced personal effort or engagement. This distinction reflects a learning-oriented rather than outcome-oriented perspective, suggesting that students associate meaningful learning with cognitive involvement, struggle, and active sense-making.

Students' responses regarding creativity reveal one of the most pedagogically significant tensions in AI-supported learning. A considerable number of students expressed concern that AI may diminish creativity, particularly when it generates ready-made content. These students associated creativity with personal effort, exploration, and ownership of ideas—elements they felt were at risk when AI assumed a dominant role in content production. At the same time, 35.7% of students reported that AI partially or fully enhances their creativity. These students described using AI as a source of inspiration, a brainstorming partner, or a means of exploring alternative perspectives. A further 15.2% expressed uncertainty, suggesting either limited experience or difficulty evaluating AI's impact on their creative processes. Pedagogically, these findings indicate that students conceptualize creativity not as mere output production but as an active cognitive and personal process. AI is perceived as supportive only when it preserves student agency and does not displace the learner's role in meaning-making.

Students' perceptions of teachers' ability to recognize AI-generated or AI-assisted work point to emerging pedagogical challenges in assessment. Only a very small number of students believed that teachers can reliably identify AI-generated content. Approximately half suggested that teachers may suspect AI use without being able to confirm it. More specifically, 18.9% of students reported that AI-generated content is occasionally recognizable, while 27% believed that AI use is largely imperceptible to teachers. These perceptions highlight uncertainty surrounding authorship, authenticity, and evaluation practices in AI-mediated learning environments. From a pedagogical perspective, this finding underscores the need to rethink assessment practices, shifting emphasis from product-based evaluation toward process-oriented learning, reflection, and documentation of thinking.

Ethical considerations—particularly data privacy—emerged as a central learning-related concern. More than half of the students expressed uncertainty or skepticism about the safety of their personal data when using AI tools. While 26.1% reported feeling relatively safe, 11.7% expressed clear concern about data misuse, and only 6.3% reported complete confidence in data security. These findings suggest that students possess an emerging ethical awareness but lack structured understanding of how AI

systems collect and process data. Pedagogically, this points to a need for explicit instruction in digital ethics and data literacy as integral components of AI education.

One of the most pedagogically consistent findings relates to students' concerns about dependency. A substantial majority (74.1%) agreed that AI has the potential to foster dependency, particularly due to its speed, convenience, and ability to reduce effort. Students associate dependency with diminished persistence, reduced tolerance for difficulty, and weakened engagement with learning processes. By contrast, 18.8% rejected the notion of dependency, emphasizing individual responsibility and self-regulation, while 7.1% were unable to take a clear position. Overall, these responses reveal a high level of student metacognitive awareness regarding the relationship between tools, effort, and learning autonomy.

Despite acknowledging that AI may significantly transform education, students overwhelmingly rejected the idea that AI could replace teachers. While 53.6% recognized AI's transformative potential, 80.4% opposed the replacement of educators by AI systems. Students emphasized that teachers provide guidance, emotional support, ethical framing, feedback, and dialogic engagement—dimensions of learning that extend beyond information delivery. This finding strongly reinforces the pedagogical centrality of human mediation in AI-enhanced educational contexts.

Finally, students articulated forward-looking proposals that reflect a pedagogically grounded vision for AI integration. The majority emphasized the need for systematic training for both students and teachers (57.1%), improved infrastructure, transparent guidelines, and clear boundaries to protect creativity, effort, and critical thinking. These proposals position students not as passive recipients of educational innovation but as informed contributors to pedagogical decision-making.

Student Research Presentation and Skill Development

An important pedagogical dimension of the research was the dissemination of the students' findings in a student academic conference, where participants presented the outcomes of their investigation to a wider audience. Students' participation in this authentic scholarly context was met with highly positive feedback, indicating not only the quality of their empirical work but also their ability to communicate complex ideas clearly and confidently.

From an educational perspective, this experience functioned as a powerful extension of the research process itself. Preparing for and participating in the conference required students to synthesize data, structure arguments, design presentations, and articulate conclusions in a coherent and accessible manner. Moreover, students engaged in responding to questions, justifying methodological choices, and reflecting on limitations—practices that mirror core academic and scientific conventions.

This process contributed substantially to the development of transversal or "soft" skills that are central to contemporary educational goals (Rotherham & Willingham, 2010). These included communication skills, collaboration, organization, time management, public speaking, adaptability, and critical responsiveness. Equally important, the conference experience strengthened students' sense of ownership over their work and

reinforced their identity as legitimate contributors to knowledge rather than passive recipients of information Larson & Miller, 2011).

Pedagogically, the public presentation of research findings transformed the learning activity into an authentic knowledge-building experience (Tan et al., 2021). It provided students with a real audience, meaningful purpose, and social recognition, thereby enhancing motivation, self-efficacy, and reflective awareness of the learning process (Larson & Miller, 2011). This dimension of the project illustrates how participatory research, when extended beyond the classroom, can support both cognitive development and the cultivation of skills essential for academic, civic, and professional contexts.

Discussion

The findings of the present study provide insight into how upper secondary students conceptualize, use, and evaluate AI within educational contexts, while also highlighting the pedagogical value of engaging students as active participants in inquiry-based research. Interpreted through a pedagogical lens, the results suggest that students' attitudes toward AI are not merely shaped by exposure to technology but are significantly influenced by the learning frameworks within which AI is introduced and discussed.

One of the most salient findings is the absence of extreme patterns of AI use. Students neither adopt AI uncritically nor reject it altogether; instead, they engage with it selectively and purposefully. This pattern aligns with broader research indicating that students' use of digital technologies becomes more reflective when embedded in pedagogically structured learning environments (Haleem et al., 2022; Timotheou et al., 2023).

From a pedagogical perspective, this moderate use suggests that students are beginning to exercise judgment regarding when AI meaningfully supports learning. Such behavior reflects core principles of inquiry-based learning, where tools are employed in response to authentic cognitive needs rather than as default solutions (Kuhn, 2011; Konieczny, 2024). The findings therefore challenge deficit-oriented narratives that frame students as inevitably over-reliant on AI, instead portraying them as capable of developing situational awareness when appropriate guidance is provided.

Students' recognition of AI as a tool that supports understanding, explanation, and organization is consistent with research on AI-powered tutoring systems, which highlights their potential to enhance learning when used as scaffolding rather than substitution (Banjade et al., 2024; Mittal et al., 2024). However, students' responses also reveal an implicit epistemic caution: AI is seen as helpful, but not authoritative.

This finding resonates with studies on critical digital literacies, which emphasize that learners must understand how algorithmic systems shape knowledge representation and credibility (Ilomäki et al., 2023; Biagini, 2025). The participatory research design of the present study appears to have strengthened students' awareness of these epistemic boundaries by exposing them to processes of data interpretation, questioning, and validation. As Hyytinen et al. (2014) argue, students' epistemological beliefs are

closely linked to their capacity for critical thinking—an association clearly reflected in the students' nuanced positioning of AI as supportive but not neutral.

The ambivalence surrounding AI and creativity highlights a fundamental pedagogical tension between efficiency and meaningful engagement. Students who perceived AI as limiting creativity emphasized the importance of struggle, originality, and personal involvement, while those who reported creative enhancement tended to describe AI as a catalyst rather than a producer.

This distinction aligns with research on design-based and project-based learning, which shows that digital tools can foster creativity and reflective thinking when learners remain cognitively active (Lin et al., 2015; Saritepeci & Yildiz Durak, 2024). Moreover, students' reflections point to emerging metacognitive awareness, particularly regarding how AI influences their thinking processes. Such awareness is consistent with findings that metacognitive scaffolding supports deeper engagement and computational thinking in technology-rich learning environments (Wang et al., 2023; Titus & Muttungal, 2024).

Students' perceptions of teachers' limited ability to recognize AI-generated content reveal less a disciplinary concern than a pedagogical one. Rather than framing this issue as a technical problem of detection, the findings point toward the need for rethinking assessment practices in AI-mediated contexts. Contemporary research suggests that traditional product-oriented assessment is increasingly misaligned with AI-supported learning environments (Pedro et al., 2019; Biagini, 2025). In contrast, inquiry-based and knowledge-building approaches emphasize process, justification, and reflection as indicators of learning quality (Kuhn, 2011; Scardamalia & Bereiter, 2006). The students' responses implicitly support this shift, highlighting the pedagogical importance of transparency, dialogue, and epistemic accountability over surveillance-based control.

Ethical concerns—particularly regarding data privacy, dependency, and responsibility—emerged as one of the strongest dimensions of student reflection. Students' uncertainty about data protection mirrors findings from international studies showing that young people often recognize ethical risks without fully understanding underlying data practices (Livingstone & Third, 2017; Biagini, 2025). At the same time, the strong consensus around the risk of dependency suggests a high level of self-awareness and reflective judgment. This finding supports arguments that ethical AI education should focus not only on abstract principles, but on students lived experiences and decision-making processes (Ilomäki et al., 2023). Integrating ethical reflection into everyday learning activities thus appears essential for fostering responsible and autonomous engagement with AI.

Despite acknowledging AI's transformative potential, students overwhelmingly rejected the idea of replacing teachers with AI systems. This finding aligns with sociocultural theories of learning, which emphasize the irreplaceable role of human mediation, dialogue, and emotional support. Importantly, the participatory nature of the study positioned teachers not as controllers of technology, but as facilitators and co-inquirers. This pedagogical stance resonates with research on student–teacher partnerships and "brave spaces," where shared inquiry enhances agency and mutual trust (Cook-Sather, 2016; Smit, 2013). Students' strong affirmation of the teacher's role

suggests that AI integration is most effective when grounded in pedagogical relationships rather than technological determinism.

Finally, it is essential to recognize that students' critical and reflective attitudes toward AI were not merely measured but cultivated through the research process itself. By participating as co-researchers—and later presenting their findings at a student conference—students developed a range of transversal skills, including organization, collaboration, public speaking, and responding to critical questions. This experience aligns with research highlighting the educational value of involving students in authentic research and public knowledge-sharing practices (Smit, 2013; Lin et al., 2015). The positive reception of students' presentations further reinforces the pedagogical potential of participatory research to bridge classroom learning with broader academic and civic contexts. In this sense, the study demonstrates that participatory, inquiry-based pedagogy not only deepens students' understanding of AI, but also equips them with critical, ethical, and communicative competencies essential for navigating AI-enhanced educational environments.

The findings of the present study provide insight into how secondary students conceptualize, use, and evaluate Artificial Intelligence (AI) within educational contexts, while also illuminating the pedagogical value of engaging students as active participants in research. The discussion that follows interprets the results in relation to the study's theoretical framework and situates them within broader debates on AI, learning, and educational practice.

Conclusion

This study demonstrates that the educational integration of Artificial Intelligence cannot be meaningfully addressed without attention to pedagogy, student agency, and ethical reflection. By engaging students as co-researchers within a participatory and inquiry-based framework, the project revealed that learners can develop nuanced, critical, and responsible positions toward AI when supported by appropriate pedagogical structures. The findings underscore that AI is most productively understood as a cognitive and educational tool whose value depends on how it is embedded in human-mediated learning processes. Ultimately, the study affirms the central role of educators and participatory pedagogy in shaping AI-literate, reflective, and ethically aware learners, positioning schools not merely as sites of technological adoption, but as spaces for critical engagement and knowledge construction in the age of AI.

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The Educator as an AI-based Mediator in the Era of Education 5.0: Reducing Educational Inequalities

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Abstract—The advent of new technologies and their integration into educational settings have carried a great promise to transform teaching and learning, to foster creativity, to advance critical thinking, and to democratize knowledge. The introduction of Artificial Intelligence (AI) applications in education is seen by some as a blessing and by others as a curse. The concerns are intense, mainly due to the fact that minors are involved, whose personalities are shaped within the educational process. This does not mean that we should ban the introduction of AI tools in education, but that we must limit their application with the basic aim of improving the educational process without losing sight of its fundamental goal, which is to shape responsible and conscious citizens and cultivate ethical thinking. This requires the educator's role to become that of a coordinator and advisor and not that of the transmitter of knowledge, moving toward an era of future education in which teachers and AI technologies work together.

Keywords: Artificial Intelligence, Educational Inequality, Educator Mediation, Inclusive Education, Learning Analytics.

1. Introduction

Historically, schools, as a microcosm of society, marginalized and separated any student who differed from the norms of typical development and considered them abnormal. In this context, the teacher-centered view of school prevailed where the teacher was the authority, the one who knew, and the students were the ones who had to learn. However, the modern educational reality is characterized by rapid changes and multiple interrelated crises, rendering this mindset inadequate. The transition to a new pedagogical model fundamentally redefines the role of the teacher, whose new role is that of coordinator and advisor rather than transmitter of knowledge, who does not offer ready-made solutions, but rather organizes the lesson in such a way that the students discover it for themselves. Now, the teacher is transformed into a motivational guide and collaborator, who creates a learning environment and promotes freedom, equality, respect, and participation. This shift is particularly important in inclusive education, where the effective implementation of inclusion, in addition to academic and social learning outcomes, requires the commitment of teachers to collaboratively resolve the daily issues of school life (Nikolidakis & Tromara, 2025). Teachers are increasingly understood as intermediaries who guide students in their engagement with AI-supported learning environments. In this sense, the educator's role extends beyond technical facilitation to active pedagogical and ethical mediation. Within this paper, an *AI-based mediator* is understood as an educator who frames learning goals, makes informed decisions about when and how AI tools are used, and critically evaluates AI-generated outputs in relation to bias, accessibility, and pedagogical relevance. At the same time, this role involves safeguarding student data and supporting learners' metacognitive, social, and emotional development, ensuring that AI functions as a means of promoting inclusion and educational equity rather than reproducing existing inequalities (Baghavathi Priya, 2024).

This reconceptualization of the teacher's role is not merely a response to technological change but reflects a broader critique of contemporary schooling. As Nikolidakis and Kota (2026) argue, dominant pedagogical models have increasingly reduced education to memorization, standardization, and high-stakes accountability, positioning teachers as performers within market-oriented systems rather than facilitators of meaningful learning. In contrast, they propose a mediatory model in which the teacher shifts from being the focal point of instruction to acting as a *director of learning*, supporting learners in constructing knowledge, reflecting on their thinking processes, and developing autonomy. This perspective is particularly relevant in the context of AI-enhanced education, where the educator's mediating role becomes essential in ensuring that technological tools serve pedagogical, ethical, and inclusive aims rather than reinforcing existing inequalities or narrowing educational purposes.

However, the application of AI in educational contexts raises profound questions – for example about what should be taught and how, the evolving role of teachers, and AI's social and ethical implications. The deployment and use of AI in education must be guided by the core principles of inclusion and equity. Without effective policy intervention, the deployment of AI in education is likely to inevitably magnify rather than ameliorating existing learning inequalities (UNESCO, 2021). A major concern is that AI systems designed to perform critical functions may encode social biases and unfairly disadvantage already marginalized student groups. Excessive reliance on AI-based services and sophisticated educational platforms is diminishing computer literacy

and internet accessibility rates for students from low-income backgrounds, those with specific disabilities, English language learners, and racially or ethnically marginalized groups. This trend risks exacerbating existing educational disparities (Ojha et al., 2025)

The success of AI in the education system depends upon the collaborative efforts of teachers, technology providers, government, and students (Baghavathi Priya, 2024). The integration of artificial intelligence, combined with human expertise that handles many critical back-end functions and guides students throughout their development, removes barriers to access at scale, making system processes more powerful and bringing benefits to everyone (Ojha et al., 2025). We must continue to advocate for the importance of educators as human facilitators of knowledge and skill acquisition (Shah, 2023). The role of the educator as an AI-based mediator is crucial for reducing educational inequalities, as technological transformation, guided by an ethical vision, is sure to write a more enlightened chapter in higher education, where diverse contributions are welcomed (Ojha et al., 2025).

2. Artificial Intelligence and Education 5.0: Redefining Inclusive Learning and Digital Transformation

Technological advances are shaping new perspectives for the development of learning experiences characterized by flexibility and increased appeal. AI in education is expected to play an even more important role, not only in how students acquire knowledge, but also in the teaching methodologies of educators. This transition marks the beginning of the Education 5.0 era, in which established teaching practices are being redefined, facilitating personalized learning, optimizing learning effectiveness, and enhancing accessibility (Ioannidou & Poimenidis, 2025). According to UNESCO-UNEVOC (n.d.), "Education 5.0 is the use of new technologies to provide more human-centered teaching, with an emphasis on the social and emotional development of students and solutions that improve life in society." With an extensive use of AI in education and related activities, there is a quick transition from Education 4.0 to Education 5.0 in late 2022 (Mahendra Gowda, 2023).

From time to time, various terms and concepts have been formulated regarding the co-education of students with special educational needs in "general education" school settings. The most notable concepts in Greece are "Inclusion" and "Integration", and it is advisable to distinguish between them as they are concepts that are often confused, creating misunderstandings among researchers and educators. Initially, by "integration" we mean "the union of many into one body." and in educational contexts, integration relates to the complete educational and social "equalization/assimilation" of children with special educational needs "into the whole," with the obvious risk of losing the uniqueness of each member. Inclusion involves the participation of students with special educational needs or difficulties in all activities without the need for separate support and assistance from an additional teacher (other than the general classroom teacher) or specific adaptation or differentiation of teaching materials or activities. On the other hand, the term "inclusion" is broader and has positive connotations. Specifically, it relates to "placing an individual among others" while recognizing and maintaining the diversity and autonomy of each member of the group. "Inclusion" in the field of education relates to the enrollment of students with special educational needs or disabilities in "mainstream" school classes Education, recognizing diversity and making efforts to promote learning as a right for all students. Finally, "Inclusion"

refers to making all necessary and appropriate adjustments at the level of educational policy and schools so that schools themselves can respond to the needs of all students, regardless of their background (Papazoglou, 2020).

As much as we want to believe that artificial intelligence is an achievement of recent years, we are forced to admit that it is based on computer science, which was developed from logic and probability theory. However, logic and probability theory are intertwined with philosophy, Aristotelian ontology, inductive logic, and reasoning, as reflected in the artificial intelligence handbook. One approach to defining the scientific field comes from Nils J. Nilsson and remains important, but not the only one, to this day. "Artificial intelligence is the activity of making machines intelligent, while intelligence is the property that allows an entity to function correctly and with insight into its environment."(Vergopoulos, 2020). In April 2018, the European Commission's Communication proposed the following definition of AI: “AI refers to systems that display intelligent behavior by analyzing their environment and taking actions – with some degree of autonomy – to achieve specific goals. AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications).”(Independent High-Level Expert Group on Artificial Intelligence, 2019).

In a constantly changing educational environment, where the demands of the knowledge society and technological developments are reshaping teaching and learning, schools are called upon to evolve into digital learning organizations. Today's students need to prepare for an uncertain future by acquiring skills even for professions and technologies that do not yet exist. This puts pressure on schools to adapt quickly, but also on teachers, who are called upon to develop new teaching practices. In this light, many educational policies internationally propose the reorganization of schools according to the principles of digital transformation as a response to contemporary challenges. The concept of digital transformation in education refers to the systematic integration of digital technologies and innovative practices into the educational process with the aim of improving the quality, accessibility, and effectiveness of learning. Digital transformation in education is not limited to the use of digital tools, but includes the radical reorganization of teaching methods, facilitating the personalization of learning, and promoting a culture of continuous innovation (Kalogeratos, 2025).

The discussion on the adoption of new technologies starts from the assumption that existing educational models often fail to be truly inclusive and, instead of taking students into account individually, we operate with a one-size-fits-all mentality. School standards and the established educational and learning model do not allow students to be proactive and leave no room for action and fruitful dialogue. Children often say that they are not satisfied with school. We categorize as disabled those students for whom a printed textbook, a lecture, a blackboard, or a video is difficult or impossible to use (Rose & Meyer, 2002), and this approach leads to a superficial and incorrect understanding of inclusion, also known as fauxclusion (pseudo-inclusion) , which is an appropriate term for the name change that has so far hindered the real development of inclusive education (Graham, 2024).The student ceases to be a passive listener who studies the school textbook, memories and is examined on a specific subject. They become active receivers and, at the same time, transmitters and receivers of

information, studying sources and bibliographies, trying to gradually build their own knowledge (Nikolidakis & Tsantali, 2013).

Artificial intelligence in education refers to a modern model of education, which includes innovative supportive digital tools and applications and deals with the intersection of artificial intelligence and learning at all its levels. The most common areas of reference include intelligent tutoring systems, intelligent learning environments, adaptive hypermedia systems, certain computer-supported collaborative learning systems, etc. and regarding the teaching method, they refer to both the in-person education of minors (Primary, Junior High, High School) and adults (Post-secondary and Technical studies, Universities), as well as to their corresponding distance education forms. Furthermore, modern AI techniques have been developed and integrated into the educational process in various ways, such as machine learning, deep learning, educational analytics, interactive learning systems and other types, which are characterized as weak AI and constitute the contribution of AI to the educational community, which could never stay behind in progress and developments (Vergopoulos, 2020).

3. The role of the teacher as mediator

The traditional view of the teacher as an authority figure and sole source of knowledge has now been superseded by modern pedagogical and technological developments. According to author and educational reformer John Holt, learning is not the product of teaching, but the product of the activity of learners. In order to develop the same developmental mindset that they should instill in their students, teachers need to adapt their teaching practices and resources as new innovations emerge (Shah, 2023). To meet the needs of the learners of today and tomorrow, teachers need to recreate themselves. They need to rethink how they do their job. They need to redefine their actions as educators so that they are teaching students how to learn, in part by modeling the role of lead learner. They need to stop thinking of a teacher as the giver of all knowledge and students as passive receivers of all knowledge and adopt a learner-first attitude (Nussbaum-Beach & Hall, 2011).

Like everything in our lives, the role of the teacher in the classroom has also changed. The teacher is no longer the person who transmits information to the class or to a group of individuals – students, but is the one who gives the impetus and leads the students to search for and discover knowledge, is the one who fills them with self-confidence so that they believe in themselves and develop their skills (Doliopoulou, 2000). Their role is more encouraging than guiding. They must create a climate of trust both between themselves and the students, as well as among the classmates. They should also accept the opinions of their students, whether they agree with them or not, and adapt them to the teaching objective they have set (Xanthakou, 2011). Of course, the role of the teacher is decisive in the development of students' critical thinking. It is important for the teacher to understand the way their students think, as well as how easy it is for them to develop their critical ability. If they judge that it is difficult for the students, then they should identify what makes it difficult for them. This important role of the teacher requires them to be able to respect the diversity of each student, to recognize the characteristics and personality of each one, to see the environment and the social criteria of the students which can influence their thinking, and then to set the goals, to check the progress of critical thinking on the goal – reflection, and to proceed accordingly.

Finally, an important ability that a teacher must have is to be able to understand that each student and the pace they have is different (Doliopoulou, 2000).

AI can also solve many of teachers' pedagogical problems by providing them with custom, individualized, technology- based solutions to the issues we are facing. Creating personalized, interactive, and dynamic learning opportunities is becoming easier and more accessible for a broader range of educators to meet our students where they are and help keep them engaged in the learning process. Recent developments in AI technology will allow teachers to tailor their instruction and assignments to individual students, creating a more equitable and effective teaching strategy. In addition, AI systems will be able to help teachers analyze student data, and pinpoint learning difficulties and gaps quicker to provide targeted support for struggling students. Teachers spend countless hours outside their instructional time planning lessons and activities, preparing instructional materials, providing assessment feedback, and managing administrative tasks. The development of generative AI technology thus offers a path to offloading much of the workload that happens behind the scenes of instructional time. AI can help outline curriculum, draft lesson plans, generate assessments, and draft communication and feedback for teachers. The more teachers can rely on AI for this portion of their workload, the more time and energy they will have to focus on providing students with direct instruction (Shah, 2023). In this technology-enhanced environment, the role of the teacher is not diminished, on the contrary, it becomes even more important. The teacher acts as the link between technology and the student, ensuring that technology is used in an educational manner and that the human factor remains at the center (Vazoura & Samaras, 2024).

AI as a Tool for Enhancing Learning AI has already begun to change the way students learn, and teachers teach at all levels of education. Platforms that utilize personalized learning through AI algorithms offer the ability to tailor teaching to the needs of each student. For example, systems that incorporate adaptive learning have the ability to analyze each student's weaknesses and skills and recommend appropriate activities to address the former and further improve the latter. These technologies are not just auxiliary tools but offer the possibility of a holistic review of the way we approach knowledge. Information technology (IT) helps teachers identify students' needs in real time, enabling more effective and targeted interventions, as smart systems allow students to receive educational material tailored to their individual abilities. As a result, the learning experience becomes richer and more meaningful, as each student learns at their own pace and approaches knowledge in a way that meets their personal needs. In addition, teachers can use IT tools to improve their lessons and anticipate educational needs, which gives them more time for meaningful communication with their students, while at the same time allowing them to gather useful information about their progress, facilitating targeted support and problem solving. IT also contributes significantly to the creation of a more inclusive educational environment, as tools that facilitate learning for people with special needs, such as speech-to-text software or language learning support programs, students with disabilities gain equal opportunities for participation and success. Finally, IT systems provide educators with the tools to create dynamic, data-driven educational content, where the use of multimedia, augmented reality, and simulations broadens the scope of learning, making it more attractive and meaningful (Vazoura & Samaras, 2024).

Despite the benefits and potential offered by new technologies in inclusive education, there are still challenges related to ethical, social, technical, and pedagogical issues. Ethical issues concerning the use of AI applications in special education focus on accuracy, accountability, transparency, and consent, especially as the results are used to make critical decisions about students(Harkins-Brown et al., 2025). An inaccurate or biased AI algorithm could unfairly affect a student's educational path, and if the AI system produced incorrect or harmful recommendations, it would not be clear who is responsible: the developers, the teachers using the system, or the educational administrators who operated the system. Generative Artificial Intelligence, as it exists today, is deeply flawed, demonstrably biased, and unrepresentative of the diversity of populations or the multitude of voices in our world (Pratschke, 2024). Such biases can be inherent in both the data used to train AI and the algorithm itself, disproportionately affecting specific groups and leading to misleading or inaccurate results. Suggested solutions to mitigate the impact of these biases include training to ensure that teachers are aware of the issue of AI bias, as well as training in AI prompting to help teachers improve and upgrade the quality of the questions and commands they enter(Yuan & Hart Barnett, 2024). The use of AI in special education often involves the use of sensitive student data, including disability type, assessment results, student behavior, and disability information. As with other technologies and systems that handle personal data, security and privacy issues are of paramount importance. Student data entered into an IT system should be anonymized, with names and other personally identifiable information removed, while ensuring that students and parents or guardians are aware of how the data is being used to make decisions about the student's learning (Waterfield et al., 2024). Establishing clear policies regarding the use of student data through AI can help ensure trust with stakeholders that any AI queries and recommendations are aligned with the specific needs and goals of each student.

In Special Education, the role of the teacher as a mediator takes on particular importance, as students with special learning needs face challenges that require an individualized approach on the part of the teacher. In the apparent name of equality, greater tolerance of diversity and community cohesion, global policy makers and educators alike are becoming inadvertently complicit in creating a compelling veneer of inclusive education that is blinding society to its real inequitable educational consequences (Gordon-Gould & Hornby, 2023). Väyrynen (2005) explored students' experiences of inclusion in two schools in Finland and South Africa to understand their experiences in relation to policies, practices and cultures of the schools. The findings showed that schools, which were working towards inclusion, were also generating exclusion. The teachers and staff members were not aware of exclusionary pressures that presented at the schools whether they were evident or subtle ones. Some examples of apparent ones were structural arrangement of special classes where students were strongly perceived as a separated group and general teachers calling the students 'integration learners' when they participated in mainstream classes sending a message that they did not belong to mainstream classes. Meanwhile, an example of not so apparent exclusionary pressures was lack of support for learning where teachers were ignoring or actively excluding disengaged students.

The mediating role of the teacher aims to promote the academic, social, and emotional learning of all students (Väyrynen, 2015) and to achieve this, the practice of inclusive education involves collaboration and co-teaching, grouping, modification (of assessment, content, scope, teaching, learning environment, materials, process, product,

and time frame), individual motivation, and feedback. The philosophy behind these practices is that all students, regardless of their abilities, can support the learning processes of their classmates (Lindner & Schwab, 2025). Unless students feel that they belong in the classroom, that they are accepted, and believe in being supported by their peers and teachers, it is unlikely that they will feel accepted for what they are. To be motivated, students need to develop and maintain a positive image of themselves. One of the reasons why some students tend to disengage is due to some teachers' lack of help, guidance and learning support, in cultivating the necessary engaging motivational atmosphere for all students (Zajda, 2023). A typical example comes from the study by Gal and Ryder (2025), where teaching a class in small working groups led by the teacher significantly improved the learning experience of students with learning difficulties. These students participated more actively, developed bonds with each other, showed greater interest and satisfaction with the learning process, and understood the content better. In fact, the study recorded 20-25% more positive responses compared to traditional teaching. This example shows how a teacher-facilitator can transform the classroom into a collaborative environment that enhances the sense of belonging and improves both learning and social outcomes.

The mediating role of the teacher is not limited to academic progress but also extends to strengthening the social dynamics of the classroom. A promising practice for increasing social skills in children with autism spectrum disorder is peer-mediated intervention. This approach activates typically developing peers as social models for improving social initiatives, responses, and interactions, and the effectiveness of this method lies in the fact that peers can model appropriate social behaviors and are readily available in school settings to serve as intervention agents. In this context, the teacher guides peers, who in turn ask children who are isolated or play alone to participate in an activity or game. The results show that these interventions lead to improvements in social integration into the network, nonverbal social skills, play skills, reciprocal social-communicative skills, as well as greater social interaction and increased friendships (Chang & Locke, 2016).

Students' cultural identities, their self-conceptions, levels of self-esteem and self-efficacy represent one of the key factors in their engagement in the classroom, and performance, and resultant educational outcomes. Engaging and motivational cultures in the classroom generated by teachers invariably impact students' identity, attitudes, values, their sense of belonging, engagement, well-being, and performance. The role of the teacher-mediator in inclusive education is multidimensional, and in order to create effective learning environments in inclusive schools that produce high academic achievement, we must take into account the nature and quality of the classroom environment, the well-being and sense of belonging of students, and the quality of teacher interactions (Zajda, 2023). As we move into the second decade of the 21st century, it is timely for the inclusive education community to consider the implementation of human rights. In this new landscape, Artificial Intelligence in the form of technological innovations poses unique challenges for inclusive education and emerges as a powerful ally, as it significantly enhances the lived experience of students with needs in the classroom, providing opportunities to augment their experience, such as optical character recognition, text-to-speech conversion, mapping, and immersive role-playing games (Thomas et al., 2021).

The concept of the teacher as a facilitator represents the distribution of power and responsibility in the classroom, where the teacher consciously removes himself from the center of the classroom and students have the power to exercise their will and participate in learning activities that correspond to their interests. The sign of success for a teacher is to be able to say that the children are now working as if he or she were not in the classroom. The decentralisation of education removes the privileged role of the teacher in a classroom and is consistent with the idea that the teacher is not the absolute authority on the subject matter, but authority is shared so that students participate in and evaluate the education they receive, taking responsibility for themselves from an early age (Vergopoulos, 2020).

4. Conclusions

The integration of technology into the educational process is not an end, but a means to achieve deeper pedagogical and social goals. The integration of digital technology into education is inevitably increasing, as is the urgent need to move beyond the practices of standardization, competition, and efficiency, in order to help students read the world, broaden their possibilities for interpreting reality, and open new windows onto the vision of the future (Mamlok, 2021). This new reality is transforming the role of the teacher, who is now called upon to act as a "weaver" of knowledge, since in the new learning context, good teaching is no longer determined by how well knowledge is conveyed, but by how eloquently knowledge is woven based on the initial knowledge that students found inside or outside the classroom (Lee & Tan, 2018).

IT tools must serve the fundamental principles of protecting human dignity, privacy, transparency, promoting prosperity, and pluralism. At the same time, they must be monitored by a supervisory authority. The following recommendations are made for their introduction into the educational process: Tools should assist, not replace, the teacher. It is also recommended that they be used to supplement conventional education and not replace it. Traditional education based on dialogue between teacher and learner should not be abandoned but enriched by new educational methods. Furthermore, particular emphasis should be placed on the ethical use of technology in education. Finally, IT should not distract us from the basic goal of education, which is to create responsible and conscious citizens (Panagopoulou, 2025).

Human contact remains at the core of the educational relationship, and the teacher is no longer the strict teacher of the student's childhood years, whom they must fear and passively respect, but rather a helper in knowledge with whom they collaborate to achieve the benefit of learning. The challenge for the future is to develop a new educational model that will leverage innovation to promote equality and humanism, with teachers taking on the role of agents of change, progress, and contributors to innovation, equality, and humanism (Nikolidakis & Tsantali, 2013).

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The Peripheral Thought Accelerator: A Critical Pedagogical Framework for Integrating LLMs in Folk Guitar Education

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Abstract—The recent institutionalization of the Folk Guitar (*Laikí Kithára*) in the Greek music education system (Government Gazette 77/2022) introduces a pedagogical paradox: the necessity to codify an orally transmitted tradition into a rigorous diploma curriculum without compromising its embodied, improvisational essence. This paper proposes the "Peripheral Thought Accelerator" model, a critical pedagogical framework where Large Language Models (LLMs) such as Google Gemini and NotebookLM function not as generative performers, but as "Socratic interlocutors." Through a qualitative action research study of three distinct student profiles—a novice adolescent, a technical professional, and a mature scholar—we demonstrate that AI integration varies significantly based on the learner's epistemological background. The findings suggest that when the "core" of musical action is strictly human-governed, AI can effectively manage the "peripheral" cognitive load. However, this utility is contingent on the student's maturity, acting as a broadening tool for novices while serving as a dialectical partner for experts.

Keywords— Folk Guitar, Critical Digital Pedagogy, Artificial Intelligence in Music, Peripheral Thought Accelerator, Gemini, NotebookLM, Cognitive Offloading.

1. Introduction

1.1. The institutional turn: From the "Tekes" to the Conservatory

For decades, the Greek Folk Guitar (*Laiki Kithara*) existed on the margins of formal music education. Its transmission followed the laws of oral tradition: learning by ear (*mimesis*), osmosis in live performance settings ("palco"), and an intuitive understanding of the guitar's role as the rhythmical backbone of the Rebetiko genre (Mystakidis, 2013). However, on January 17, 2022, the Greek state formally recognized the instrument through the *Government Gazette (ΦΕΚ) 77/B/2022*, establishing the "School of Traditional Music" and integrating the Folk Guitar into the official conservatory system.

This legislative reform marks a historic "Institutional Turn." While it legitimizes the instrument—defining it as an element of Intangible Cultural Heritage (Mystakidis et al., 2020)—it also creates a significant "Institutional Gap." The new curriculum sets demanding standards: Article 9 requires students to master "personal sound" (*prosopikos echos*), while Article 12 mandates the ability to improvise (*taxim*) within complex modal networks (Government Gazette, 2022). Yet, the methodology for teaching these intangible qualities within a sterile 40-minute lesson remains under-defined.

The conservatory environment inherently risks prioritizing "exam-centric" skills—reading scores and memorizing scales—over the "meraki" (soul/passion) and "kefi" (spirit) that define the genre. As Kokkonis & Zoubouli (2014) argue, the academicization of folk music can lead to a "museumification," where the notes are preserved, but the ethos is lost. It is within this fragile transition that Artificial Intelligence enters the classroom, not merely as a tool, but as a potential disruptor of the traditional master-apprentice relationship.

1.2. The AI paradox in folk music

The emergence of generative AI tools tailored for music (such as Google's MusicFX or Suno AI) presents a paradox. On one hand, these tools offer unprecedented access to information, capable of analyzing vast discographies or generating backing tracks in seconds. On the other hand, they threaten the very core of folk musicianship: the "productive struggle."

In the oral tradition, the struggle to decode a blurry recording of Kostas Skarvelis or to physically master a difficult "bass run" was not an obstacle to learning; it was the learning. If an AI can instantly generate a tabulature or a stylistic imitation, does it liberate the student, or does it rob them of the embodied experience required to develop a musical identity?

This paper, serving as a continuation of previous theoretical work (Athanasiou, 2025), moves from skepticism to a concrete pedagogical proposal. We argue that the solution is not to ban AI, but to strictly define its territory using the concept of the "Peripheral Thought Accelerator."

2. Theoretical framework

2.1. Critical Digital Pedagogy and the "Human Core"

Our approach is grounded in *Critical Digital Pedagogy (CDP)*, which posits that technology in education is never neutral; it either empowers human agency or diminishes it (Sullivan, 2023). In the context of music, CDP requires us to distinguish between *information* and *knowledge*. Information (dates, scales, discography) is disembodied and manageable by AI. Knowledge (tone, timing, emotional weight) is embodied and strictly human.

We utilize the cognitive science concept of "cognitive offloading"—the act of using physical or digital resources to reduce the cognitive demands of a task. While offloading is beneficial for data management (e.g., using a calculator), it becomes detrimental when applied to skill acquisition (e.g., using AI to compose a melody one cannot play).

Therefore, our model imposes a "Digital Prohibition" on *the core* of the curriculum:

- The Core (Human only): Sound production (touch), rhythmic feel (*kounima*), emotional expression, and the physical act of improvisation. Here, the "struggle" must remain unassisted.

2.2. The "Peripheral Thought Accelerator" model

In contrast to the Core, the *Periphery* of the curriculum involves the vast contextual knowledge required to be a complete musician. A diploma-level Folk Guitarist must not only play but also understand the complex modal systems (Mavroeidis, 1999; Andrikos, 2018) and the stylistic evolution of the repertoire. Traditionally, gathering this information required years of archival research. Here, *Large Language Models* (LLMs) like *Google Gemini* and *NotebookLM* function as "Peripheral Thought Accelerators." They allow the student to query complex databases, compare theoretical treatises (e.g., Mystakidis vs. Mavroeidis), and synthesize historical contexts instantly. By offloading this "peripheral" cognitive load to the AI, the student liberates mental energy to focus on the "core" labor of the hands.

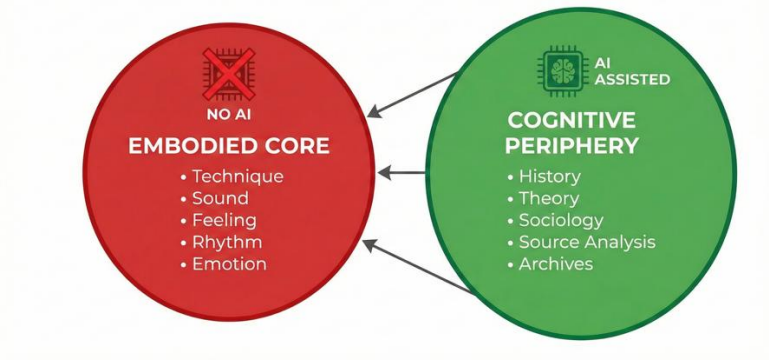


Figure 1. The Core-Periphery Model

2.3. AI as a Socratic interlocutor

Crucially, our model shifts the use of AI from *Generative* (creating content) to *Dialectical* (challenging thought). We employ the "Socratic Method" via prompting.

Instead of asking Gemini "Write a history of the Folk Guitar," the student is trained to ask, "If I treat the *Sabah* mode as a transformation of the Dorian scale, what historical inconsistencies arise regarding the use of the leading tone?". This approach is particularly relevant for NotebookLM, which allows for *Grounding*. By uploading the specific corpus of Greek Folk Music scholarship (Mystakidis, 2013; Andrikos, 2018), the AI is constrained to "think" within the boundaries of the specific academic tradition, avoiding the generic or Western-centric hallucinations common in general LLMs.

3. Methodology

3.1. Research Design: Action Research in the Conservatory

To evaluate the proposed model, we employed a qualitative *Action Research* methodology. Action Research is particularly suited for educational settings where the researcher is also the practitioner (the teacher), allowing for a cyclical process of planning, acting, observing, and reflecting (Cohen et al., 2017). The study was conducted during the academic year 2024-2025 at a recognized Greek Conservatory (Higher School - Diploma Level), specifically within the newly established Folk Guitar department.

3.2. Participants and Ethics

The sample consisted of three male students, selected via *purposive sampling* to represent distinct developmental stages and epistemological backgrounds. To ensure ethical compliance, all participants provided informed consent, and their identities were anonymized using pseudonyms and profile descriptors. The selection criteria were: (a) enrollment in the Diploma year, (b) adequate digital literacy, and (c) diverse prior musical experiences.

- Subject A (The Novice): 17 years old, Music High School student. Digital native but lacking in research methodology. Musical background: Self-taught electric rock guitar.
- Subject B (The Technocrat): 27 years old, Professional Computer Scientist. Highly structured thinking, views music as a logical system. Musical background: Basic music theory.
- Subject C (The Scholar): 37 years old, Professional Jazz Musician with an MA in Philosophy. Abstract thinker, seeks synthesis. Musical background: Jazz Guitar, Advanced Jazz Harmony.

3.3. The digital toolkit: Grounding the AI

A critical innovation was the use of *Retrieval-Augmented Generation* (RAG) via Google NotebookLM. The system was "grounded" in a curated corpus including the standard textbook *Laiki Kithara* (Mystakidis, 2013), theoretical works on modal systems (Mavrodis, 1999; Andrikos, 2018), and extensive discographical archives (e.g., Kourousis & Kopanitsanos, 2022; Ordoulidis, 2014; Maniatis, 2001).

By restricting the AI's "knowledge" to these texts, the students could query the system with the confidence that the answers were derived from peer-reviewed musicological sources, not random blog posts.

4. Case studies analysis: Vignettes from the classroom

The application of the "Peripheral Thought Accelerator" revealed that the interaction between Human and Machine is not uniform; it is deeply colored by the user's maturity.

4.1. Case A: The "Young Researcher" – From hallucination to verification

Profile: Subject A approached the AI with the enthusiasm of a "digital native," initially treating Gemini as an omniscient Oracle.

Vignette: During a lesson on the "Piraeus Style," the student asked the AI about the instrumentation of a specific 1930s recording. The generic model provided a historically inaccurate answer. The instructor intervened, prompting him to use *NotebookLM* grounded in the works of Kourousis & Kopanitsanos (2022) to verify.

Pedagogical outcome: The "failure" of the generic AI became a teaching moment. The student realized that historical truth in folk music is often fluid. The AI ceased to be an answer-machine and became a "search compass," guiding him to listen to the recording more closely to identify the stylistic "fingerprint" of the player—something no AI could do for him.

4.2. Case B: The "Knowledge Organizer" – Structuring the chaos

Profile: Subject B, with his background in Computer Science, struggled with the "oral" nature of the curriculum. He found the empirical rules of folk harmonization (e.g., *"here we usually play a Diminished chord"*) frustratingly vague compared to the strict rules of western music theory.

Vignette: The student utilized *Prompt Engineering* to systematize the curriculum, creating comparative tables between Folk Modes (*Dromoi*) and Ottoman *Maqams* based on the theoretical frameworks of Mystakidis (2013), Mavrodis (1999) and Andrikos (2018).

Pedagogical outcome: The AI acted as a "Cognitive De-fragmenter." It took the dispersed information from the oral tradition and organized it into a logical syntax that the student could understand. This did not replace practice; rather, it accelerated his theoretical comprehension, allowing him to spend his practice time applying these rules on the fretboard rather than memorizing them.

4.3. Case C: The "Philosopher musician" – The dialectical sparring partner

Profile: Subject C presented the most complex challenge. As a Jazz musician, he constantly tried to apply "Western" functional harmony and extended chords (Major 7ths, 9ths) to *Rebetiko*, creating a fusion that often sounded stylistically anachronistic.

Vignette: Instead of using the AI for information retrieval, Subject C used Gemini as a critical peer reviewer. He set up a prompt asking the AI to adopt the persona of a strict, contemporary researcher of Modal Traditions.

Excerpt from the Dialogue Log:

Student Prompt: "I am harmonizing a *Taxim* in Hicaz (D). At the final cadence to the tonic, I want to use a D Major 7th (Dmaj7) chord to create a 'nostalgic' atmosphere, similar to jazz ballads. Critique this choice based strictly on the stylistic norms of the 'Piraeus Style' (1932-1940)."
AI Response (Grounded in Mystakidis, Andrikos & Discography): "Based on the structural analysis of the Piraeus repertoire, this choice is stylistically invalid. 1. Harmonic Anachronism: The Major 7th interval (C# over D) introduces a 'sweetness' associated with the European *Elafro* song or post-1960s Pop-Folk (*Skyladiko*), which contradicts the 'heavy' and austere ethos of the pre-war Hicaz. 2. Tonal Clarity: In the 1930s style (e.g., recordings by Skarvelis or Tsaousakis), the tonic is almost exclusively harmonized as a clean Major Triad. The harmonic tension typically comes from the Dominant (Eb) or the secondary dominant chords, not from extensions on the tonic. Recommendation: To maintain authenticity, avoid the 7th. If you want to color the cadence, focus on a rhythmic bass run (*kounima*) descending from the 5th (A) to the 1st (D), rather than adding vertical harmonic extensions."

Figure 2. Socratic dialogue example

Pedagogical outcome: The AI functioned as a "Mirror of Style." It forced the student to confront his own jazz biases. Through this dialogue, the student didn't just learn the "correct" chord; he understood the *aesthetic boundaries* of the genre, realizing that in Folk Guitar, "less is often more."

5. Results and Discussion

The comparative analysis of the three case studies allows us to construct a theoretical framework regarding the efficacy of LLMs in music education. The findings suggest that the "Peripheral Thought Accelerator" is not a static tool; its impact acts as a variable function of the user's pre-existing epistemological maturity.

5.1. The Maturity Matrix: From oracle to tool to mirror

The most significant finding of this study is that AI acts differently depending on the developmental stage of the musician.

For the Novice (Case A), the AI poses a high risk of "epistemic pollution." Lacking a critical filter, the student is prone to the "oracle effect," accepting hallucinations as facts. However, under strict pedagogical supervision, the AI serves as a "Compass," broadening the student's horizons beyond the limited repertoire of the textbook.

For the Technocrat (Case B), the interaction is utilitarian. The AI is stripped of its conversational "persona" and reduced to a high-speed data processor. Here, the risk is low, but the artistic gain is also capped; the tool organizes knowledge but does not necessarily deepen it.

For the Scholar (Case C), the interaction becomes dialectical. The AI transforms into a "Mirror," reflecting the student's own biases and forcing a sharper articulation of artistic intent. This confirms that the most profound use of AI requires more, not less, human expertise.

Profile (Age)	AI Metaphor	Primary Risk	Primary Benefit
The Novice (17)	Compass	Hallucination Absorption	Cultural Immersion
The Technocrat (27)	Power Tool	Over-systematization	Structural Clarity
The Scholar (37)	Mirror	Over-intellectualization	Critical Synthesis

Figure 3. The Maturity Matrix

5.2. The "Pre-quel" connection: Embodiment as truth-checker

Validating the hypothesis set forth in our previous work (Athanasiou, 2025), this study confirms that *Embodied Knowledge* acts as the ultimate "truth-checker."

In Case C, when the AI suggested a theoretically correct but stylistically inappropriate chord voicing, the student rejected it not because he consulted a book, but because it "felt wrong under the fingers." This visceral reaction—the somatic memory of the genre—proved superior to the probabilistic logic of the algorithm. This finding is crucial for the "Peripheral" model: it proves that as long as the student remains grounded in the physical act of playing, the risk of AI-induced atrophy is minimized. The hands protect the mind.

5.3. Technical efficacy: The necessity of Grounding

From a technical standpoint, the study conclusively demonstrates the superiority of RAG (Retrieval-Augmented Generation) over generic LLMs for specialized domains. General models like ChatGPT-4o often failed to distinguish between the distinct "schools" of Rebetiko (Smyrna vs. Piraeus). In contrast, NotebookLM, grounded in the specific uploaded corpus (Mystakidis, Ordoulidis), provided answers with academic citations. For the preservation of Intangible Cultural Heritage, "out-of-the-box" AI is insufficient; we require "Curated AI," trained on the specific canon of the tradition.

6. Conclusion

6.1. The new role of the Educator: From transmitter to curator

The integration of the "Peripheral Thought Accelerator" model necessitates a reimagining of the music teacher’s role. In the pre-digital era, the teacher was the sole repository of repertoire and history. Today, when a student can access every recording of Markos Vamvakaris in seconds, the teacher’s value lies not in providing information, but in curating experience.

The modern teacher must become a "Curator of Embodiment." Their primary task is to guide the student away from the screen and back to the instrument, ensuring that the "peripheral" knowledge gained from the AI is metabolized into "core" musical feeling.

6.2. Preserving "Meraki" in the age of algorithms

As the Greek educational system formalizes the Folk Guitar, we stand at a crossroads. We can either allow technology to sanitize the tradition, reducing it to a set of prompt-generated rules, or we can use technology to reignite the critical spirit of the genre.
This paper argues that the "labor" of the hands—the calluses, the missed notes, the struggle to make the string weep—is non-negotiable. AI cannot have *meraki*. It cannot feel the weight of a *zeibekiko*. But it can clear the path, answering our questions and organizing our chaotic history, so that when we finally pick up the guitar, we play with more knowledge, more consciousness, and ultimately, more soul.

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Beyond the Museum Walls: Policy proposals for the educational use of AI in disseminating national cultural heritage

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Abstract—Artificial Intelligence (AI) is emerging as a catalytic factor capable of radically transforming the educational utilization of National Cultural Heritage (NCH). It offers the potential to transcend the physical boundaries of museums, providing innovative methods for personalized access, dynamic interaction, and the integration of cultural content into the context of lifelong learning. This paper situates itself within the theoretical framework of Digital Transformation in the sectors of Culture and Education. It critically examines current practices and institutional challenges arising from the adoption of AI tools—such as recommender systems, virtual guides, and natural language processing—to enhance the educational dimension of NCH. The primary objective of this research is to formulate specific, actionable Policy Proposals that will facilitate the systematic and ethically responsible integration of AI into heritage education. Based on a qualitative review of international literature and a comparative analysis of European strategies, the study identifies a critical "institutional lag" between technological advancement and educational adaptation. The paper proposes a comprehensive policy framework focusing on establishing a National Strategy through inter-ministerial cooperation, designing mandatory professional development for educators, creating "AI-ready" digital repositories, and instituting robust ethical guidelines. Ultimately, the transition "Beyond the Museum Walls" is presented not merely as a technological upgrade, but as a critical political choice essential for fostering an inclusive and democratic cultural education.

Keywords— Artificial Intelligence, Cultural Heritage, Educational Policy, Museum Education, Digital Transformation, Lifelong Learning.

Introduction

The dawn of the Fourth Industrial Revolution has brought about a paradigm shift in how societies preserve, interpret, and disseminate their cultural memory. Artificial Intelligence (AI) is no longer a futuristic concept but a tangible reality reshaping the landscape of Cultural Heritage (CH) institutions. As museums and educational organizations strive to remain relevant in a hyper-connected world, the concept of the "museum" is expanding beyond its physical walls, transforming into a distributed, digital, and interactive network of knowledge.

The integration of AI into heritage education promises to democratize access to culture, offering personalized learning experiences that cater to individual needs, learning styles, and interests. However, this technological leap is not without its challenges. The rapid pace of AI development has outpaced the evolution of regulatory frameworks, pedagogical strategies, and institutional readiness, leading to a phenomenon often described as "institutional lag" (UNESCO, 2024). This paper addresses the urgent need for a cohesive policy framework to govern the educational use of AI in the context of National Cultural Heritage. It argues that without a robust national strategy, the benefits of AI will remain unevenly distributed, potentially exacerbating digital divides and failing to fulfill the museum's modern role as a hub of social learning and inclusion (Stylianou-Lambert et al., 2016).

Theoretical framework: The Museum as a learning ecology

This study is grounded in the intersection of two major theoretical constructs that have shaped modern museum education: Constructivism and the Participatory Museum model.
Historically, the role of the museum has shifted from the "temple" model—an authoritative repository of objects—to the "forum," a space for dialogue and active engagement (Cameron, 1971). This evolution aligns with constructivist learning theories, which posit that knowledge is not passively transmitted but actively constructed by the learner through experiences and reflection (Hein, 2023; Hooper-Greenhill, 2007). In this context, AI serves as a powerful scaffold for constructivist learning. Unlike traditional, linear audio guides, AI-driven tools can adapt to the learner’s queries, offering non-linear pathways of discovery that transform the visitor from a passive observer into an active researcher and creator of meaning.

Furthermore, the concept of the "Participatory Museum" redefines the relationship between the institution and the public, viewing visitors as co-creators of content and value (Simon, 2010). AI amplifies this participatory dimension by enabling crowdsourcing, personalized storytelling, and interactive tagging of collections. As digital technologies reshape the museum experience, the educational process extends beyond the physical visit, creating a hybrid learning environment or a "post-museum" space where cultural heritage becomes a living part of the user's daily digital life (Parry, 2010). Therefore, the integration of AI must be viewed not as a technical add-on, but as a fundamental reimagining of the museum’s educational mission in the digital age.

Methodology

This research employs a qualitative methodology to investigate the policy landscape of AI in cultural heritage education. The study design utilizes a systematic literature review and comparative policy analysis to identify best practices and gaps in existing frameworks. By examining current digital strategies from the European Union—such as the European Data Space for Cultural Heritage—and reports from international bodies like UNESCO and ICOM, the research highlights the disparity between the technological potential of AI and the actual readiness of educational and cultural institutions (European Commission, 2024). The analysis specifically focuses on identifying the structural barriers, or "institutional lag," that prevent the effective and ethical scaling of AI innovations in heritage education (Condliffe et al., 2017).

The Digital Transformation: Challenges and institutional lag

Despite the transformative potential of AI, the analysis reveals a profound disconnect between technological capabilities and institutional readiness. While museums have made significant strides in digitization, the transition to an AI-driven educational model is hindered by structural inefficiencies.

A primary challenge is the lack of "AI-readiness" regarding data. Many cultural institutions possess digitized collections, yet these datasets often lack the structured metadata and semantic interoperability required for machine learning algorithms to process them effectively. Without high-quality, machine-readable data, the potential for AI to generate educational insights or personalized recommendations is severely limited.

Furthermore, there is a significant skills gap among museum professionals and educators. The effective use of AI requires a new form of "AI literacy"—an understanding of how these systems work, their limitations, and their ethical implications. Current professional development programs rarely address these competencies, leaving educators ill-equipped to guide students in the critical use of AI tools (International Council of Museums [ICOM], 2022). This gap is exacerbated by the "institutional lag," where policy formulation fails to keep pace with rapid technological change, leaving institutions to operate in a regulatory vacuum regarding data privacy and algorithmic ethics. Finally, while AI promises personalization, it also threatens to widen the digital divide, as access to advanced AI-driven educational platforms often depends on high-speed connectivity and modern hardware that are not universally available (Stylianou-Lambert et al., 2016).

Policy proposals for a sustainable AI integration

To address these challenges and harness the full potential of AI for heritage education, this paper proposes a comprehensive policy framework comprising four strategic pillars.

Pillar I: Governance and National Strategy: The complexity of integrating AI into the cultural and educational sectors requires a coordinated approach that transcends individual ministries. A primary recommendation is the establishment of an Inter-ministerial Task Force, comprising representatives from the Ministries of Culture, Education, and Digital Governance. This body would be responsible for formulating a unified National Strategy for AI in Culture and Education. Rather than relying on

fragmented, project-based funding, this strategy should ensure sustainable, long-term infrastructure investment. It must align national efforts with broader European standards, such as those set by Europeana, to ensure cross-border interoperability and the scalability of digital heritage solutions (European Commission, 2024).

Pillar II: Data Infrastructure and AI-Readiness: AI algorithms are fundamentally dependent on the quality of the data they process. To facilitate the educational use of AI, policy must mandate the creation of a central, "AI-Ready" Digital Repository for National Cultural Heritage. This repository should not merely serve as storage but as a structured data ecosystem utilizing open standards and Linked Open Data. Crucially, this infrastructure must include APIs (Application Programming Interfaces) specifically designed for educational developers. This would empower EdTech companies and universities to build learning applications that draw directly from authoritative national archives, ensuring that educational content is both accurate and accessible.

Pillar III: Capacity Building and Professional Development: Technology cannot replace pedagogy; the successful integration of AI depends on the human agents who mediate it. Therefore, a critical policy intervention is the design and implementation of mandatory training programs for museum staff and educators. These programs must go beyond basic digital skills to cover AI literacy and pedagogical strategies for inquiry-based learning in digital environments (Condliffe et al., 2017). Educators need to be empowered to use AI not just as a delivery mechanism for information, but as a tool to foster critical thinking and creativity. Additionally, fostering partnerships between university computer science departments and humanities faculties can help cultivate a new generation of professionals capable of bridging the gap between code and culture.

Pillar IV: Ethical Shielding and Democratic Oversight: The deployment of AI in education raises profound ethical questions regarding privacy, surveillance, and the authenticity of cultural narratives. To safeguard the values of the "forum" museum (Cameron, 1971), policies must establish a strict Code of Ethics for AI in Heritage Education. Key principles should include transparency, ensuring that users are aware when they are interacting with AI systems, and algorithmic accountability to prevent the reinforcement of cultural biases. Furthermore, strict adherence to data privacy regulations (GDPR) is non-negotiable; student data generated during museum interactions must be anonymized and protected from commercial exploitation. This ethical shielding ensures that the digital interpretation of national heritage strengthens democratic values rather than compromising them.

Conclusion

The integration of Artificial Intelligence into the educational management of National Cultural Heritage is not merely a technical inevitability; it is a profound political and social choice. As we move "Beyond the Museum Walls," we are engaging in a process of re-contextualizing our collective memory for the digital generation.

The proposals outlined in this paper—Strategic Governance, AI-Readiness, Capacity Building, and Ethical Oversight—constitute a roadmap for a transition that is both technologically robust and human-centric. AI should not be viewed as a threat to the traditional role of the educator or the curator, but as a tool for the radical

democratization of knowledge. It offers the unprecedented ability to tailor the cultural experience to the needs of every student, regardless of their geographical location or physical ability (Stylianou-Lambert et al., 2016).

However, this future is contingent upon immediate and decisive policy action. We are currently in the paradoxical position of educating the citizens of tomorrow using the tools of the future, yet often within the institutional frameworks of the past. By adopting these comprehensive policy proposals, we can ensure that National Cultural Heritage remains a living, breathing, and relevant part of modern society, fostering a sense of identity, continuity, and critical citizenship in an increasingly digital world.

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Investigation of the Use of Artificial Intelligence Tools by Primary School Teachers

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Abstract—The present study aims to investigate teachers' familiarity with artificial intelligence, as well as their perceptions and attitudes toward its integration into the educational process. Specifically, the study examines teachers' level of knowledge and skills related to the basic principles and applications of AI, the frequency of AI tool use in teaching practice compared to everyday life, the types of AI tools most commonly used, and potential differences based on gender, years of teaching experience, and training background. In addition, the study explores teachers' experiences with AI use both in their personal lives and in instructional settings.

To achieve these aims, a quantitative research design was employed using a self-report questionnaire that included mainly closed-ended questions, along with a limited number of open-ended questions that were analyzed qualitatively. The sample consisted of 190 primary school teachers, kindergarten teachers, and teachers of various specialties. Convenience sampling was used, as participants were selected based on their availability and accessibility.

The findings indicate that the majority of teachers primarily use general-purpose AI tools, such as ChatGPT, Gemini, and Canva. Although these tools are not specifically designed for educational purposes, teachers adapt them to support instructional tasks. In contrast, specialized AI tools explicitly developed for educational use—such as Magic School, Curipod, Diffit, and Teachy—were mentioned rarely or not at all, suggesting that the pedagogical potential of AI has not yet been systematically exploited.

Overall, the results highlight a clear need for targeted teacher training focused on the pedagogical and critical use of AI, increased familiarity with specialized educational AI tools, and the cultivation of ethical and responsible attitudes toward AI integration. The findings are expected to contribute to the ongoing scientific dialogue on the educational use of artificial intelligence and to emphasize the importance of well-designed professional development initiatives that support the creative and effective integration of AI into the teaching process.

Keywords—Using AI tools, Greek Primary school teachers, Primary Education

Introduction

The rapid development of artificial intelligence (AI) technologies has transformed multiple sectors of contemporary society, including education. In recent years, AI has emerged as a powerful set of tools capable of supporting teaching and learning processes through intelligent tutoring systems, adaptive learning platforms, automated assessment software, and generative applications. These technologies provide opportunities to personalize instruction according to students' individual needs, reduce teachers' administrative workload, offer immediate feedback, and foster creativity and engagement. In the context of primary education, where students develop foundational skills and early cognitive abilities, the potential impact of AI tools is particularly significant (Azzam & Charles, 2024; Holmes et al, 2019). When meaningfully integrated, AI can contribute not only to improved learning outcomes but also to teachers' professional development, enabling the adoption of innovative instructional strategies and more responsive pedagogical practices.

Despite these possibilities, the adoption and effective use of AI tools in primary school classrooms remain uneven. Previous research highlights that teachers' knowledge of AI, digital competence, pedagogical beliefs, and institutional support play a decisive role in shaping how and whether these technologies are integrated into everyday teaching practice. At the same time, concerns related to ethical implications, data privacy, algorithmic bias, and the risk of over-reliance on technology may limit teachers' willingness to adopt AI-based solutions. While an increasing body of research has examined AI integration in secondary and higher education, primary education remains comparatively underexplored, despite the fact that early encounters with educational technologies can have long-term effects on students' learning trajectories and attitudes toward learning. Consequently, understanding teachers' perceptions, experiences, and practices regarding AI use in primary education is essential for informing educational policy, designing effective professional development initiatives, and maximizing the pedagogical benefits of AI-enhanced learning environments.

To conceptualize teachers' engagement with AI, the present study adopts a multi-layered theoretical framework that views AI integration as a progressive process encompassing acceptance, competence, and pedagogical transformation. At the first level, the Technology Acceptance Model (TAM) proposed by Davis (1989) serves as the foundational lens for understanding teachers' initial willingness to adopt AI tools. According to TAM, the acceptance of a new technology is primarily determined by two key factors: Perceived Usefulness and Perceived Ease of Use. Regardless of the technological capabilities of AI systems, their integration into educational practice depends largely on teachers' beliefs that these tools will enhance their teaching effectiveness and that they can be used without excessive effort. In this sense, TAM functions as a "gatekeeping" mechanism, explaining the psychological predisposition of teachers to accept or reject AI technologies before any meaningful pedagogical application can occur.

Once acceptance is established, attention shifts to the second level, the Competence Layer, which is grounded in the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra & Koehler (2006). TPACK emphasizes that effective technology integration requires more than technical familiarity; it necessitates the dynamic interplay of technological knowledge, pedagogical knowledge, and

content knowledge. Within this framework, AI ceases to be merely an accepted tool and becomes pedagogically actionable only when teachers possess the competence to align AI functionalities with instructional goals and subject matter. For primary school teachers, this competence is particularly crucial, as pedagogical decisions must be developmentally appropriate and responsive to young learners' needs. The TPACK framework thus bridges the gap between basic AI usage and meaningful instructional integration, highlighting the importance of professional knowledge and instructional design in AI-enhanced teaching.

At the third and most advanced level, the Transformational Layer, the integration of AI is examined through the lens of the Integrated AI-Oriented Pedagogical Model proposed by Creely & Carabott (2024). This model reflects the emerging educational paradigm shaped by generative AI technologies and redefines the role of AI in teaching and learning processes. Rather than viewing AI as a passive tool (as in TAM) or as a component of teachers' professional knowledge (as in TPACK), this approach conceptualizes AI as an agentic partner in the learning process. The model emphasizes a shift in teachers' positionality and the development of new forms of relationality between humans and machines. In this transformative perspective, AI has the potential to reshape pedagogical practices, redefine teacher–student–technology relationships, and support more collaborative, reflective, and creative forms of learning.

Against this theoretical backdrop, the present study aims to investigate the use of AI tools by primary school teachers within the Greek educational context. Specifically, it seeks to explore how teachers perceive and adopt AI technologies, the extent to which they feel competent in using them pedagogically, and whether AI use contributes to more transformative teaching practices. The study examines teachers' instructional applications of AI, perceived benefits and challenges, and the contextual and personal factors influencing adoption. By integrating perspectives from technology acceptance, professional competence, and pedagogical transformation, this research contributes to a deeper understanding of how AI is currently shaping primary education and provides insights that can guide educators, policymakers, and researchers in promoting the effective, ethical, and responsible integration of artificial intelligence in early learning environments.

Review of Empirical Studies on Teachers' Perceptions of Artificial Intelligence in Education

In recent years, and particularly since 2022, a growing body of empirical research has emerged examining teachers' knowledge, perceptions, and attitudes toward the use of Artificial Intelligence (AI) in education (Mazi & Yildrim, 2025). This line of research has developed primarily within the context of postgraduate dissertations and small-scale empirical studies, reflecting the relatively recent introduction of generative AI technologies into educational practice. Although the volume of research remains limited, especially in primary education, the findings across studies reveal consistent patterns regarding both the perceived potential and the practical challenges of AI integration in teaching.

A recurrent finding in the literature concerns teachers' recognition of the educational potential of AI alongside its limited pedagogical use in classroom practice. Multiple studies report that teachers acknowledge the capacity of AI tools to support instruction,

facilitate personalized learning, and enhance assessment processes. However, this recognition is not accompanied by systematic or frequent classroom implementation. Instead, AI use tends to remain sporadic, exploratory, or confined to non-instructional purposes (Siggeri, 2025; Aletras, 2024; Petropoulou, 2024). This discrepancy between perceived usefulness and actual use aligns with technology acceptance research, suggesting that positive attitudes alone are insufficient to ensure meaningful pedagogical adoption.

Furthermore, the literature consistently identifies a set of key barriers that hinder the effective integration of AI in educational settings. Among the most prominent obstacles are insufficient training and limited pedagogical knowledge regarding AI, technical difficulties, and inadequate technological infrastructure, including unreliable internet connectivity and limited access to appropriate digital devices. In addition, teachers frequently express concerns related to the pedagogical value, reliability, and ethical implications of AI tools. These challenges have been documented not only in Greek studies but also in international research, indicating that they constitute a broader, systemic issue rather than a context-specific phenomenon (Siggeri, 2025; Aletras, 2024; Yim, 2024; Calleja & Camilleri, 2025; Yim & Wegerif, 2024).

Several studies further suggest that teachers' engagement with AI is often characterized by a basic level of conceptual familiarity rather than deep pedagogical understanding (Lamanauskas, 2025). While educators demonstrate awareness of AI as a concept and express interest in its applications, they frequently report uncertainty about how to integrate AI in pedagogically sound and developmentally appropriate ways. This lack of confidence contributes to cautious or minimal use and reinforces reliance on general-purpose AI tools rather than specialized educational applications.

Overall, the existing literature underscores the urgent need for targeted professional development initiatives that focus not only on technical skills but also on the pedagogical and ethical dimensions of AI use in education (Ding et al., 2024). The findings point to the importance of creating supportive institutional conditions and developing coherent training frameworks that enable teachers to move beyond initial awareness toward meaningful, responsible, and transformative use of AI in educational practice As AI technologies continue to evolve rapidly, further empirical research is required to capture teachers' changing experiences and to inform evidence-based strategies for effective AI integration in education.

Aim of the study

The study seeks to examine teachers' knowledge and skills related to the basic principles and applications of Artificial Intelligence (AI), as well as their perceptions, attitudes, and experiences regarding its integration into teaching practice. In addition, the study seeks to examine whether teachers' use of AI tools is primarily limited to general-purpose applications or extends to specialized educational AI tools, as well as to investigate their perceptions of AI's role in enhancing lesson planning, instructional design, student engagement, and overall teaching effectiveness. Particular emphasis is also placed on identifying potential differences in teachers' familiarity, acceptance, and use of AI based on demographic and professional characteristics, such as gender, years of teaching experience, and participation in AI-related training or professional development activities.

Finally, the present study aspires to contribute to the continuously expanding body of research on the educational use of Artificial Intelligence by providing empirical evidence on current practices, challenges, and needs related to AI integration in primary education. The findings are expected to inform the design of targeted professional development initiatives and the development of pedagogical and institutional conditions that support the effective, ethical, and transformative integration of AI into the teaching and learning process.

Research questions

- What is the level of primary school teachers' knowledge and skills regarding the basic principles and applications of Artificial Intelligence (AI)?
- How frequently do teachers use AI tools in their teaching practice compared to their use of AI in everyday life?
- Which types of Artificial Intelligence tools do teachers most commonly use?
- Are there statistically significant differences in teachers' knowledge, acceptance, and use of AI based on demographic and professional characteristics, such as gender, years of teaching experience, and participation in AI-related training or professional development activities?

Method

Research design

This study employed a quantitative research design, utilizing a convenience sample supplemented by elements of snowball sampling. Participants were selected based on accessibility, while additional respondents were recruited through referrals from initial participants, allowing for broader reach within the target population. Although this non-probability sampling approach does not permit full generalization of the findings, it was considered appropriate for the exploratory nature of the study and the practical constraints of data collection.

Sample

The sample of the study consisted of N = 190 primary school teachers, working in both general and special education. Participation was voluntary. A convenience sampling method with a snowball technique was employed. The heterogeneity of the sample (classroom teachers, kindergarten teachers, and teachers of various specialties) contributes to capturing a broader spectrum of perceptions.

Variable	Category	Frequency	Percentage (%)
Gender	Male	41	21.6
	Female	149	78.4
	Total	190	100.0
Specialty	Kindergarten Teachers	71	37.4
	Primary School Teacher	78	41.1
	Other Specialty	41	21.6

	Total	190	100.0
Years of Service	1 - 10 years	36	18.9
	11 - 20 years	82	43.2
	21 - 30 years	72	37.9
	Total	190	100.0

Table 1. Sample

Research instruments

The questionnaire items were developed by the researcher based on a comprehensive review of the relevant literature, drawing on recurring findings and key variables identified in previous studies (Mazi & Yildrim, 2025; Lamanauskas, 2025). The statements focused on several aspects: which AI tools teachers use in preparing their lessons, whether they have attended related seminars, how they evaluate their knowledge of Artificial Intelligence, how frequently they utilize AI tools in the classroom, and which AI tools they employ most extensively. To ensure content validity, the instrument was reviewed by experts in the field, and items were refined to accurately reflect the constructs under investigation. This approach ensured that the questionnaire was both theoretically grounded and methodologically sound, aligning with established research evidence.

Results

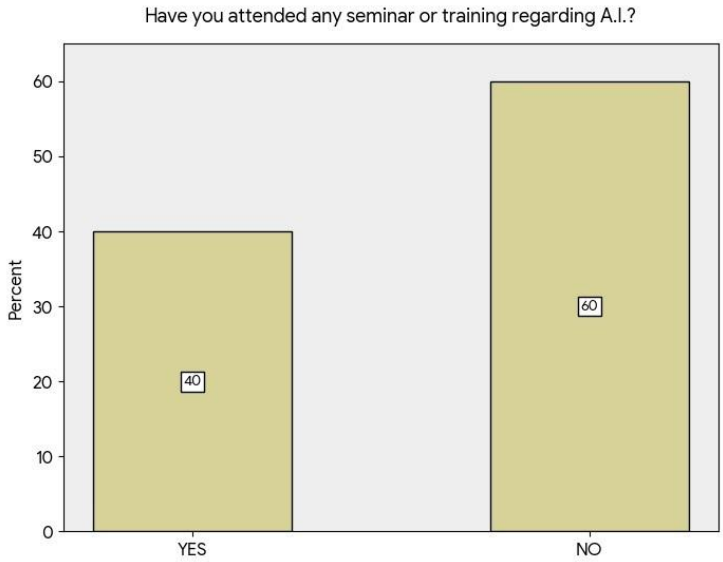


Table 2. Level of teachers' professional development in the basic principles and applications of Artificial Intelligence

The results indicate that 40% of the participants have attended a seminar or professional development program related to Artificial Intelligence, while 60% report that they have not received any corresponding training. This distribution highlights that the majority of teachers lack systematic professional development experience in this field, a factor that may affect both their level of knowledge and their ability to pedagogically integrate Artificial Intelligence applications into teaching practice. At the same time, although the proportion of trained teachers is noteworthy, it remains a minority, suggesting that

training in Artificial Intelligence has not yet been widely integrated into teachers' professional development.

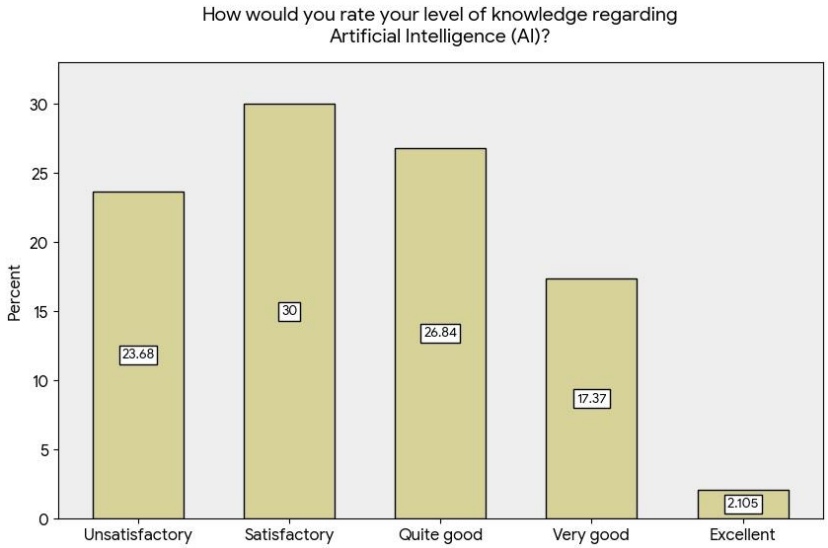


Table 3. Teachers' self-assessment of their level of knowledge regarding Artificial Intelligence

The largest proportion of participants (30%) characterize their level of knowledge as satisfactory, followed by 26.84% who rate it as fairly good. These findings suggest that the majority of teachers perceive themselves as having a moderate to relatively adequate level of knowledge in Artificial Intelligence, without, however, considering it to be high. At the same time, a noteworthy proportion (23.68%) report that their level of knowledge is not satisfactory, highlighting gaps in theoretical training and/or practical familiarity with the basic principles of Artificial Intelligence. In contrast, lower percentages are observed in the higher evaluation categories, with 17.37% describing their knowledge as very good and only 2.1% as excellent.

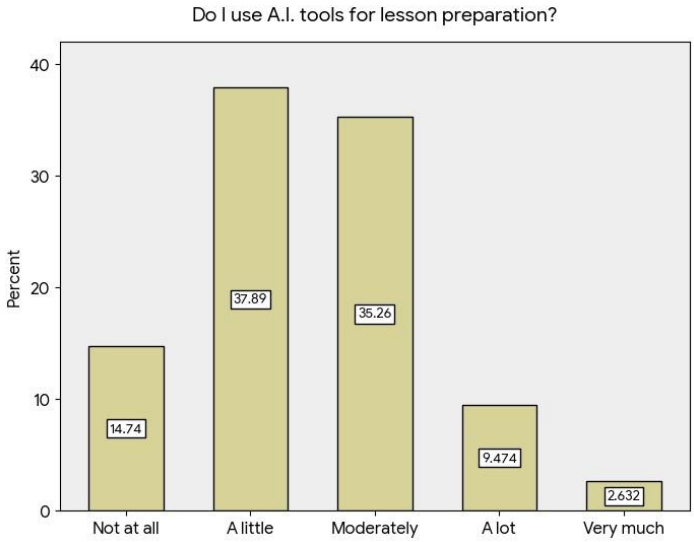


Table 4. Frequency of utilization of Artificial Intelligence tools by teachers in lesson preparation

We observe that the largest percentage of teachers report using AI tools a little (37.89%) or quite a lot (35.26%), indicating moderate but growing integration of these technologies into teaching preparation. In contrast, 14.74% report not using AI tools at all, which may be linked to limited familiarity, lack of training, or reservations about their use. At the same time, lower percentages are recorded at the higher usage levels, with 9.47% stating they use them a lot and only 2.63% very much. The limited presence of high usage levels suggests that, despite increasing interest in Artificial Intelligence, systematic and extensive adoption in educational practice has not yet been fully established.

AI Tool	**Frequency (Mentions)**
ChatGPT	105
Canva (AI Features)	32
Gemini (Google)	19
None / I do not use	14
Microsoft Copilot / Bing	9
Magic School / Curipod / EdTech	8
Gamma / Slides AI	6
Others (Perplexity, DeepSeek, Suno)	7

*****Participants were allowed to provide more than one option

Table 5. Which Artificial Intelligence (AI) tools do teachers use? *

The table presents the frequency of references to various Artificial Intelligence tools used by respondents. ChatGPT is by far the most frequently mentioned tool, with 105 references, indicating its dominant role in AI usage. Canva's AI features follow with 32 mentions, while Google's Gemini ranks third with 19 references. Fourteen respondents reported not using any AI tools at all. Microsoft Copilot/Bing was mentioned 9 times, and educational platforms such as Magic School, Curipod, and other EdTech tools were referenced 8 times. Gamma and Slides AI received 6 mentions. Finally, other tools, including Perplexity, DeepSeek, and Suno, were collectively mentioned 7 times.

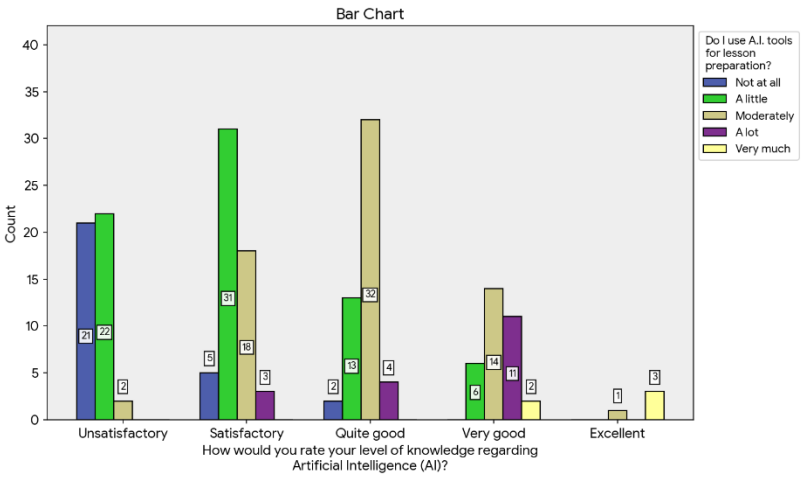


Table 5. Analysis of differences between perceived knowledge of Artificial Intelligence and the use of AI tools

There is a clear and strong positive correlation between teachers' perceived knowledge of Artificial Intelligence and its practical application. Teachers who rate their knowledge as "unsatisfactory" tend not to use AI tools at all or use them very minimally. In contrast, the turning point occurs at the "fairly good" level of knowledge, where the use of tools in lesson preparation ceases to be experimental and becomes systematic, dominating the responses "fairly often" and "very often." Depending on their level of knowledge, they use AI accordingly.

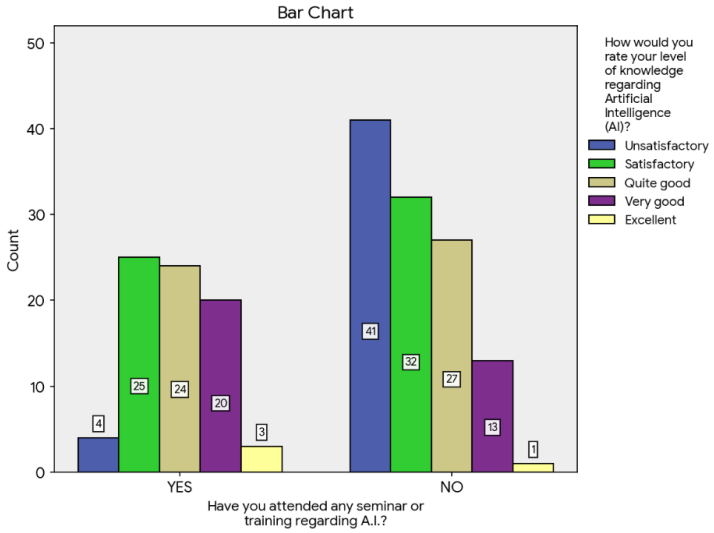


Table 6. Examination of Differences in Perceived Artificial Intelligence Knowledge in Relation to Professional Development

The chart illustrates a marked difference in teachers' self-assessment depending on their participation in professional training. In the group that has not received training (NO), a sense of inadequacy predominates (41 participants), acting as an inhibiting factor. By contrast, participation in seminars (YES) not only minimizes the "unsatisfactory" level (only 4 participants) but also significantly enhances digital self-confidence, nearly tripling the likelihood of an "Excellent" level of competence and strengthening the "Very good" level.

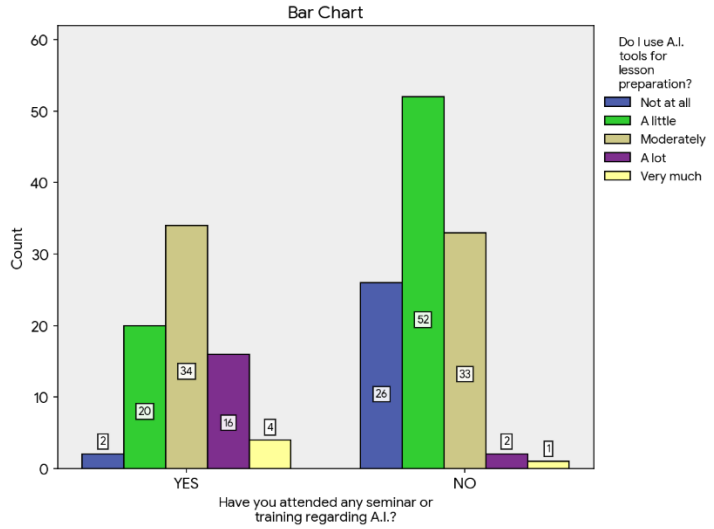


Table 7. Analysis of differences between training in Artificial Intelligence and the use of AI tools

The chart clearly highlights the "confidence gap" created by the absence of training. As observed, in the group of teachers who have not received professional development (NO), a sense of inadequacy predominates, with "unsatisfactory" knowledge representing the overwhelming majority. In contrast, the pattern is fully reversed in the trained group (YES), where insecurity is minimized and a significant shift toward higher levels of knowledge and digital readiness is recorded.

Discussion

A central focus of this study was teachers' self-assessment of their knowledge of Artificial Intelligence (AI), a field of increasing relevance in contemporary education. The findings indicate that teachers generally perceive their level of AI knowledge as moderate, with a considerable degree of uncertainty regarding their competence in this area. Despite the growing prominence of AI in educational discourse, many educators do not yet feel confident in their understanding or pedagogical use of AI-related tools and concepts. This finding is consistent with recent research in primary education, which highlights limited preparedness and confidence among teachers regarding the integration of AI in classroom practice (Mazı & Yıldırım, 2025; Philippakos & Rocconi, 2025; Varmazi, 2022). An important aspect emerging from the findings is the relationship between perceived knowledge and participation in professional development activities. Teachers who had engaged in AI-related training or professional learning opportunities tended to report higher levels of confidence in their knowledge. This observation underscores the critical role of targeted and systematic professional development in supporting educators' readiness to engage with emerging technologies. Overall, the results suggest that sustained investment in teacher training is essential for strengthening both confidence and pedagogical capacity in the effective integration of AI in educational settings.

Regarding tool adoption, most teachers reported using general-purpose AI applications such as ChatGPT, Gemini AI, and Canva, a pattern that confirms and is consistent with findings from recent research indicating that educators tend to rely primarily on widely accessible, general-purpose AI tools rather than specialized educational AI applications (Van Den Berg, 2025; Siggeri, 2025). While these platforms are not explicitly designed for educational purposes, they can be adapted to support lesson planning, content generation, and classroom interaction. In contrast, dedicated educational AI tools—such as Magic School, Curipod, Diffit, and Teachy—were scarcely utilized. This limited uptake suggests that the pedagogical affordances of AI remain underexploited and points to a potential gap between technological availability and pedagogical integration. The underuse of specialized AI tools may reflect both a lack of awareness and insufficient training, reinforcing the notion that professional development is a key determinant of effective AI implementation in schools.

The quantitative results of differentiation analyses further underscore this point. Teachers who had participated in professional development exhibited higher self-assessed knowledge and confidence, as well as more advanced use of AI tools, compared to their non-trained peers (Calleja & Camilleri, 2025). These findings support the hypothesis that familiarity and competence with AI are functions of repeated and structured engagement: the more teachers interact with algorithmic systems, the more they overcome cognitive resistance and harness the pedagogical potential of AI

(Lademann et al, 2026). Consequently, professional development is not merely a supplementary factor but a prerequisite for fostering meaningful and sustainable AI integration in educational contexts.

The implications of these findings for teacher education are multifaceted. First, structured training programs are necessary to equip educators with both technological knowledge (understanding how AI tools function) and pedagogical knowledge (understanding how to teach effectively with AI) (Tan et al., 2024, 2025). Current training initiatives often emphasize technical proficiency in general-purpose AI tools, leaving educators underprepared to leverage AI's instructional potential. Second, training must be practice-oriented and context-specific, providing teachers with opportunities to experiment with AI in real classroom scenarios. This approach aligns with constructivist principles and the notion of the teacher as a reflective practitioner, capable of co-creating digital learning experiences that are pedagogically sound and learner-centered.

Additionally, the results highlight the importance of fostering a cultural shift within schools. Teachers' adoption of AI is influenced not only by individual competence but also by organizational support, peer collaboration, and access to resources. Encouraging a community of practice around AI integration can promote knowledge sharing, reduce anxiety, and build confidence among educators. Embedding AI into collaborative lesson planning and peer mentoring can further reinforce its pedagogical value, enabling teachers to transition from procedural users to designers of innovative learning experiences (Tan et al., 2025).

Finally, the study contributes to the broader discourse on the responsible and effective integration of AI in education. While AI offers unprecedented opportunities for personalization, efficiency, and creativity, its impact is contingent upon teachers' ability to navigate and harness these tools strategically. Without targeted professional development and reflective practice, AI adoption risks remaining superficial, focused on administrative convenience rather than transformative pedagogy. Therefore, the findings underscore the dual necessity of structured training and ongoing practical engagement, highlighting a path toward AI-enhanced education that is both effective and sustainable within the Greek school context (Tan et al., 2024).

In conclusion, the study demonstrates that the meaningful integration of AI in education depends on a combination of teacher training, experiential use, and pedagogical orientation. Structured professional development programs must go beyond technical instructions to emphasize pedagogical application (Tan et al., 2024). By doing so, educators can move from basic users to reflective designers of digital learning experiences, thereby realizing the full potential of AI as a transformative educational resource. Future research should investigate longitudinal impacts of AI training programs, explore cross-cultural differences in AI adoption, and assess student learning outcomes in AI-enhanced classrooms. These directions will contribute to a more comprehensive understanding of how AI can be leveraged to foster meaningful learning and pedagogical innovation.

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Evaluating Large Language Models on Greek Primary School Mathematics Problems: Accuracy, Reasoning, and Educational Implications

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Abstract — The rapid advancement of Large Language Models (LLMs) such as the GPT family is reshaping expectations for automated tutoring, formative feedback, and assessment in education. Despite impressive progress in natural language understanding, the ability of these models to perform reliable mathematical reasoning, especially in non-English languages and primary-level educational contexts, remains insufficiently examined. This study investigates how accurately and consistently current LLMs solve mathematical problems from the Greek primary school curriculum and how their reasoning patterns relate to task difficulty.

A dataset of 70 mathematics problems was created based on the 3rd- and 5th-grade Greek mathematics textbooks. The problems are categorized by grade, topic (e.g, number sequences, fractions, geometry), and a difficulty scale (1–4), which is validated by three experienced educators and two LLMs. Using a Python-based evaluation pipeline, each problem was submitted in the Greek language to four widely known OpenAI models, i.e., GPT-3.5-turbo, GPT-4o, and GPT-4.1-mini, and GPT-5-mini, under two prompting conditions: (i) the LLM to provide a direct answer and (ii) the LLM to provide the complete step-by-step reasoning.

All answers were forwarded to a dedicated Python module to assess accuracy based on the corresponding ground truth in the database, as well as time and cost spent per model. Additionally, step-by-step responses were analyzed using an LLM-as-a-Judge approach, where the GPT-5 model rated the reasoning quality, completeness, intermediate calculations, understanding, and consistency of each model, besides accuracy. This dual analysis offers an initial exploration of hybrid methods for assessing AI reasoning in educational tasks.

The evaluation revealed systematic performance differences across grade levels, mathematical domains, and difficulty levels. The overall accuracy is higher on 3rd-grade problems and computationally oriented topics, reaching approximately 90%, while it decreased substantially for problems with greater difficulty or more complex reasoning. As task difficulty increased, accuracy declined by about 8% for GPT-5-mini and by more than 40% for GPT-3.5-turbo, indicating a sensitivity to cognitive demand, particularly for earlier-generation models.

The contribution of this work lies in showing where and why these differences in LLM performance occur and how they relate to specific task types. Beyond the quantitative findings, the study considers key pedagogical and ethical issues associated with deploying LLMs in primary mathematics education. This research proposes a small-scale yet reproducible framework for evaluating LLMs' mathematical reasoning in non-English elementary settings. Future work will expand the dataset, examine additional LLMs beyond OpenAI's models, and evaluate the quality of their tutoring capabilities in mathematics. These analyses provide initial evidence relevant to the design of LLM-based tutoring tools for elementary mathematics. The findings aim to inform both developers designing educational AI systems and educators seeking to integrate such technologies responsibly into classroom practice.

Keywords— Large Language Models, Mathematics Education, Elementary School, AI in Education, Automated Assessment

1. Introduction

Recent advances in Artificial Intelligence (AI), particularly in LLMs, have substantially improved natural language understanding, generation, and reasoning, contributing to changes in traditional teaching models (Wang et al., 2025). In recent years, the use of LLMs in educational settings has attracted increased research interest due to the wide range of applications these models enable. Given that learners have diverse preferences, abilities, and educational needs, LLMs present a promising opportunity to support personalized and effective learning experiences (Kasneci et al., 2023).

Among existing LLMs, the Chat Generative Pre-trained Transformer (ChatGPT), developed by OpenAI, has become a leading and widely used model in both research and practice, often considered a representative LLM due to its extensive pretraining on large-scale datasets (Farrokhnia et al., 2024). Prior studies highlight several strengths of ChatGPT, including its ability to adapt and improve over time, to provide personalized and real-time responses across varying levels of complexity, and to offer rapid access to information. Such features have been associated with improved learning efficiency, reduced instructional workload, and enhanced support for interactive problem solving, leading to higher-order learning outcomes, such as increased learner curiosity and critical thinking skills (Gupta et al., 2025; Farrokhnia et al., 2024; Kasneci et al., 2023). In the context of mathematics education, recent works further indicate that the application of ChatGPT is promising, particularly with respect to step-by-step problem solving, adaptation to students' levels of understanding, and support for independent learning (Turmuzi et al., 2026; Wang et al., 2025).

Additionally, the incorporation of AI into mathematics education has influenced the teaching and learning of mathematics by complementing traditional pedagogical approaches rather than replacing them (Turmuzi et al., 2026). Despite these advances, the performance of LLMs in the mathematical domain remains inconsistent. Prior studies have shown that LLMs often generate solutions that appear plausible yet contain mathematical errors, particularly in tasks requiring multi-step reasoning (Gupta et al., 2025). Moreover, the majority of existing research has focused on the English language, posing challenges for Greek educators, as findings may not be directly applicable due to structural and linguistic differences.

These observations raise concerns about the reliability of LLM-generated solutions in educational settings and highlight the need for further systematic research and evaluation under diverse conditions. In particular, empirical evidence regarding LLM performance on curriculum-based mathematical problems at the primary education level remains limited. This motivates a focused evaluation using mathematical problems from the Greek primary school curriculum, regarding accuracy, computational cost, response time, and robustness across problem types and prompting conditions.

The contributions of this study are fourfold:

- We composed a publicly available dataset of mathematical problems from the Greek primary school curriculum, covering two distinct grades, eight mathematical topics, and three different levels of difficulty.
- We implemented an open-source Python-based evaluation framework, that provides configurable benchmarking of LLMs on educational mathematical

problems, supporting the assessment of accuracy and response time of each LLM, across different prompting conditions.

- We conducted an extensive empirical evaluation of multiple state-of-the-art LLMs using both automatic and LLM-as-a-Judge approaches, to assess the response accuracy, as well as the step-by-step reasoning quality, completeness, level of understanding, and consistency for each model. This hybrid evaluation provides a more comprehensive understanding of LLMs' behavior than accuracy solely.
- We provide empirically grounded and valuable insights into the pedagogical stability, limitations, and ethical considerations of integrating LLMs into primary mathematics education, with particular focus on task difficulty, mathematical domains, and non-English settings.

The remainder of the paper presents the related work, outlines the evaluation methodology, discusses the experimental results, and concludes with directions for future work.

2. Related work

Recent research has increasingly focused on investigating the performance of LLMs, such as ChatGPT, in educational contexts (Wang et al., 2025). Existing studies explore the pedagogical strengths and limitations of LLMs in various learning scenarios, concerning problem-solving performance, quality of response and explanation, and their suitability as instructional tools.

More specifically, Turmuzi et al. (2026) indicate that ChatGPT is effective in providing instant feedback and personalized support, especially in topics of algebra and statistics, while exhibiting degraded performance in complex problem-solving tasks. The study highlighted ethical considerations regarding the students' overreliance and academic integrity as well. Farrokhnia et al. (2023) identify strengths, including improved access to information, support for personalized learning, and reduced teaching workload, and weaknesses, such as shallow understanding, and bias, among others. Similar findings were observed by Chu et al. (2025), who introduced a task-centric taxonomy, categorizing LLM agents into pedagogical and domain-specific educational, highlighting the ethical considerations of the LLMs' impact on engagement, automation, and reliability, alongside the challenges of integrating LLMs in the educational practice. Additionally, Kasneci et al. (2023) emphasize the potential of LLMs to enhance accessibility in special education, especially when combined with assistive technologies, such as text-to-speech or speech-to-text.

Recent studies empirically evaluate LLM performance across diverse educational settings and everyday problem-solving tasks. For instance, Orrù et al. (2023) investigate problem-solving capabilities of ChatGPT in practice- and transfer-related everyday tasks, using verbal insight problems. Pauzi et al. (2025) conducted a pilot-study to compare human tutors and LLM-based conversational agents, focusing on Socratic dialogues, revealing the ability of LLMs to perform similarly to humans, in encouragement and guidance. Additionally, there are several works investigating the impact of LLMs in learning process. In this context, Kumar et al. (2023) examined how LLM explanations and feedback affect learning, using groups of participants with and without the assistance of LLM-based tools for questions, concluding that when

assistance is used appropriately, LLM explanations can foster learning gains. To enhance students' performance, multiple AI-based tools have been developed and used, including ChatGPT-MWPS, introduced by Liu et al. (2025). They proposed an AI-enhanced learning system, which translates textual descriptions into structured mathematical representations, designed to support students in developing mathematical problem-solving skills through scaffolding and step-by-step feedback.

On the other hand, there are several research studies on the systematic assessment of different LLM models' performance in education, and especially in the mathematical domain. Wei (2024) employed a logistic regression model to assess ChatGPT-4 and ChatGPT-4o capabilities in solving mathematical problems, across multiple grades, content areas, types of problems, and difficulty levels. Results showed that both models surpass U.S. students' performance across all domains besides geometry and measurement, as well as in higher difficulty problems. Gupta et al. (2025) developed a Python-based tool to systematically evaluate LLMs' responses in mathematical problems in terms of accuracy and response quality. They evaluated ChatGPT's models 3.5-turbo, 4, 4o, o1-mini, and o1-preview in two different modes: (a) their problem-solving capabilities through an Intelligent Tutoring System (ITS), and (b) as a tutor rather than a solver. Throughout the evaluation, the authors concluded that, besides the advanced capabilities of ChatGPT models and their overall potential, LLMs are not yet suitable as tutors without the support of either a human or an advanced mechanism to ensure the quality of feedback they provide. A similar work was proposed by Wang et al. (2025), in which three different LLMs, namely ChatGPT-4o, DeepSeek-V3, and Gemini-2.0, were evaluated on three benchmarking datasets (GSM8K, Math500, and a University exam-based) through an automated evaluation framework. For the evaluation, metrics from the Structured Chain-of-Thought (SCoT) framework were used, and their results indicate that GPT-4o achieves the most consistent performance, while DeepSeek-V3 and Gemini-2.0 exhibit strengths in structured tasks but limitations in statistical inference and multi-step mathematical reasoning.

This study extends existing research on the evaluation of LLM performance in mathematics education, by shifting the focus to primary-level, curriculum-based problems in a non-English setting, specifically the Greek language. To this end, a hybrid evaluation framework is implemented, to examine the overall LLM performance, including reasoning quality, consistency, and pedagogical robustness, in addition to final-answer accuracy.

3. Methodology

3.1 Database

In order to investigate the accuracy and consistency of LLMs, a publicly available dataset[58] was developed based on the Greek mathematics textbooks for the 3rd and 5th grades. The selected grade levels enable the evaluation of ChatGPT's performance in early mathematics as well as in more advanced mathematical topics. The dataset consists of 70 mathematical problems, accompanied by information regarding grade level, mathematical topic, and problem difficulty. Difficulty levels were determined

[58] https://github.com/Argivol/llm_evaluation/blob/master/Database_LLM_Eval_Greek.csv

based on the Task Analysis Guide (TAG), which classifies mathematical tasks into four groups according to increasing levels of cognitive demand (Stein & Smith, 1996).

Specifically, Level 1 tasks require simple recall of facts, rules, or explicitly stated information, Level 2 tasks require the application of learned procedures without explicit connection to underlying mathematical concepts, Level 3 tasks involve connecting procedures to underlying mathematical ideas through interpretation or non-routine steps, and Level 4 tasks require complex, non-algorithmic reasoning, such as exploring relationships or constructing solution strategies. Since Level 4 tasks typically correspond to complex real-world problem-solving situations, the database includes only problems from the first three levels of difficulty. The difficulty labeling was conducted by three experienced primary school teachers and two widely used LLMs (ChatGPT-5.1 and Gemini Pro), with the median score assigned to each problem.

An equal number of problems was selected from the following mathematical domains: number sequences, geometry, place value, equalities and inequalities, fractions, probability, word problems, and arithmetic operations (i.e., addition, subtraction, and operations with decimals). For each problem, the dataset provides a corresponding ground-truth (GT) solution, as only closed-ended problems with a single correct answer were included.

3.2 Evaluation Tool

For the purposes of this study, an open-source tool was developed in Python to automatically submit each problem from the database, in the Greek language, to four OpenAI models, GPT-3.5 turbo, GPT-4o, GPT-4.1 mini, and GPT-5 mini, under two prompting conditions: (i) direct-solution and (ii) step-by-step explanatory.

3.2.1 Architecture

The architecture of the LLM evaluation tool is depicted in Figure 1, and the codebase is publicly provided via a GitHub repository[59]. The tool comprises five discrete components, each of which is responsible for a different functionality in the overall system:

- User Interface (UI): Implemented using the open-source Streamlit framework. UI allows users to configure models, runs, evaluation methods, and prompting variants, while also supporting dataset uploads (CSV/XLSX format) and secure API key management.
- API Layer: Contains the API connectors for OpenAI models, along with a Submission Manager (SM) responsible for handling API request submission and response retrieval.
- Database and Preprocessing: Loads the problem records from the database file into memory, preprocesses them, and prepares them for submission.
- Evaluation Engine: The core evaluation logic with the two different modes supported: (i) Automatic Evaluation, based on the ground-truth comparison, and

[59] https://github.com/Argivol/llm_evaluation

(ii) LLM-as-a-Judge Evaluation, based on qualitative criteria of model-generated solutions.

- Statistics and Results: Aggregates evaluation metrics, organizes, and exports results in multiple formats, including tables, charts, and a PDF report.

The modular design allows for extension of models, prompting variations, evaluation approaches, metrics, and result reporting mechanisms.

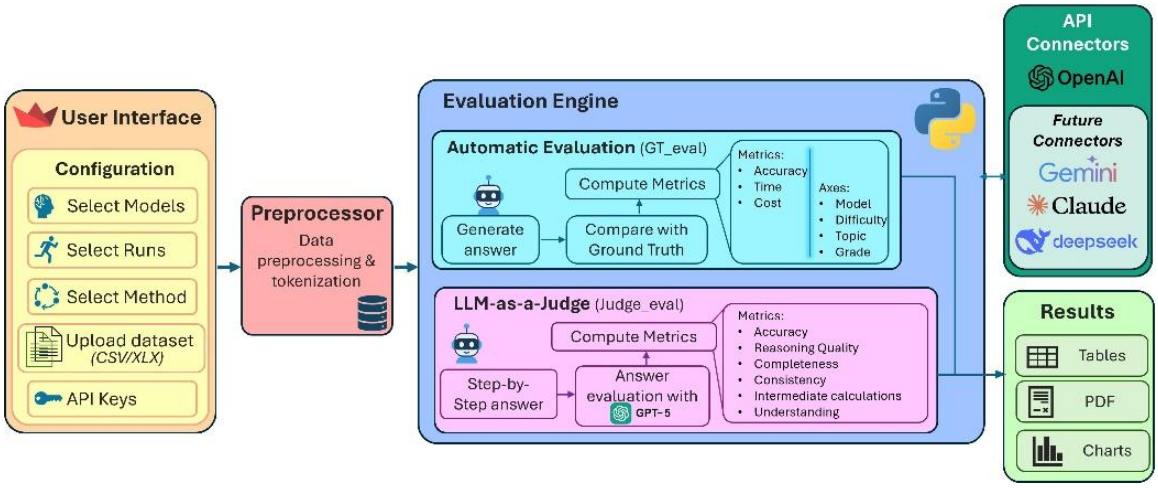


Figure1: Python-based evaluation pipeline

3.2.2 End-to-End evaluation process

Through the UI, several parameters can be configured, including the selection of the models to be assessed, the number of execution runs, and the method of evaluation (Automatic Evaluation and/or LLM-as-a-Judge).

Once the dataset is uploaded, each problem record is loaded and preprocessed by a dedicated module, with multiple steps that the ground-truth field of each problem undergoes. The first step is the segmentation of ground-truth into individual answer components, by detecting Greek alphabetical letters (used as labels) that denote sub-answers, and extracting these answers. When explicit labels are not present, a fallback strategy assigns labels to all non-empty lines of the ground-truth. Therefore, a mapping between sub-questions and the corresponding answers is created for each problem. In the second step, a dual representation of each answer is constructed, with the first one being the original textual representation and a second one a token-level representation, obtained by extracting numerical values and comparison symbols. For example, the token-level representation of the answer 345 < 354 will be {‘345’, ‘<’, ‘354’}. This dual representation enables both textual and numeric evaluation depending on the semantic nature of the answer. Subsequently, numeric tokens and symbol tokens are separated into distinct lists. In the previous example, the numeric token list contains [‘345’, ‘354’] while the symbol token list contains [‘<’]. Both text and numeric representations are normalized as a last step, while the answer type is also detected, and included in the final enhanced representation.

The evaluation phase is then orchestrated by the SM module, and carried out using the selected methods. Specifically, the first method, referred to as Automatic Evaluation, prompts the aforementioned AI models to generate only the final answers, which are

then compared against the ground-truth solutions of the dataset. Model responses undergo the same preprocessing pipeline, and evaluation is performed by comparing the normalized representations of model outputs against the normalized ground-truth representations. Accuracy, response time, and cost are computed for each model, difficulty level, mathematical topic, and grade level.

The second evaluation method, referred to as LLM-as-a-Judge, prompts the models to generate step-by-step solutions for each problem. The generated solutions are then assessed by GPT-5, which was selected as the judging model due to its strong performance in mathematics and its advanced reasoning capabilities when addressing challenging problems. As reported by OpenAI (2025), GPT-5 achieves a score of 94.6% on the American Invitational Mathematics Examination (AIME) without the use of external tools. In the LLM-as-a-Judge evaluation mode, the metrics used are based on the Structured Chain-of-Thought (SCoT) framework (Wang et al., 2025) and include accuracy, reasoning quality, completeness, consistency, accuracy of intermediate calculations, and question understanding.

Finally, all the results maintained throughout the evaluation process are aggregated and presented in the form of tables, charts, and a comprehensive PDF report, all of which are available for immediate download. Figure 2 and 3 depict the UI of the evaluation tool with the configuration sidebar on the left, and the evaluation results, as reported to the end user.

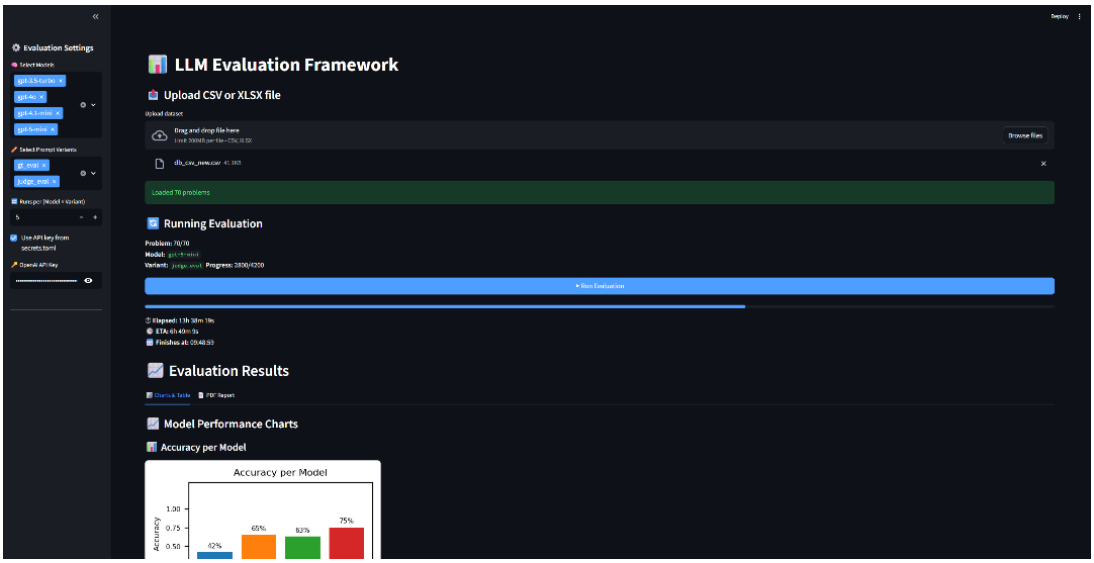


Figure 2: UI of the evaluation tool (1)

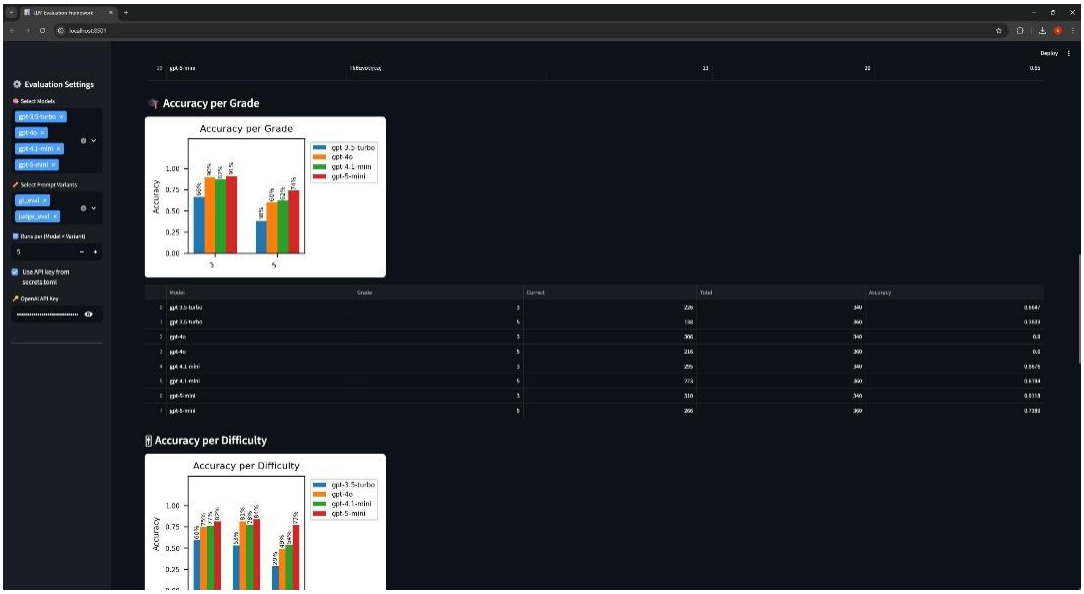


Figure 3: UI of the evaluation tool (2)

3.3 Evaluation Metrics

Evaluation metrics are computed and aggregated per model, across multiple dimensions, allowing for both global and fine-grained analysis. For the automatic evaluation mode, problem-level accuracy is computed as the ratio of correctly answered problems to the total of evaluated ones. A problem is considered correctly answered if all subtasks are evaluated as correctly solved. In addition to the overall accuracy, the results are categorized by grade, difficulty level, and topic, and are reported to the user. Besides accuracy, the evaluation time is also calculated for each model, and for all of the aforementioned dimensions, as well as the overall model cost, which is computed based on token usage reported by the API.

As already mentioned, for the LLM-as-a-Judge evaluation mode, the metrics are based on the SCoT framework (Wang et al., 2025) including:

- accuracy, i.e., if the output answer is consistent with the correct answer, without performing a strict wording comparison,
- reasoning quality, i.e., if the step-by-step explanation contains clear and reasonable steps,
- completeness, i.e., if all subtasks are answered correctly, all conditions are taken into account, and no steps are skipped,
- consistency, i.e., if the output is consistent across multiple runs of the same problem,
- accuracy of intermediate calculations, i.e., if any intermediate values are computed correctly with no calculation errors, and
- question understanding, i.e., if all conditions and tasks are interpreted correctly.

Each dimension is scored on a discrete scale from 0 to 5 by the GPT-5. In addition, the judge provides a binary final verdict (correct or incorrect), which is used to compute judge accuracy as the ratio of correctly evaluated answers to the total ones.

4. Results

Each model's performance is evaluated in terms of accuracy, execution time, and cost. The analysis is conducted across multiple dimensions, including model type, difficulty level, mathematical topic, and grade level. In total, 4.200 API requests were issued during the experiments, resulting from the evaluation of 70 problems across four models, with each experiment repeated five times. Additional requests were generated during the judge-based evaluation phase. The results are presented in the corresponding Figures and Tables.

4.1 Model axis

As shown in Figures 4 and 5, GPT-5-mini achieves the highest overall accuracy, yet exhibiting the longest response time, approximately 10 seconds higher than that of the next best-performing models. Notably, GPT-5-mini is the second most expensive model among those evaluated (Table 1). GPT-4o and GPT-4.1-mini exhibit comparable accuracy levels across the conducted experiments, achieving 65% and 63% under automatic evaluation, and 84% and 85% under the LLM-as-a-Judge evaluation, respectively. GPT-4o and GPT-4.1-mini exhibit significantly lower response time compared to GPT-5-mini, thereby outperforming it in terms of execution speed. Regarding cost, GPT-4o is the most expensive model, with a cost approximately five times higher than that of GPT-4.1-mini (Figure 6). Finally, GPT-3.5-turbo demonstrates the lowest accuracy and cost, while simultaneously achieving the shortest response time among the aforementioned models.

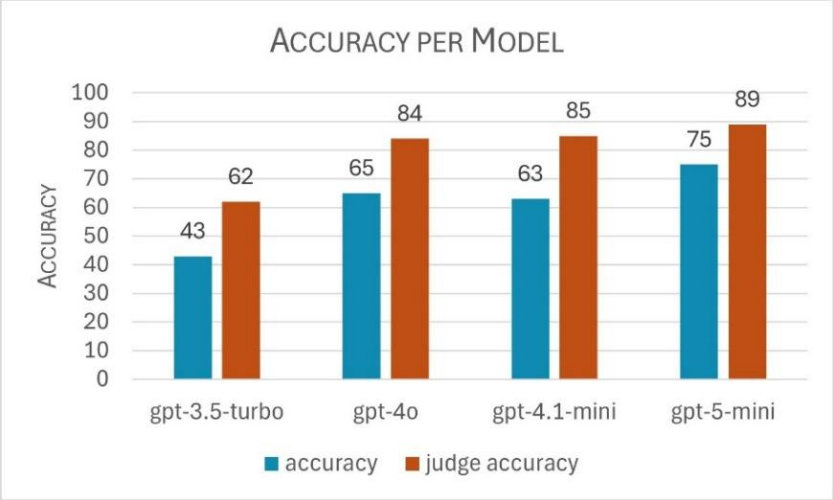


Figure 4: Accuracy per model

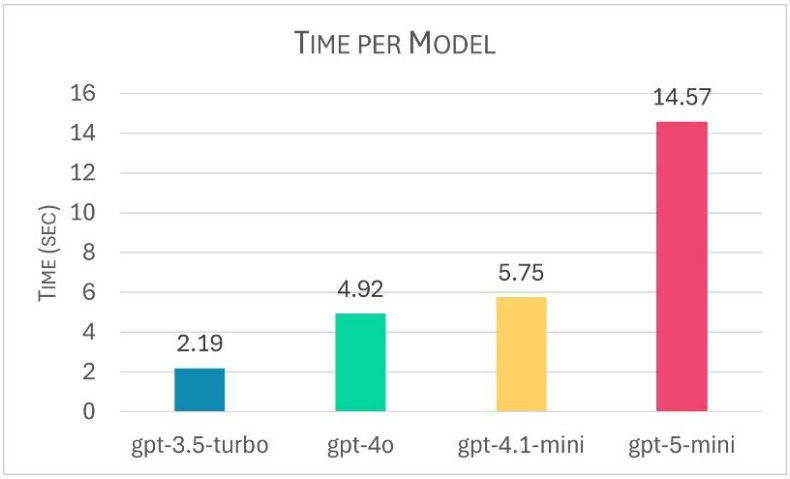


Figure 5: Time per model

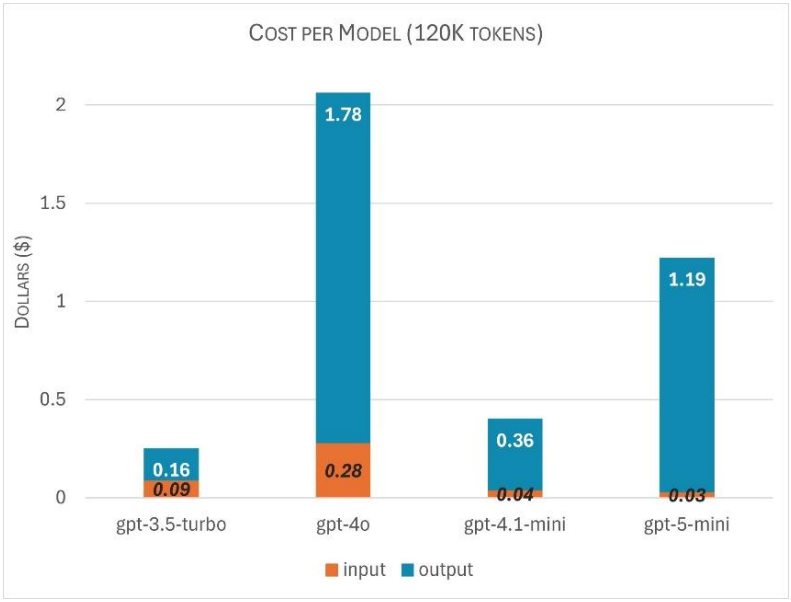


Figure 6: Cost per model

GPT Model	Cost
3.5 turbo	0.25 $
4o	2.06 $
4.1 mini	0.4 $
5 mini	1.22 $

Table 1: Total cost of each model

4.2 Other dimensions

4.2.1 Accuracy

The topic-based analysis reveals substantial differences in model performance across mathematical domains. Higher accuracy is observed in computationally oriented topics, such as arithmetic operations, and number sequences, suggesting that current LLMs perform particularly well on tasks that rely on pattern recognition and procedural computation. In contrast, conceptually demanding domains, such as equalities and inequalities or probabilities, are associated with lower accuracy, indicating challenges

in reasoning-intensive mathematical concepts (Figure 7). These findings suggest that, while LLMs show strong potential in supporting routine mathematical tasks, their reliability may vary substantially depending on the underlying cognitive demands of the problem domain. This observation is further supported by the analysis across levels of cognitive demand, as illustrated in Figure 8. Accuracy decreases as task complexity increases, with the highest performance observed in lower-demand tasks (Levels 1 and 2) and lower performance in more cognitively demanding tasks (Level 3). As tasks advance from lower- to higher-demand levels (Level 2 to Level 3), accuracy exhibits a relative decrease of 8% for GPT-5-mini, 30% for GPT-4.1-mini, 40% for GPT-4o, and 45% for GPT-3.5-turbo.

In addition to topic and levels of cognitive demand analysis, model performance was further assessed across the two grades, 3rd-grade and 5th-grade (Figure 9). These findings provide additional evidence that model accuracy decreases as the overall problem difficulty increases. For example, the accuracy of the most advanced model (GPT-5-mini) shows a relative decrease of approximately 19% from 3rd-grade to 5th-grade.

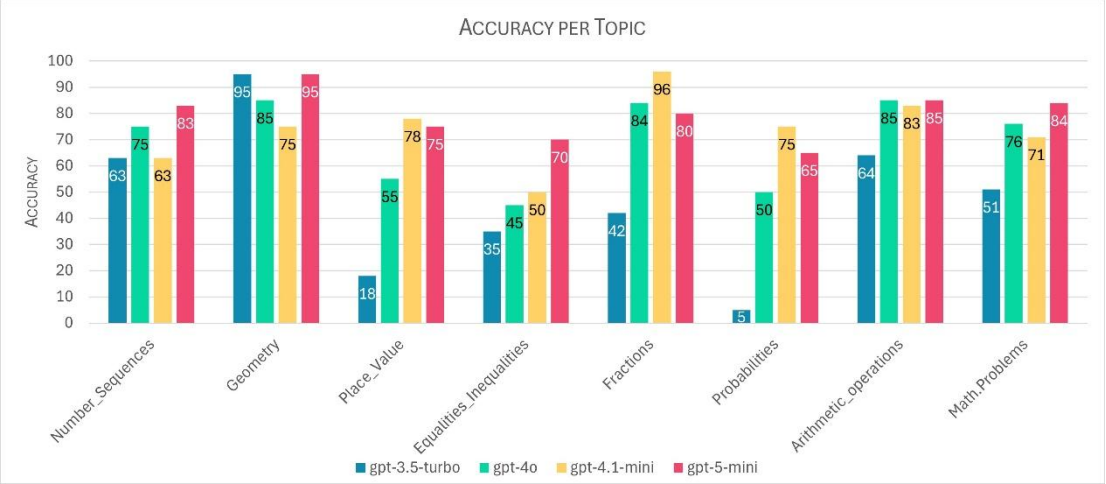


Figure 7: Accuracy per Topic

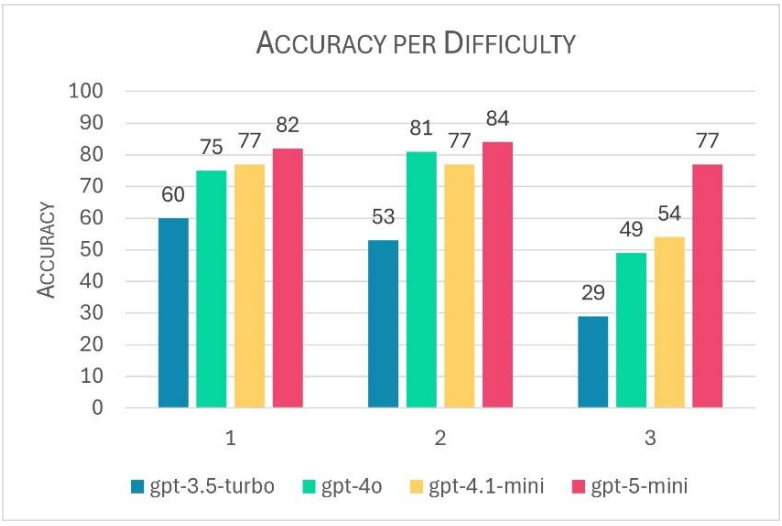


Figure 8: Accuracy per Difficulty

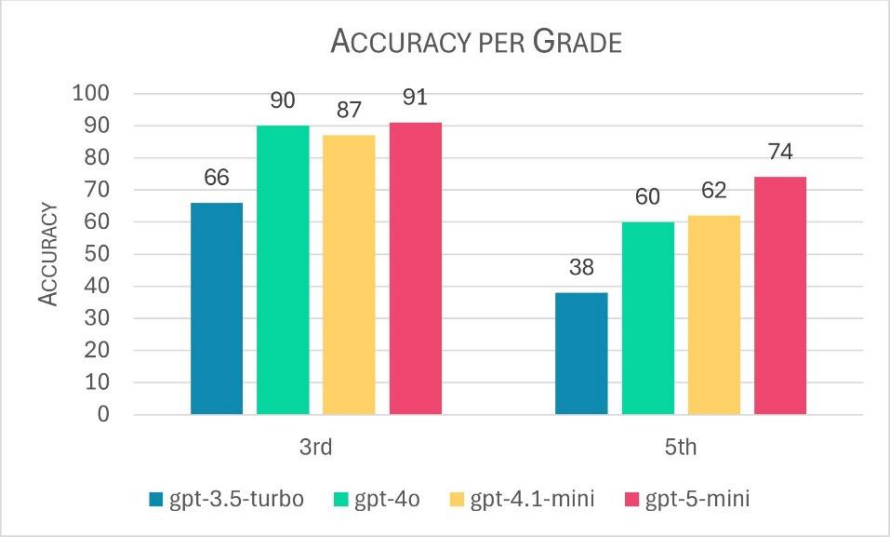


Figure 9: Accuracy per Grade

4.2.2 Time

As demonstrated earlier, GPT-5-mini exhibits the longest response times, a finding that is further confirmed by the analysis of response time across mathematical topics presented in Figure 10. Overall, newer model versions tend to require longer response times across most topics. However, this increase in latency is not necessarily detrimental, as it coincides with improved accuracy, indicating a clear trade-off between response time and performance.

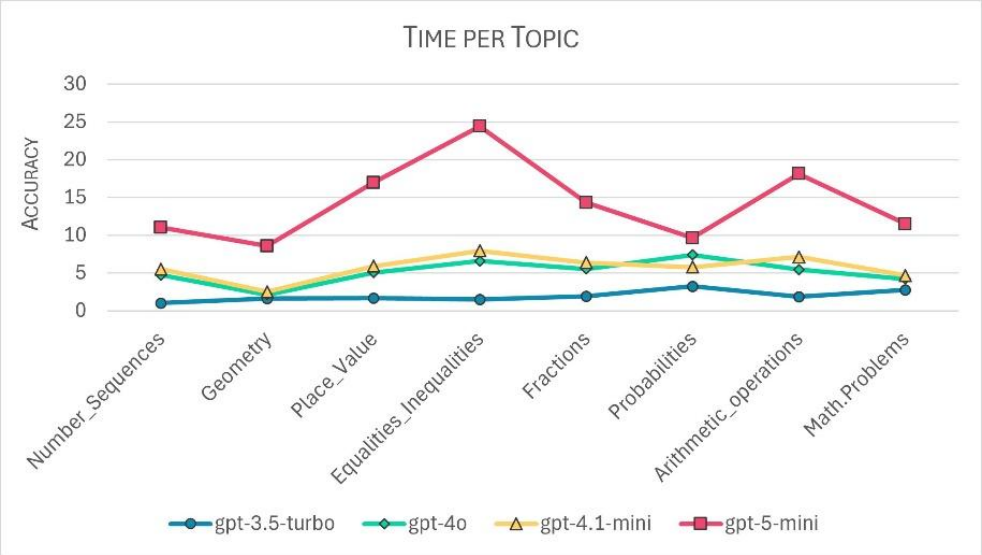


Figure 10: Time per Topic

4.3 Judge Evaluation

The judge-based evaluation (Figure 11) demonstrates a clear ranking of the assessed models. GPT-5-mini achieves the highest overall performance across all evaluation dimensions, followed by the GPT-4 family, with GPT-4.1-mini performing slightly better than GPT-4o, while GPT-3.5-turbo consistently exhibits the lowest scores. The GPT-5-mini model attains high scores in the axes of reasoning quality, completeness,

consistency, and problem understanding, indicating solid reasoning and explanation capabilities. However, it has a lower score in accuracy-related dimensions, probably due to occasional errors in intermediate calculations or omissions of minor or trivial solution steps.

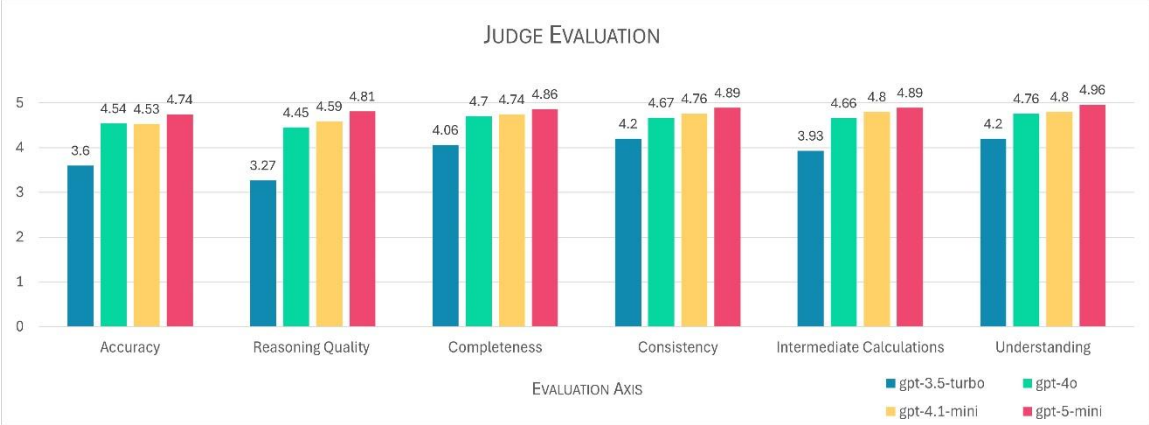


Figure 11: Judge evaluation

5. Conclusion and Future work

This study examined the accuracy and consistency of LLMs, with a particular focus on OpenAI models, in solving mathematical problems, using a hybrid evaluation framework that combines (i) automatic evaluation and (ii) LLM-as-a-Judge approach, implemented through a Python framework. To this end, a dataset of 70 mathematical problems was constructed, covering multiple topics from the 3rd and 5th grades of elementary school, based on the Greek curriculum. Each problem was assessed by four different models under the two prompting modes.

The results indicated that the newer models achieve higher overall accuracy across all evaluated dimensions, albeit with increased response time. This trend, however, is not reflected in the associated cost, as GPT-4o proves to be more expensive than newer models, such as GPT-4.1-mini, and GPT-5-mini. Furthermore, it is demonstrated that as the cognitive demand, and thereby problem difficulty, increases, the model's accuracy decreases proportionally. This behavior is confirmed by the topic-level aggregated results, where in domains with a higher level of reasoning, such as probabilities, models exhibit substantially lower accuracy.

Despite their remarkable advancements, including strong accuracy and cost efficiency, concerns remain regarding the ethical use of LLMs, particularly their tendency to generate hallucinated content (Huang et al., 2025). Such behavior raises important considerations in educational settings, where prior work has shown that confidently incorrect responses may negatively impact learning outcomes (Gupta et al., 2025). In educational practice, significant errors and omissions produced by LLMs may, in the best case, reduce students' trust in LLM-based tutors when errors are observed, while in the worst case, when left unnoticed, they may lead to misconceptions that directly affect students' future learning (Gupta et al., 2025).

Although the results provide meaningful insights into LLMs' performance in mathematical problem-solving tasks, they cannot be considered exhaustive. The

evaluation is limited to OpenAI models, and a relatively small dataset of 70 problems. Additionally, the reasoning, completeness, and quality of the responses collected by LLMs, were assessed exclusively through automated means. To address these limitations, future work aims to expand the database with a larger and more diverse set of problems, include models beyond OpenAI's (e.g., Gemini, DeepSeek, Claude), and integrate human-in-the-loop evaluation by experienced educators, to further validate response quality, pedagogical aspects, and ethical considerations.

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From Text to Image: Introducing Artificial Intelligence in the Teaching of Literature in Vocational High School

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Abstract — This paper investigates the use of text-to-image Artificial Intelligence tools in teaching Modern Greek literature within Vocational High Schools (EPAL) in Greece. Drawing on contemporary theories of multimodal literacy, human-centered AI, and the specific pedagogical conditions of vocational schooling, it examines how AI-supported visualization may enrich students' engagement with literary texts and support deeper awareness of the literary technique of description.

The educational intervention unfolded across three interconnected phases. First, students engage in close reading and systematic analysis of descriptive strategies in K. Ouranis' text "The old Athenian carnival," identifying key features and producing initial visual interpretations. The second phase introduces text-to-image AI applications, through which students transform selected passages into prompts and generate corresponding images. Collaborative prompt construction and comparison between textual and visual outputs encourages interpretive precision and introduces students to basic principles of AI-mediated representation. The final phase emphasizes on critical reflection and production of written speech, as students present their prompts and images, discuss the interpretive dynamics between text and visualization, and compose reflective pieces on their learning process.

Data sources include student artifacts, classroom observations, teacher field notes, and group presentations. A qualitative thematic analysis suggests that the intervention supported more attentive engagement with literary description, fostered emerging forms of digital and AI literacy, and encouraged collaborative participation among students who often struggle with traditional text-centered instructions. Students' reflective writing further indicated an evolving awareness of how textual and visual modes interact, as well as a recognition of AI tools as interpretive mediators rather than neutral generators.

Overall, the paper argues that integrating AI-enhanced multimodal practices into literature teaching can broaden access to literary understanding, particularly in vocational contexts where experiential and visually oriented learning is pedagogically valuable. It also highlights the importance of human-centered AI principles—transparency, critical engagement, and learner agency—in shaping meaningful educational uses of emerging technologies. By positioning students as active interpreters and evaluators of AI outputs, the intervention contributes to ongoing discussions on ethical and pedagogically grounded AI integration in education and

illustrates the potential of text-to-image tools to enrich multimodal literacy in EPAL classrooms.
Keywords: literature, Vocational High School, multimodal literacy, text-to-image AI, human-centered AI in education

1. Introduction

Teaching literature in Greek Vocational High Schools presents specific pedagogical challenges that differ significantly from those encountered in general academic tracks. In the context of Greek Vocational High Schools (EPAL), students are primarily oriented towards technical and professional specialisations, and subjects of general education—such as language and literature—are often perceived as secondary or marginal to their educational goals. As a result, literature teaching in EPAL frequently takes place in classrooms characterised by low reading motivation, fragmented prior knowledge, and limited engagement with literary texts.

Within this context, the course of Modern Greek (Language and Literature) integrates both language instruction and literary analysis, requiring students not only to comprehend texts at a surface level but also to engage with fundamental narrative modes such as narration, description, dialogue and interior monologue. Although these narrative modes are formally introduced in Secondary Education, many students in vocational settings experience difficulties in recognising their distinct functions and, more importantly, in interpreting their literary and aesthetic contribution to the text. Descriptive discourse, in particular, poses notable challenges, as it presupposes the ability to transform verbal cues into mental images and to appreciate the role of sensory detail, atmosphere and perspective in literary representation.

Empirical teaching experience in EPAL classrooms indicates that students often confuse narration with description or approach descriptive passages as static and redundant, rather than as meaningful components of literary meaning-making. At the same time, these students demonstrate a high level of familiarity with digital environments and emerging technologies, including applications based on Artificial Intelligence for text and image generation. This apparent contradiction between linguistic-literary difficulties and digital fluency highlights the need for pedagogical approaches that strategically connect students' existing digital competences with the goals of literary education.

From a didactic perspective, recent approaches to literature teaching emphasise the active role of the reader in constructing meaning, the importance of multimodal engagement, and the value of experiential and collaborative learning environments. In this framework, the integration of AI-based visualisation tools can function as a mediating mechanism between the text and the reader, supporting the comprehension of descriptive discourse by making implicit imagery more explicit and open to critical discussion. Rather than treating AI as a substitute for interpretation, this paper argues for its use as a pedagogical aid that enriches literary understanding and fosters critical and reflective reading practices.

Against this background, the present paper proposes a teaching intervention that introduces AI-supported visualisation into the teaching of literary description in the first grade of EPAL. The intervention seeks to address students' difficulties with descriptive discourse, enhance reading engagement, and cultivate emerging forms of digital and AI literacy, while maintaining a human-centred and interpretive approach to literature teaching.

2. Theoretical framework

2.1 Contemporary approaches to the teaching of literature

Contemporary literary pedagogy has shifted decisively toward learner-centered, multimodal, and constructivist approaches that emphasize students' active engagement with texts. Traditional transmissive models, in which the teacher functioned as the primary interpreter, have been challenged by theories that foreground the reader's role in constructing meaning. Rosenblatt's (1978) transactional theory remains foundational, positing that literary understanding emerges through the dynamic interaction between reader, text, and context. This shift has encouraged pedagogical practices that value interpretive plurality, personal response, and dialogic engagement.

Parallel to this development, the concept of multiliteracies has reshaped the teaching of literature. The New London Group (1996) argued that literacy education must reflect the multiplicity of modes—linguistic, visual, spatial, gestural, and digital—that characterize contemporary communication. Subsequent scholarship has expanded this framework, emphasizing the need for students to develop visual literacy and multimodal interpretive skills (Serafini, 2014; Bezemer & Kress, 2016). In literary education, this means supporting learners in navigating the interplay between textual and visual meaning-making.

The literary technique of description is particularly suited to multimodal pedagogies. Visualization has been shown to enhance comprehension, emotional engagement, and memory (Gambrell & Jawitz, 1993; Sadoski & Paivio, 2013). Yet many students struggle to translate descriptive language into mental imagery, especially in contexts where reading fluency or vocabulary knowledge is limited. Pedagogical strategies that scaffold visualization—such as illustrations, graphic organizers, or digital tools—can therefore play a crucial role in helping students understand how authors construct narrative worlds through descriptive detail.

2.2. AI in Education

Artificial Intelligence has become a significant force in educational innovation, offering new opportunities for personalization, creativity, and multimodal learning. Early applications focused on adaptive learning systems and intelligent tutoring (Luckin et al., 2016), but recent advances in generative AI—including text-to-image models—have expanded the pedagogical possibilities. These tools enable learners to generate visual representations from textual input, providing immediate, multimodal feedback that can support comprehension and creative exploration.

Recent research highlights AI's potential to democratize education by expanding access to resources, supporting diverse learning needs, and enabling differentiated instruction (Holmes et al., 2022; UNESCO, 2023). Reports such as *Educ-AI-tion Rebooted?* (Baker, Smith, & Anissa, 2019) emphasize that AI can transform learning environments by offering adaptive support, enhancing creativity, and reducing barriers for students who struggle with traditional text-based instruction.

At the same time, the field of AI in education has matured significantly. Systematic reviews (Chen, Chen & Lin, 2020; Chen et al., 2022) show that AI-enhanced learning environments increasingly support personalization, language learning, and multimodal

engagement. In Greece, emerging empirical work indicates that teachers are cautiously optimistic about AI's potential but express concerns about training, ethics, and infrastructure (Anastasiades, 2023). These findings underscore the need for pedagogically grounded, ethically informed integration of AI tools in schools.

AI also supports metacognitive development. When students compare their own mental images with AI-generated visualizations, they engage in reflective processes that deepen their understanding of how language evokes imagery. This aligns with constructivist principles, as learners actively negotiate meaning by evaluating the correspondence between textual cues, their interpretations, and algorithmic outputs. The teacher's role becomes that of a facilitator who guides students in interrogating both the text and the generated images, fostering critical thinking and interpretive awareness.

2.3. Human-Centered AI and pedagogical ethics

The rapid integration of AI into educational environments has intensified the need for frameworks that ensure its ethical, transparent, and pedagogically meaningful use. The paradigm of human-centered AI has emerged as a response to these concerns, emphasizing systems designed to augment human capabilities, preserve learner agency, and operate in ways aligned with democratic values and educational equity (Shneiderman, 2020; Benjamins et al., 2023). Rather than prioritizing automation or efficiency, human-centered AI foregrounds the role of teachers and learners as active agents who shape and critically engage with AI-mediated learning processes.

Recent scholarship stresses that AI in education must be grounded in principles of trustworthiness, transparency, and accountability. Athanasiadis (2022) argues that educational AI systems should be designed with explicit attention to human values, ensuring that they "support human flourishing rather than merely optimize performance metrics." This aligns with broader research on human-centered AI design, which identifies persistent gaps between ethical aspirations and actual engineering practices (Ahmad et al., 2023). These gaps highlight the need for interdisciplinary collaboration between educators, designers and policymakers.
Human-centered AI also requires attention to user experience and fairness. Bond et al. (2019) emphasize that algorithmic systems must be designed with the user's cognitive and emotional needs in mind, ensuring that interfaces support understanding rather than obscure decision-making processes. Similarly, Li and Gu (2023) propose a risk-based framework for human-centered AI in education, arguing that systems must be evaluated not only for technical accuracy but also for their social impact, inclusivity, and potential to reinforce or mitigate inequalities.

In the context of literature education, a human-centered approach to text-to-image AI requires careful pedagogical framing. Generative AI models do not simply visualize textual content; they also reflect the biases, limitations, and cultural assumptions embedded in their training data (Bender et al., 2021; Birhane, 2021). For this reason, their outputs must be treated not as authoritative interpretations but as provocations for critical inquiry. Students should be encouraged to interrogate why the AI visualizes certain elements and omits others, how cultural stereotypes may shape algorithmic representations, and what this reveals about both the text and the technology.

2.4. The reality of Greek Vocational High Schools

Greek Vocational High Schools (EPAL) constitute a distinctive educational environment characterized by diverse student populations, varying levels of academic preparedness, and strong orientation toward practical and technical fields. Research on Greek vocational education highlights persistent challenges, including lower student motivation, limited engagement with traditional academic subjects, and structural inequalities (Kassotakis & Flouris, 2019; Sidiropoulou & Mavrogiorgos, 2021). Literature, often perceived as abstract or disconnected from students' lived experiences, can be particularly difficult to teach effectively in this context.

At the same time, students typically demonstrate strong familiarity with digital technologies, visual media, and hands-on learning. Recent studies emphasize the importance of experiential, applied, and multimodal pedagogies that connect learning to real-world contexts and leverage students' existing competencies (Koutouzis & Fragoulis, 2020). Integrating AI tools into literature teaching aligns well with these pedagogical needs, offering opportunities for enhanced motivation, creative engagement, and differentiated support.

However, schools often face infrastructural constraints, such as uneven access to digital devices, limited teacher training in emerging technologies, and curriculum pressures. Successful implementation of AI-enhanced literary pedagogy therefore requires careful planning, professional development, and alignment with national curricular goals. Despite these challenges, the use of text-to-image AI in Vocational High Schools' classrooms can be transformative, making literary techniques more accessible and validating students' strengths in visual thinking and digital fluency.

2.5. Integrating Text-to-Image AI into the teaching of description

The literary technique of description is central to narrative construction, yet often difficult for students to grasp. Text-to-image AI provides an immediate bridge between language and visualization, enabling learners to externalize their interpretations and engage critically with both text and image. A pedagogical cycle for integrating AI might include:

1. Close reading of a descriptive passage.
2. Eliciting students' mental images and interpretive expectations.
3. Generating AI-based visualizations from the text.
4. Comparing and critiquing the AI output, students' interpretations, and the author's descriptive strategies.
5. Reflecting on how linguistic choices shape imagery and how AI interprets textual cues.

This process not only clarifies literary concepts but also fosters metacognitive awareness, critical digital literacy, and creative engagement—key competencies for learners in vocational education.

3. Methodology

3.1 Educational context and participants

The proposed teaching intervention was designed for students of the first grade of Vocational High School (EPAL) in Greece, within the course of Modern Greek Language and Literature. This educational context is characterised by a strong orientation towards technical and vocational specialisations, while subjects of general education—such as language and literature—often receive lower priority from students. Learners frequently demonstrate heterogeneous linguistic backgrounds and notable gaps in reading comprehension and literary analysis, despite having acquired basic concepts in previous educational levels. At the same time, students tend to display high familiarity with digital environments and emerging technologies, including AI-based applications.

The intervention aims to capitalize on this digital familiarity in order to support the development of literary comprehension, with particular emphasis on descriptive discourse as a narrative mode. The selected literary text is Konstantinos Ouranis' *"The Old Athenian Carnival"*, which offers rich sensory descriptions and cultural references suitable for visualisation and interpretive analysis.

3.2 Design and duration of the intervention

The intervention was designed as a six-hour sequence, grounded in a scaffolded, multimodal pedagogical framework. Its structure follows a deliberate progression in which each phase builds cumulatively on the previous one, guiding students from supported engagement with literary description toward increasingly autonomous creative production and critical reflection. This sequencing aims to cultivate interpretive depth while enabling students to navigate the transition from textual analysis to multimodal meaning-making with sustained pedagogical support. Teaching is distributed across two learning environments—the conventional classroom, equipped with an interactive whiteboard, and the school computer laboratory—facilitating the integration of analogue and digital modalities and allowing for hands-on interaction with AI-based tools.

Methodologically, the design combines close reading practices, collaborative learning structures, and the pedagogically mediated use of text-to-image Artificial Intelligence applications. Close reading activities foreground the systematic examination of descriptive techniques, while collaborative processes support dialogic interpretation and shared problem-solving during the construction and refinement of AI prompts. Central to the intervention is an emphasis on process-oriented learning, prioritizing experimentation, interpretive reasoning, and critical evaluation over the production of polished artefacts. This orientation reflects a commitment to fostering reflective, multimodal literacy practices and to positioning emerging technologies as tools for inquiry rather than as ends in themselves.

3.3 Instructional Stages

In the first stage, students engage in guided reading of the literary text and participate in teacher-facilitated discussion and collaborative tasks. They identify key features of descriptive discourse—such as sensory details, evaluative language, metaphors, and the interplay between objective and subjective elements—developing greater awareness of how literary description constructs imagery and atmosphere.

During the second stage, students work in small groups with AI-powered image-generation tools (e.g., Canva Magic Media). Each group selects a descriptive excerpt and transforms it into a structured prompt. The resulting images are compared with the original passage, enabling reflection on the accuracy, limitations, and interpretive nature of AI representations.

The final stage centres on presentation, discussion, and reflective writing. Students present their prompts and images, collectively analyse text–image relationships, and compose short written reflections that consolidate linguistic competence and critical AI literacy.

4. Educational Intervention: Structure and Implementation

The proposed educational intervention is designed to be implemented over six school hours, corresponding to approximately 1,5 weeks of teaching in the course of *Modern Greek (Language and Literature)*. The first and final 2 hours ideally take place as double periods in the regular classroom, making use of the interactive whiteboard, while the 2 intermediate hours can be conducted separately in the school's computer laboratory.

4.1 Phase 1 (2 hours): Reading and literary description

The first phase focuses on preparing students for the reading experience and introducing the literary technique of description through a systematic and guided exploration of the text "Οι παλιές αθηναϊκές αποκριές" ("The old Athenian Carnival") by K. Ouranis. The instructional aims of this phase are twofold: on the one hand to approach the literary text as an aesthetic artifact and cultivate reading enjoyment, and -on the other hand- to examine the technique of description both theoretically and through concrete textual examples.

The lesson begins with the activation of students' prior knowledge. The teacher employs short guiding questions and selected audiovisual material related to Carnival traditions and mid-war Athens. This introductory activity bridges students' personal experiences with the cultural and historical context of the text, thereby enhancing meaning-making and preparing them for deeper engagement.

The literary excerpt is then read aloud. The teacher may combine teacher-led reading with shared reading among students to sustain attention and facilitate gradual familiarization with the stylistic features of the text. Emphasis is placed on sensory impressions and the vivid imagery Ouranis employs to evoke the atmosphere of early 20th-century Athenian festivities. At this stage, auditory reception is encouraged so that students can attune to the rhythm, tone, and narrative nuances of the passage.

Following the reading, students engage in guided identification of the key features of literary description. Through whole-class or small-group discussion, they locate keywords, adjectives, metaphors, sensory details, and scenic elements. Attention is also given to distinguishing between objective and subjective components of the description, enabling students to understand how the author blends informative and evaluative discourse. The phase concludes with a brief visual representation—either on

paper or using a digital tool—of the scene described in the text, serving as a preparatory step for the subsequent integration of AI-based visualization tools.

4.2. Phase 2 (2 separate hours): Visualization through AI Application

The second phase transitions from understanding literary description to creatively representing it through text-to-image AI tool, with the aim of deepening comprehension and enhancing student engagement. At this point, linguistic/literary literacy and digital/AI literacy begin to converge.

The teacher first introduces the basic principles of image-generation applications (Canva Magic Media or other), highlighting the role of prompts, the importance of linguistic precision, and the need for critical evaluation of AI-generated outputs. A model prompt is then collaboratively constructed based on a given image of a Carnival mask. Students observe the mask and contribute descriptive elements through brainstorming. The teacher synthesizes these contributions—focusing particularly on adjectives and specific visual details—and submits the prompt to the AI tool. With the original and generated images displayed side by side, students compare similarities and differences, reflecting on both the capabilities and limitations of AI. They also propose lexical refinements to improve the accuracy of the generated image. This activity familiarizes students with the mechanics of AI prompting and prepares them for group work.

Students then work in small groups of three to four. Each group selects a short passage from the literary text and transforms it into a text-to-image prompt. They identify the characters, objects, and scenic elements described, list their attributes, and compose a detailed prompt. The teacher circulates among the groups, offering feedback to ensure the prompts include sufficiently precise descriptive information. Once finalized, groups generate their images and select the version that best corresponds to their textual prompt. If necessary, they revise and regenerate the image. Each group submits its final image along with the prompt used.

This process strengthens students' ability to identify essential descriptive features while also enabling them to recognize the distinction between literary imagination and the more literal interpretive tendencies of AI systems. The phase concludes with a comparative discussion of the generated images, focusing on both successful elements and instances of "algorithmic misinterpretation," thereby fostering critical digital and AI literacy.

4.3. Phase 3 (2 hours): Critical reflection and production of written speech

The final phase centers on deepening the learning experience through critical reflection and the production of original written work. Each group presents its materials to the class: the initial prompt derived from Ouranis' text, the corresponding AI-generated image, and a brief interpretive commentary explaining their choices. This multimodal presentation encourages students to articulate the relationship between verbal and visual representation and positions them as evaluators of their own interpretive processes.

A whole-class critical reflection follows, facilitated by the teacher. Students discuss the convergences and divergences between the literary descriptions and the AI-generated images, identifying points of successful rendering as well as instances where the system produced "creative distortions" or unintended representations. This discussion aims to cultivate both linguistic and digital/AI literacy by clarifying that AI tools function as interpreters rather than faithful reproductions of textual meaning. Students are also encouraged to reflect on how visualization influenced their own understanding of the descriptive passage.

In the final activity, each group produces an original written text. Drawing on both the literary model and their AI-generated image, they compose a 200–250-word article that comments on the relationship between text and image and articulates their conclusions and reflections regarding the use of AI in the study of a literary text. This culminating task synthesizes interpretive, critical, and creative skills, reinforcing the pedagogical value of integrating AI into literary education.

4.4. Data collection and analysis

Data collection drew on multiple sources to enable methodological triangulation and to capture the complexity of students' engagement with the intervention. Student-generated artefacts—including prompts, AI-produced images, and written reflections—provided direct evidence of interpretive processes and evolving multimodal literacy practices. Classroom observations focused on patterns of participation, collaboration, and students' interaction with AI tools, offering insight into the dynamics of learning as it unfolded in real time. Complementing these observations, teacher field notes documented instructional decisions, emerging challenges, and students' responses to the pedagogical design. Group presentations further illuminated students' reasoning, allowing researchers to examine how learners articulated interpretive choices and critically evaluated the relationship between textual and visual meaning.

Data analysis followed a qualitative thematic approach aimed at identifying recurring patterns in students' engagement, interpretive strategies, and reflections on AI-supported visualization. Particular attention was given to students' understanding of literary description, as evidenced in their identification of descriptive features and the construction of prompts; to the interplay between textual and visual representations, as reflected in discussions and written work; and to students' emerging digital and AI literacy, especially their capacity to critique AI outputs and recognize algorithmic constraints. Coding proceeded inductively while remaining informed by the study's theoretical grounding in multimodal literacy, human-centered AI, and vocational education.

5. Results

The analysis of student artefacts, classroom observations, and reflective texts indicates that the integration of text-to-image AI tools contributed to a more attentive and nuanced engagement with literary description. While students initially struggled to distinguish between objective and subjective descriptive elements, their work during the prompt-construction phase revealed increasing sensitivity to adjectives, sensory cues, and spatial relations. As prompts became more precise, students demonstrated a

deeper awareness of how linguistic choices shape imagery. The iterative comparison between AI-generated images and the original text further encouraged students to refine their interpretations, suggesting the emergence of metacognitive awareness regarding the function of descriptive language in multimodal contexts.

Findings also point to the development of foundational digital and AI literacy. Students' early assumptions that the AI would produce a single "correct" visualization gradually gave way to a more critical understanding of the interpretive nature of algorithmic systems. Through guided discussion and collaborative experimentation, students identified omissions, distortions, and over-literalizations in the AI outputs and proposed targeted lexical adjustments to improve them. This shift from passive reception to critical engagement reflects growing competence in evaluating and shaping AI-mediated representations.

Across all phases, the intervention fostered high levels of engagement and collaborative learning. Group work in the computer laboratory encouraged active participation, negotiation of meaning, and peer-supported problem-solving. Notably, students who were typically less responsive in traditional text-centered activities participated more readily when tasks involved digital tools and visual creation. Group presentations further reinforced collaborative reasoning, as students articulated interpretive decisions and evaluated the relationship between textual cues and visual outcomes.

Finally, students' reflective writing revealed a sophisticated awareness of the interplay between text and image. Many noted that AI visualizations prompted them to reconsider descriptive details, while others highlighted how the AI's interpretive "misreadings" illuminated ambiguities in the literary passage. Overall, students recognized AI tools as interpretive mediators rather than neutral reproductions of meaning, aligning with the principles of human-centered AI and underscoring the value of critical, informed engagement with emerging technologies.

6. Discussion

The findings indicate that the integration of text-to-image AI tools can substantially enrich students' engagement with literary description. In line with multimodal literacy frameworks, students benefited from working across linguistic and visual modes, with the process of translating descriptive passages into prompts making their interpretive reasoning more explicit. The iterative movement between text, prompt, and AI-generated image reflects the transactional view of reading articulated by Rosenblatt (1978), as students actively negotiated meaning rather than receiving it passively.

The results also support claims that AI can broaden access to literary understanding by offering alternative representational pathways (Holmes et al., 2022; Baker et al., 2019). In the EPAL context, where abstract literary concepts often pose challenges, AI-supported visualization provided concrete scaffolding that increased motivation and participation, resonating with research on experiential and applied pedagogies in vocational education.

Furthermore, the intervention aligns with principles of human-centered AI (Shneiderman, 2020; Athanasiadis, 2022), as students not only used AI tools but also critically evaluated their limitations and interpretive tendencies. This development of

critical AI literacy responds to calls for user-centered, reflective engagement in AI-mediated learning environments (Ahmad et al., 2023; Bond et al., 2019). Collectively, the findings highlight the pedagogical value of AI-enhanced multimodal practices in vocational literature classrooms.

7. Conclusion

The intervention demonstrates that integrating text-to-image AI tools into the teaching of Literature can substantially enhance students' engagement, interpretive precision, and multimodal literacy. By combining close reading with AI-supported visualization and structured reflection, students approached literary description as a dynamic meaning-making process, developing a more nuanced understanding of descriptive techniques and strengthening their ability to articulate interpretive decisions. They also cultivated foundational competencies in digital and AI literacy.

The findings highlight the pedagogical value of human-centered AI in vocational education. Rather than replacing literary interpretation, AI functioned as a catalyst for deeper inquiry, collaboration, and critical engagement. Students learned to evaluate algorithmic representations, recognize the interpretive nature of AI systems, and negotiate the relationship between textual and visual modes—outcomes aligned with contemporary frameworks emphasizing ethical, transparent, and learner-empowering uses of AI.

Overall, the study suggests that thoughtfully designed AI-enhanced activities can bridge students' digital strengths with the demands of literary analysis, supporting more inclusive and meaningful learning in EPAL classrooms.

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Studies Designed as a Game: Rethinking Curriculum through Play, Flow, and AI co-agency

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Abstract —This conceptual paper proposes a framework for transforming higher education distance learning by reconceptualizing an entire Master's curriculum as a Serious Video Game. Rather than gamifying isolated modules, the proposal restructures the full academic program as a coherent game world. AI-powered tools are integrated to lower the technical threshold of game development, enabling novices to co-create complex content through assisted programming and asset generation. Learning unfolds within a narrative-driven environment structured around role-based collaboration, player development, and a dynamic progression system. An inverted scoring model—beginning at its maximum and gradually decreasing—introduces productive tension that mirrors gameplay logics while sustaining engagement. A central narrative of a fragmented "book of knowledge" positions students as active agents who restore disciplinary coherence by confronting domain challenges. Player agency, including character customization and thematic choice through in-game currency, supports identity formation and professional orientation. The framework synthesizes Huizinga's "Magic Circle" and Csikszentmihalyi's "Flow" with a posthumanist understanding of Human–AI co-agency, positioning AI not as a tool of assistance but as a co-constitutive actor in learning. In doing so, the model contributes to Education 5.0 by operationalizing symbiotic Human–AI collaboration within an accredited academic structure. Methodologically, the study employs a research-through-design approach grounded in long-term pedagogical praxis to articulate a scalable model that preserves full academic equivalence through formal LMS certification of in-game progression.

Keywords— Artificial Intelligence in Education; Co-agency; Posthumanism; Game-Based Learning; Curriculum Design

1. Introduction

The landscape of distance education, particularly post-COVID-19, has necessitated a paradigm shift where technology acts as an active force in cultivating skills and, more broadly, in shaping learner attitudes and behaviors. This phenomenon can be interpreted as a "hybridization of agency" of non-human actors, specifically computational and information systems, raising fundamental questions regarding the power technologies wield and their capacity to fundamentally reconfigure the social fabric. Following Donati "hybridisation" is defined "*as entanglements and interchanges between digital machines, their ways of operating, and human elements in social practices"* (Donati 2021:213). From a research perspective, it argues that our main research concern must be how digital machines, robots and Artificial Intelligence interact with humans and affect their social identities and relationships, thereby generating a new kind of society (Donati 2021).

A negative consequence of this hybridization can be seen in the mass use of digital tools, which has reinforced a reliance on static Learning Management Systems (LMS) that prioritize administrative content delivery over the learner's authentic, lived experience (Selwyn, 2016; Garrison et al., 2000). Moore (1993) characterizes such an environment as a high "transactional distance," marked by a pronounced sense of psychological isolation and a pedagogical shift toward "passive consumption." According to Freire (1970), these conditions lead to the 'banking concept of education,' which transforms the learner into a passive consumer, stripping them of agency (autonomy and action) and contributing to the psychological isolation that characterizes high transactional distance (Simpson, 2013).

As a response to these challenges, this paper proposes a pedagogical approach that transforms the teaching methodology of the Master's distance learning program into a Video Game. The approach focuses on reducing the "transactional distance" and psychological isolation, and aims to cultivate a more engaging, creative, and meaningful educational experience. At the same time, positioning Artificial Intelligence as a co-agent in the learning process (Katsenou et al 2025) offers a meaningful response to contemporary debates on digital transformation in education. Crucially, the significance of the Master's program being framed as a video game is the fundamental shift from passive consumption of content to a dialogical, lived practice where students, acting as co-agents within a digital game environment, cultivate skill, understanding, and creative expression.

2. Objectives of the Conceptual Paper

The objectives of this conceptual paper are:

A. To propose an alternative framework for higher education distance learning that shifts from a conventional linear model to one grounded in RPG design principles and AI co-agency. Drawing on game development logic, the framework emphasizes role-based collaboration, structured progression, and narrative coherence as organizing principles of the curriculum. The paper provides a theoretical integration of core mechanisms—"play" (Bourdieu; Huizinga), "Flow" (Csikszentmihalyi), RPG-based progression and collaboration (Garneli et al., 2018), and "AI co-agency" (Katsenou et al., 2025)—within a game-engine structure to cultivate immersive learning. The anticipated pedagogical outcomes include sustained flow, enhanced learner autonomy, and strengthened collaboration.

B. To foreground AI as a learning partner by demonstrating how students without programming expertise can create video games through AI-assisted development.

3. Related Work

The discourse on game-based learning (Gee, 2007), gamification, and virtual learning environments (VLEs) in higher education reflects a field in a state of vigorous yet fragmented innovation. While the academic community has extensively experimented with ludic elements, the comprehensive pedagogical architecture of a Master's program as a unified and cohesive 'video game' — which, however, is explicitly designed to maintain the full academic rigor and the level of the postgraduate degree — remains a field for which we have not yet collected sufficient research data.

A primary trend in the literature focuses on the integration of gamification elements (Bell, 2018) within online postgraduate programs, primarily to enhance student engagement and retention (Lai-Kwon et al., 2023). Studies by De Freitas et al. (2015) demonstrate the efficacy of reward systems such as badges and leaderboards; however, these elements often function as an external "skin" applied to a traditional academic body. In these models, knowledge transmission remains linear, and play is relegated to a role of extrinsic motivation, failing to achieve the ontological reorientation required for deep, lived learning.

Concurrently, research into Serious Games (SGs) and 3D Virtual Environments (Annetta et al., 2010) has provided valuable data on the technological feasibility of immersive learning (Baptista et al., 2024; Vodenicharova, 2022). While these projects prove that digital environments can foster complex competencies, their application remains "insular." They are typically confined to single modules or specific simulations, lacking the scalability required for a full, multi-year curriculum. The closest pedagogical precursor is the work of Sheldon (2020), who designed entire courses as Multiplayer Role-Playing Games (RPGs). However, despite transforming the classroom flow, the literature indicates that such models are restricted to the individual course level, lacking the institutional scale and accreditation necessary for a complete postgraduate degree (Mari et al., 2023).

In summary, current literature presents a picture of vigorous but fragmented activity. Existing models are either limited in scope or technologically immersive but academically conventional. This study addresses this exact void by proposing the convergence of academic rigor with a complete ludic ontology. The innovation lies in a program where the curriculum is not merely gamified but inhabited as a storyworld, transforming distance education into a truly lived learning experience.

4. Methodology

Methodologically, this study adopts a Research-through-Design approach (McKenney & Reeves, 2018). This methodology was employed to translate the accumulated knowledge from long-term pedagogical praxis and empirical data, derived from the activities of the 'Gaming Gamification Node (NoGG),' a research node/activity within the Institute for Game Research at the Ionian University, into a formal, structured conceptual framework.This framework, which constitutes the core intellectual

contribution of this conceptual paper, was articulated through a rigorous process of iterative design practices, reflective analysis, and co-design(Sanders & Stappers, 2008).

In pursuit of establishing a distance MSc in Game Design & Development, the first step was recognizing the systemic 'crisis of engagement' in current distance learning. According to Moore's (1993) theory of Transactional Distance, traditional, static Learning Management Systems (LMS) create a profound sense of psychological isolation. These systems prioritize content delivery over the lived experience, leaving the learner in a state of passive consumption and contributing to high attrition rates.

To address this gap, the research group of the Institute of Games Research sought alternative approaches, drawing from a rich empirical corpus developed within the 'Gaming Gamification Node (NoGG)' under the academic supervision of Dr. Ioannis Deliyiannis. This phase synthesizes years of pedagogical praxis and research, drawing from an extensive database accumulated over the years, which includes data from three academic levels: the creative prototypes of undergraduate projects, the advanced theoretical frameworks of postgraduate dissertations, and the longitudinal experimental evidence from supervised doctoral research. This multi-level input provides the foundational evidence for a shift toward more interactive models based on gamification and AI Co-agency, highlighting the need for learning environments that support agency, progression, and social presence—core characteristics of role-playing and multiplayer game systems.

Building on this empirical foundation and aligning the Master's requirements with the prospects of Education 5.0, which focuses on Human-AI Co-agency, emotional intelligence, and personalized, co-creative learning experiences (Ijiri & Marette, 2025), Ioannis Deliyiannis introduced the idea of a 'Postgraduate Program as a Video Game.' The basic principle was to construct a playable degree—a distance learning curriculum that could be played like a video game. The vision was to transform distance learning into an in vivo experience. Through this approach, students would not only learn video game theory but also actively engage with and reconstruct that theory through the central narrative structure (storyworld) with quests, the inverted scoring system, full learner autonomy, collaboration in Guilds aligned with professional game-production roles, and Human-AI Co-agency.

Concurrently with the conceptualization of the Master's-as-Game model, the Institute's researchers initiated an experimental, iterative design phase. This practical work involved the articulation of the game's map and core structure, the development of instructor avatars, and critical testing to empirically validate the model. The primary focus of this validation was to ensure the sustained state of Flow, validate RPG-based progression and collaborative structures, verify the successful acquisition of core concepts, and identify any structural or pedagogical gaps. This continuous feedback-driven process directly informed the subsequent design of the video game and concurrently served to fully articulate the essential theoretical foundations of the postgraduate program, as detailed in the following sections.

5. Theoretical Framework

By reframing the curriculum as a "Video Game," we shift the focus from the creation and provision of educational content to the user's experience. This approach aligns with

requirements of Education 5.0, ensuring that the academic experience is cohesive, lived, and transformative. Education 5.0 represents a transformative framework that redefines contemporary digital education by prioritizing human agency alongside rapid technological advancements(Luckin, 2018; Albakri & Wood-Harper, 2025) . Within this paradigm, the educational focus shifts toward a symbiotic relationship between humans and machines, aligned with the principles of Industry 5.0 which emphasizes human needs, resilience, and sustainability (Albakri & Wood-Harper, 2025; Anthuvan et al., 2025).A central pillar of this model is the transition of Artificial Intelligence from a mere assistive tool to a collaborative "co-agent" or intellectual partner, which enhances the human experience by fostering critical thinking and autonomy (Katsenou et al., 2025). This evolution promotes a dialectic of human-AI co-agency, where interactions are transformed into intellectual partnerships that support the co-construction of knowledge (Ijiri & Marette, 2026; Katsenou et al., 2025). Furthermore, Education 5.0 adopts a posthumanist pedagogical perspective that rejects traditional dualisms between human and machine, regarding agency as "more-than-human" (Gourlay, 2020). This approach acknowledges the deep entanglements between students and technological algorithms, advocating for a more expansive understanding of participation in digital higher education (Bayne & Jandrić, 2017; Gourlay, 2020).

Theoretically, the approach is based on Huizinga's concept of 'play' as a source of creativity and Csikszentmihalyi's concept of 'Flow,' where the difficulty is dynamically adjusted to the student's abilities for sustained engagement. From this perspective the Master's program ceases to be a mere repository of information and instead becomes, in the tradition Huizinga's perspective, “play,” a fundamental cultural activity that pre-exists culture (Huizinga 1955). According to Huizinga, real learning and creativity occur in the sphere of play. But when the sense of "play" shifts to the sense of "work," to "seriousness," real creativity stops to emerge.

From Csikszentmihalyi's perspective, and focusing on the learners' experience in the game, the proposed framework can cultivate a sense of 'Flow'—the feeling of fulfillment necessary for continuing the educational journey in a digital environment where a lack of interaction and stimuli often leads to boredom and inertia (Csikszentmihalyi 1990). Furthermore, the program is designed so that the difficulty increases as the student's abilities increase, thus providing distance learning with a flexibility that the static nature of traditional distance programs cannot achieve.

5.1 Translating Theory into Practice

To transfer the above theoretical model into a living video game, students navigate a dynamic quest map rather than a linear list of modules, discovering hidden "Easter eggs" within the learning materials and overcoming performance-based challenges. The narrative core of the program centers on a fragmented "Book of Knowledge"; students must reconstruct this book by embarking on quests and interacting with the "Guardians of the Field"—the professors and experts who guard the gates of each cognitive domain.

This narrative of the serious game reinforces the link to the learning subject and the establishment of the 'Magic Circle,' a concept derived from Huizinga’s (1955) study of play as a voluntary, bounded activity. By reframing a graduate program as a sanctuary, we deliberately suspend the "ordinary" rules of high-stakes academic judgment that often paralyze creative risk-taking. In traditional distance education, the constant

pressure of assessment frequently triggers a fear of error, which Robinson (2006) identifies as the primary inhibitor of divergent thinking. Within the Magic Circle, however, failure is stripped of its stigma and repositioned as a structural necessity (Juul, 2013). This shift facilitates what Kapur (2008) terms Productive Failure, where the learner's struggle with complex, systemic challenges becomes the very catalyst for conceptual insight. By treating "Game Over" as a temporary state—a prompt for reflection and iterative retrial—the program reclaims the creative ethos of childhood play. It invites adult learners into a space of "serious play" where the mind is permitted to experiment, prototype, and mess around, ultimately releasing the creative forces that abstract theories alone struggle to cultivate (Resnick, 2017).

6. Pedagogical Outcomes of a Distance Learning Experience as a Video Game

6.1 Enhancement of Student Autonomy and Agency

The gamification of the Master's program into a live Serious Video Game can initiate a profound pedagogical transformation, directly addressing the crisis of low engagement and student disconnection prevalent in traditional distance learning. Its primary benefits focus on enhancing fundamental psychological needs, specifically by cultivating learner agency. Specifically, the mechanism of progression is based on choice, visualized through the curriculum structured as a Skill Tree. This approach enables students to move beyond a fixed, linear course list and select their own learning trajectory, thereby forging a personal learning pathway. For instance, one student might elect to specialize in the programming component of game design, while another could choose to develop the aesthetic and narrative dimensions of the game.

The functionality of this choice-based structure is further defined by the completion of "Prerequisites," which unlock advanced branches, fulfilling the intrinsic human need for self-determination and personal control over one's educational journey (Ryan & Rigby, 2006). Furthermore, students customize their academic characters and are granted the agency to "purchase" preferred thematic directions for assignments using in-game currency that align with their specific interests and professional objectives. This structure fundamentally transforms the student from a passive recipient into an active Agent (e.g., a Researcher, Cadet, or Agent), significantly boosting engagement.

6.2 Experiencing Optimal Experience (Flow)

The concept of Flow, as outlined in the work of Csikszentmihalyi (1990), is central to the pedagogical framework, positing that optimal experience occurs when an individual's perceived challenges are dynamically balanced with their perceived skills. Within the Game Engine architecture, learning is transformed into a deeply experiential process because the system is designed to maintain this precise equilibrium; the difficulty is dynamically adjusted to the student’s evolving competence. This dynamic balance is crucial for keeping students fully engaged and focused, preventing the disengagement caused by boredom (if the challenge is too low) or the anxiety and withdrawal caused by being overwhelmed (if the challenge is too high). These continuous and automatic balancing pushes learners to operate at the dynamic boundary between the achievable and the demanding, ensuring that learning is a continuous, absorbing experience.

Furthermore, the mechanism of the Inverse Scoring Model is integrated to enhance the Flow state: grades commence at the maximum possible point and gradually decrease based on performance. This unique approach generates a "playful tension" that mirrors the suspenseful structures of real gameplay and sustains the learner's interest. By combining the dynamic challenge-skill balance with the motivational pull of the inverse scoring model, this framework fundamentally shifts the educational model away from the "Passive Learning" inherent in traditional Learning Management Systems (LMS) that rely on static materials, replacing them with a state of sustained, intrinsic motivation.

6.3 Fostering Collaboration and a Sense of Collective Belonging

In a world where distance education often leads to psychological isolation, the Guilds model emerges as the social core of the Master's-as-Videogame. Drawing direct inspiration from Massively Multiplayer Online Role-Playing Game (Steinkuehler, 2004), students are not trapped in the isolation of distance education but actively participate in group assignments, thereby strengthening the ethos of cooperation and the exchange of ideas. are no longer solitary learners, but cooperative adventurers. Group assignments are transformed into "Raids," high-stakes missions that demand collective strategy and collaboration to retrieve the fragmented pages of the "Book of Knowledge" from the "Guardians of the Field" (the professors).This structure, where success is dependent on the team, breaks the "Transactional Distance" and cultivates a Sense of Belonging (Relatedness) and the importance of social interaction in learning (Vygotsky, 1978). In doing so, isolation gives way to "Social Flow," transforming learning into a shared, lived adventure.

6.4 Developing AI Literacy Skills through Collaborative Co-agency with AI

A cornerstone and one of the most innovative elements of the Master's program is the complete recognition of Artificial Intelligence (AI) as a Co-agent in learning. In this context, the program aims for all students to acquire deep AI Literacy. This is not achieved through a passive system of automated prompts, but through an active approach where students are taught to engage with AI through specific challenges and a continuous creative dialogue(Holstein & Tighe, 2025). This process transforms AI into an active teammate in the educational process. Furthermore, all students are trained to co-create content with the aid of AI, extending the ability for even students with no experience in writing code, to produce complex content, such as games, without needing technical expertise (Becker et al., 2023). The proposed methodology of co-creation naturally leads students to understand the limits and constraints of AI. Ultimately, this perspective elevates Artificial Intelligence from a mere content-generation machine to a genuine partner in learning, fostering critical thinking and the students' ability to thrive in the digital landscape of the future.

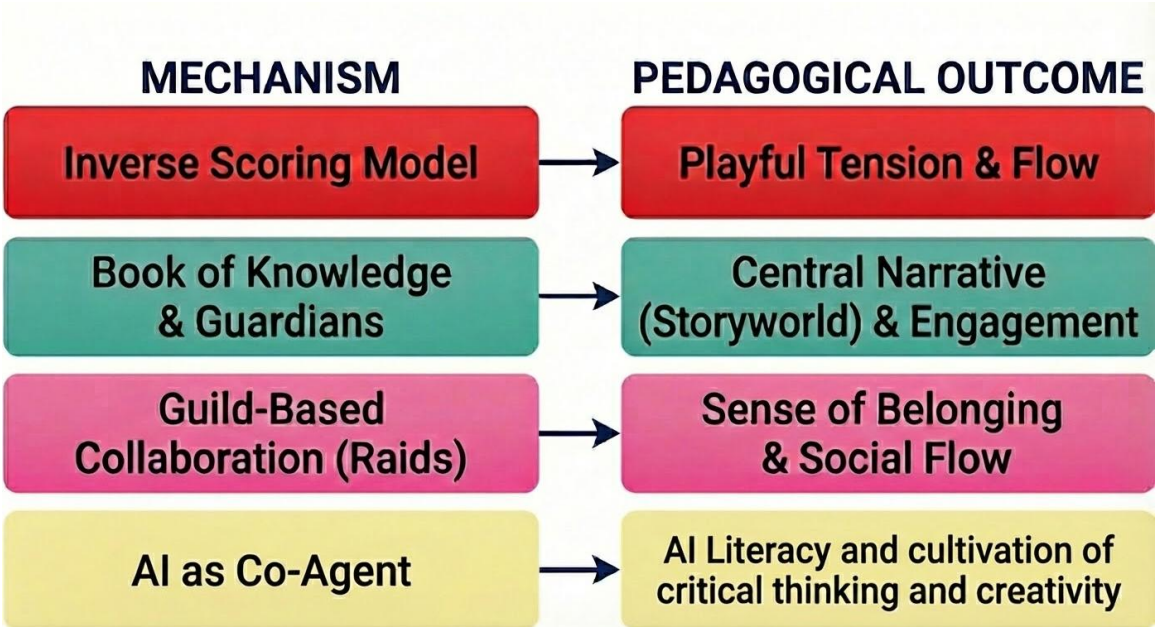


Figure 1: Game-Based Learning Mechanisms and Pedagogical Outcomes

7. Technical Implementation

The technical foundation of The Playable Degree requires a robust architecture to seamlessly blend the immersive gaming experience with institutional academic requirements. The Front-End relies on a high-fidelity Game Engine, specifically suggesting platforms such as Unity or Unreal Engine 5, to provide rich graphics, interactivity, and the foundation for the persistent virtual world. The Back-End integrates with an LMS API (Learning Management System Application Programming Interface). This critical connection allows the game to link securely with the university's existing database—such as Moodle or Canvas—to log academic progress. When a student completes an in-game "Quest" (academic assignment), the corresponding "grade" (XP/Points) is recorded safely in the official database, ensuring that the game-based progression is fully accredited and recognized by the University's administrative system.

8. Challenges & Risks

The implementation of curriculum as a video game, while promising, is not without significant challenges and risks that must be carefully considered for long-term viability and successful adoption. These challenges primarily fall into three categories: High Cost, Adoption, and Maintenance.

The challenge of High Cost is primarily driven by the required Development Investment. Constructing a persistent virtual world—featuring complex game mechanics, integrated narrative structures, and the high-fidelity graphics associated with platforms such as Unity or Unreal Engine 5—necessitates a specialized, multidisciplinary team. This typically involves game developers, graphic designers, narrative designers, and educators working collaboratively within an advanced production pipeline, substantially increasing the overall resource demands compared to conventional LMS-based course design.

Furthermore, running a robust Game Engine that supports a full degree program requires specialized server infrastructure and cloud computing resources, which can be expensive to scale as student enrollment increases. Finally, the Initial Overhaul involves not only building the system but also converting the entire existing curriculum into game-based quests, skill trees, and narrative beats, which is a massive content-development project.

Another significant hurdle lies in adoption, stemming from internal resistance and capability gaps within the academic institution. This risk manifests in several ways. Faculty resistance is a key concern, as experienced members may oppose the shift to a gamified model, viewing it as a trivialization of academic content or a deviation from established practices. Addressing this requires professional development and clear evidence of academic rigor and learning outcomes. Simultaneously, the technical skill gap means that teaching staff may lack the expertise to manage or teach within a dynamic Game Engine environment integrated with the LMS via API, making structured training necessary. Finally, despite the model's aim to enhance engagement, student acceptance is not guaranteed; some learners, particularly non-traditional or older students, may find the gaming framework intimidating or confusing, potentially increasing the risk of disengagement or withdrawal. For this reason, students will always have the option to follow the conventional structure of a standard distance-learning postgraduate program, should they prefer a more traditional academic pathway.

Maintenance also presents ongoing operational challenges. Unlike static learning materials such as PDF documents or recorded lectures, the Game Engine demands continuous maintenance. A game-based system requires continuous updates, including technical support, bug fixes, content revisions, and periodic refreshes to sustain student engagement and system security.

9. Conclusion

This study demonstrated a paradigm shift in higher education distance learning by reconceptualizing an entire certified postgraduate curriculum as a cohesive, playable system grounded in RPG design and Human–AI co-agency. Rather than proposing incremental gamification, the framework advances a structural reorganization of curriculum, assessment, and learner engagement within an immersive, interactive environment. By repositioning learning as participation (“being in”) rather than passive reception (“learning about”), the model prioritizes experiential understanding, structured progression, and narrative coherence. Mechanisms such as the Inverse Scoring model, Skill Trees, and Quest-based progression cultivate sustained engagement, autonomy, and collaborative knowledge construction. In alignment with Education 5.0, AI is positioned not merely as a support tool but as a collaborative partner in content creation and learning design. Academic legitimacy is preserved through formal LMS certification of in-game progression.

Despite its conceptual readiness, the model presents practical challenges, including high development costs, faculty adoption barriers, and long-term maintenance demands. Empirical validation remains essential. Future research should examine longitudinal effects on sustained Flow and Social Flow, as well as the operational

effectiveness of Human–AI co-agency in enabling complex production by novice creators.

Ultimately, this framework reframes the student as an active co-agent within a dynamic digital environment. Beyond distance education, it signals a potential reconfiguration of how accredited academic programs may evolve within game-based and Metaverse-oriented infrastructures

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Beyond the Chatbot: Co-Learning and Co-Teaching through a Dual-Persona Generative-AI Assistant

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Abstract—In this paper we present a generative-AI application developed to support both teachers and students in secondary education. The system employs two Large Language Models (LLMs) – Gemini and DeepSeek, and a Small Language model (SLM) – Gemma, integrated within a Retrieval-Augmented Generation (RAG) framework to create a pedagogically grounded, Greek-language assistant capable of adapting its reasoning and communication style to the user's role. Unlike conventional chatbots, the assistant introduces *Pedagogical Persona Switching*, a dual-role mechanism that enables the same AI model to act as both a teaching companion and a learning guide. When interacting with a student, the assistant produces accessible, curriculum-grounded explanations that promote conceptual understanding while remaining faithful to the officially approved educational sources. When addressing a teacher, the assistant generates diverse artifacts, including assessment items, classroom activities, and structured lesson plans. This dual-persona approach bridges knowledge retrieval with pedagogical creativity, enhancing differentiated learning. Utilizing a RAG paradigm tailored to the Greek educational domain, the architecture segments official textbooks into coherent units. Enriched with specific metadata, these units preserve curricular structure and instructional context, demonstrating how generative AI optimizes modern instructional design.

These units are represented by domain-specific sentence embeddings fine-tuned on Greek semantic similarity tasks. This linguistic adaptation ensures precise meaning alignment between user queries and content segments, maintaining fidelity to the official curriculum. All representations are organized within a retrieval index, guaranteeing transparent and source-grounded generation.

The initial case study focuses on Home Economics in Greek lower-secondary education (Grades A–B), a cross-disciplinary subject that integrates elements of economics, health education, and social responsibility. The assistant has been developed to support both learners and educators in complementary ways. In future classroom implementations, students will be able to use it to clarify key concepts such as financial literacy, resource management, and healthy living, while teachers could employ it to design authentic instructional materials, formative assessments, and classroom activities aligned with the official curriculum. Home Economics (HE) was chosen as the pilot domain because it is a non-STEM, value-oriented subject focused on early adolescents, emphasizing ethical reasoning, social awareness, and everyday decision-making. This unique context allows us to explore generative AI's pedagogical potential

beyond traditional core subjects, particularly its capacity to foster reflective reasoning and civic responsibility in young learners.

The project introduces an innovative generative framework combining three key elements: (a) a localized, curriculum-specific Retrieval-Augmented Generation (RAG) environment, (b) semantic educational text segmentation, and (c) adaptive persona-driven prompting. More than just a technical solution, this framework demonstrates how generative AI can be pedagogically and linguistically aligned with national curricula and local educational contexts. The resulting model offers a reproducible foundation for future AI integration into authentic learning settings, supporting teacher agency, learner engagement, and values-based secondary education. The study elevates the concept beyond a simple chatbot, proposing a structured, contextually adaptive framework for pedagogical generative assistants that effectively bridge technology, curriculum, and human learning.

Keywords— Generative Artificial Intelligence, Retrieval-Augmented Generation (RAG), Pedagogical Design, Teacher Agency, Dual-Persona Systems

1. Introduction

The rapid evolution of Generative Artificial Intelligence (GenAI) is fundamentally reshaping the educational landscape, moving past simple digital assistants toward sophisticated systems capable of complex content creation (Kuhail et al., 2023). While first-generation chatbots focused primarily on quick information retrieval (Kuhail et al., 2023), modern Large Language Models (LLMs) enable the development of tools that can understand, generate, and predict human-like language for advanced pedagogical tasks. Recently, the emergence of Small Language Models (SLMs) has offered a more compact and resource-efficient alternative (Touvron et al., 2023). These models feature fewer parameters and require significantly less computational power, making them ideal for specialized educational applications where resources are constrained.

Despite these advancements, a significant challenge remains: bridging the gap between raw knowledge retrieval and the nuanced needs of classroom instruction. Traditional chatbots often lack the contextual grounding required to remain faithful to specific national curricula. To address this, the Retrieval-Augmented Generation (RAG) paradigm has emerged as a crucial solution (Lewis et al., 2020).

RAG enables a model to search a specific, external knowledge base to retrieve factual, up-to-date information before generating a response. This approach significantly reduces hallucinations and ensures that answers are grounded in real, verified data (Lewis et al., 2020).

This article introduces S.T.A.R.T. BOT (Student Tutor Adaptive Role Tool Bot), a generative AI application specifically tailored to the Greek education sector. The system utilizes a RAG framework to ensure that AI responses are strictly based on official school textbooks[60]. Through this architecture, formal learning materials are semantically segmented into coherent units enriched with metadata, ensuring that the curriculum structure and teaching framework are maintained.

The key innovation of S.T.A.R.T. BOT lies in its Pedagogical Persona Switching mechanism. This dual-role approach allows the same AI model to act as both a teaching assistant for educators and a learning guide for students. By utilizing persona-based prompting techniques (Zamfirescu-Pereira et al., 2023), the assistant generates instructional materials for teachers—such as assessment items and lesson plans—while providing curriculum-based explanations and feedback to students. Our research focuses on a pilot study in Home Economics, examining whether SLMs can effectively compete with LLMs in providing safe, reliable, and curriculum-aligned educational support.

Thus, the research questions we pose in this paper are:

1. Can Small Language Models compete with Large Language Models in teaching and learning applications?
2. Can an AI Digital Assistant rely on Small Language Models?

2. Related Work

[60] https://ebooks.edu.gr/ebooks/

The landscape of educational technology is currently undergoing a transformative shift, precipitated by the rapid progression from static information retrieval tools to dynamic, generative systems. Historically, the integration of digital assistants began with reactive tools designed primarily for rapid information access and the execution of rudimentary, pre-defined commands (Kuhail et al., 2023). These early iterations operated within rigid, rule-based frameworks, which inherently constrained their capacity to address complex or divergent pedagogical queries.

However, the emergence of Generative Artificial Intelligence (GenAI) has fundamentally disrupted this paradigm. Modern AI chatbots have moved beyond simple command execution to the synthesis of sophisticated outputs, including text, code, and multimodal content. Unlike their predecessors, contemporary systems leverage deep learning architectures to facilitate fluid, context-aware dialogues, a capability that has significantly enhanced their efficacy within academic environments (Baidoo-Anu & Owusu Ansah, 2023). In the modern classroom, these assistants provide multifaceted support: they alleviate administrative burdens for educators through automated grading and content generation, while fostering student engagement via interactive and gamified learning experiences. Furthermore, these systems enable personalized tutoring, offering adaptive support for special education and granular feedback for language acquisition.

The core computational engines driving these advancements are Large Language Models (LLMs), characterized as sophisticated deep learning architectures trained on expansive datasets to generate human-like language (Touvron et al., 2023). While LLMs have revolutionized natural language processing, their deployment in education is often hindered by challenges such as the generation of factually inaccurate content and the limitations of static training data.

To address these constraints, recent scholarship has explored the utility of Small Language Models (SLMs). (Touvron et al., 2023). Models such as Gemma offer a compact alternative to high-parameter systems like Gemini or DeepSeek.. Having significantly fewer parameters, SLMs require substantially less computational power while maintaining competitive performance levels. Consequently, they represent an affordable and scalable solution for specialized educational tasks, particularly in environments where hardware resources are constrained.

A persistent obstacle in the pedagogical application of AI is the phenomenon of "hallucination," wherein a model generates factually incorrect information. To mitigate this risk, the Retrieval-Augmented Generation (RAG) paradigm has emerged as a robust architectural solution (Lewis et al., 2020). RAG functions by enabling a model to query a specific external knowledge base—such as verified curriculum textbooks—to retrieve factual, contemporary data prior to response generation. This approach bridges the gap between a model’s generative capacity and the necessity for empirical accuracy.

According to Lewis et al. (2020), RAG effectively synthesizes "parametric memory," derived from pre-training, with "non-parametric memory," consisting of external document repositories. The technical workflow begins with indexing, where external data is segmented and converted into vector representations through embeddings. As Johnson et al. (2019) observe, the utilization of vector databases facilitates efficient

similarity searches in high-dimensional spaces, allowing for the rapid retrieval of relevant context based on metrics such as cosine similarity. By utilizing retrieved data as a grounding context, the probability of hallucinations is drastically reduced, as the model's output is constrained by the real-time information provided. Shuster et al. (2021) demonstrate that incorporating such external knowledge not only improves response fidelity but also allows the system to cite its sources, thereby enhancing transparency and institutional trust. Consequently, RAG serves as a dynamic architecture that ensures AI systems remain current without the prohibitive costs of continuous fine-tuning.

To transition these theoretical frameworks into functional educational tools, deployment frameworks such as Streamlit[61] are frequently employed to transform Python-based RAG backends into accessible web applications. Such platforms facilitate complex user-interaction models, including "dual-persona" mechanisms. This allows a single underlying model to serve distinct roles—such as "Student" or "Teacher"—thereby providing role-specific functionalities within a unified interface (Zamfirescu-Pereira et al., 2023).

Building upon these advancements, this study introduces **S.T.A.R.T. BOT (Student Tutor Adaptive Role Tool Bot)**, a generative AI application tailored for the Greek educational sector. In our work, we use the aforementioned technologies to create a digital assistant leveraging a Retrieval-Augmented Generation (RAG) framework to ground responses in official textbooks. This architecture employs semantic segmentation to preserve curriculum integrity through metadata-enriched units. A core innovation is the Pedagogical Persona Switching mechanism, which utilizes persona-based prompting to allow a single model to pivot between an educator's assistant and a student's learning guide. Our pilot study in Home Economics evaluates if Small Language Models (SLMs) can offer a safe, cost-effective alternative to LLMs.

The remainder of this paper is organized as follows: The Methodology section delineates the framework and technical implementation of S.T.A.R.T. Bot. In the Experiments section, we detail the empirical evaluation of the chatbot's functionality and provide a comparative analysis between Large Language Models (LLMs) and a Small Language Model (SLM). The findings of this comparison are presented in the Results section, while the paper concludes with a summary of the research and its pedagogical implications.

3. Methodology

The methodology for implementing the system is divided into three main phases: the pre-processing of the data, the creation of the search index and the design of the interaction mechanisms.

A. Data Pre-processing and Semantic Chunking

The process begins with the use of official school textbooks (Student's books) as primary data. To optimize recovery, the Chunking technique is applied:

1. The text is divided into conceptual units per chapter.

[61] https://streamlit.io/

2. Each section is limited to a size of up to 350 words, ensuring that the information remains focused and manageable by the model.
3. Each chunk is enriched with metadata, which includes the module, subsection and type of document, in order to maintain the structure of the curriculum.

B. Semantic Indexing and Vector Storage

To convert text into embeddings that allow semantic searching, the lighteternal/stsb-xlm-r-greek-transfer encoder from the SentenceTransformers library is used, which is specially trained for the Greek language.

- The generated vectors are stored in a FAISS index (specifically in the faiss formula.IndexFlatL2) for fast search based on Euclidean distance.
- This process allows the system to find the most relevant quotes from books based on the meaning of the user's question and not just the keywords.



Figure 1: The S.T.A.R.T. BOT application using the Streamlit library

C. Dual-Persona Prompting and Deployment

The application is implemented with the **Streamlit** framework, offering an interactive web interface where the user chooses their role: **Student** or **Teacher**.

- **Persona Switching:** The architecture uses specialized Prompts that combine role, behavioral instructions, retrieved data (RAG), and response rules.
- **Student Mode:** Focuses on providing explanations and feedback based on the syllabus.
- **Tutor Mode:** Allows for the creation of educational materials, such as assessment tests and experiments.

The system supports the use of both large models (LLMs) such as Gemini-1.5-Flash-Lite and **DeepSeek,** as well as smaller models (SLMs) such as **Gemma 3:4b**, to evaluate their efficiency in an educational environment.

4. Experiments

The experimental phase of this study was designed to evaluate the pedagogical effectiveness and technical reliability of the S.T.A.R.T. BOT across its two distinct operational modes. The primary subject for the case study was Home Economics for Greek lower-secondary education, chosen for its cross-disciplinary nature and focus on practical life skills

Language Models and Setup

To assess the impact of model scale on educational outcomes, the system utilized three different language models:

- Large Language Models (LLMs): Gemini (gemini-1.5-flash-lite) and DeepSeek (deepseek-chat).
- Small Language Model (SLM): Gemma (gemma3:4b), representing a resource-efficient alternative.

All models were integrated into a Retrieval-Augmented Generation (RAG) framework using a specialized Greek semantic encoder (lighteternal/stsb-xlm-r-greek-transfer) and a FAISS index for high-performance vector retrieval.

Prompt Engineering and Persona Logic

A unified prompt structure was applied to maintain consistency across all experiments. The prompts followed a modular architecture:

Prompt Structure:

“Role” + “Role Prompt” + “RAG Context” + “Rules” + “User Question”.

This structure ensured that each model strictly adhered to its assigned pedagogical persona while grounding its responses in the retrieved educational segments from official textbooks.

Student Mode Experiments

Question	Gemma Answer
Να περιγράψετε την αγοραστική δραστηριότητα μιας οικογένειας. Να χρησιμοποιήσετε ένα παράδειγμα	Σύμφωνα με τα αποσπάσματα, η αγοραστική δραστηριότητα μιας οικογένειας περιλαμβάνει διάφορα στάδια. Πριν αγοράσει ένα προϊόν, η οικογένεια διαπιστώνει την ανάγκη που πρέπει να ικανοποιήσει, αναζητά πληροφορίες για τα διάφορα προϊόντα, διερευνά τις διάφορες αγορές από τις οποίες μπορεί να προμηθευτεί το προϊόν, συγκρίνει τις τιμές και γενικότερα τις διάφορες προσφορές, αξιολογεί όλες τις προτάσεις, και λαμβάνει την τελική απόφαση. Για παράδειγμα, αν μια οικογένεια επιθυμεί να αγοράσει ένα αυτοκίνητο, πρέπει αρχικά να
Gold Answer	

Η αγοραστική δραστηριότητα μιας οικογένειας έχει ως εξής: διαπίστωση της ανάγκης, αναζήτηση των κατάλληλων πληροφοριών, έρευνα των διάφορων αγορών και τέλος σύγκριση των τιμών και γενικότερα των διάφορων προσφορών. Ως παράδειγμα οι μαθητές θα μπορούσαν να αναφέρουν την αγορά ενός αυτοκινήτου.	συλλέξει πληροφορίες για τους διάφορους τύπους και μάρκες αυτοκινήτων, να συγκρίνει τις τιμές των αυτοκινητοβιομηχανιών και, αφού τις αξιολογήσει, να αποφασίσει ποιο αυτοκίνητο θα αγοράσει τελικά. Επίσης, η οικογένεια έχει βασικές πηγές εισοδήματος (μισθό, ελευθέριο επάγγελμα) και καταρτίζει έναν οικογενειακό προϋπολογισμό για να διαχειριστεί τα έσοδά της και να αποφασίσει πώς θα ξοδέψει τα χρήματά της. Πηγές από την ύλη που χρησιμοποιήθηκαν: 21-0035-02_Oikiaki-Oikonomia_A-Gymnasiou_Vivlio-Mathiti.pdf | 2.2.3 — Οικογενειακός προϋπολογισμός 21-0035-02_Oikiaki-Oikonomia_A-Gymnasiou_Vivlio-Mathiti.pdf | 2.2.2 — Ο οικονομικός ρόλος της οικογένειας 21-0095-03_Oikiaki-Oikonomia_A-B-Gymnasiou_Vivlio-Mathiti.pdf | 4.4.6 — είναι «άπιαστα».

Figure 2: An example of Student mode S.T.A.R.T. BOT response – model gemma3:4b

In the Student Mode, the primary objective was to measure the accuracy of curriculum-grounded explanations.

- Execution: A set of 10 curriculum-based questions was presented to each of the three models.
- Evaluation: The generated answers were compared against "gold answers" extracted from the official teacher's guide.
- Metrics: Semantic similarity scores were calculated between the models' outputs and the reference answers to quantify factual and conceptual alignment.

Tutor Mode Experiments

In the Tutor Mode, the focus shifted to the assistant's ability to act as an instructional partner by generating complex pedagogical artifacts.

- Execution: Each model was requested to generate fully structured assessment tests.
- Scope: Two different chapters from the Home Economics curriculum were selected for test generation (e.g., "Family Budget" and "Modern Technology and Food").
- Evaluation Criteria: The generated tests were evaluated based on three key metrics: coverage rate of the instructional units, quality of question formulation for junior high school students, and overall relevance to the provided educational material

Question	Gemini Answer

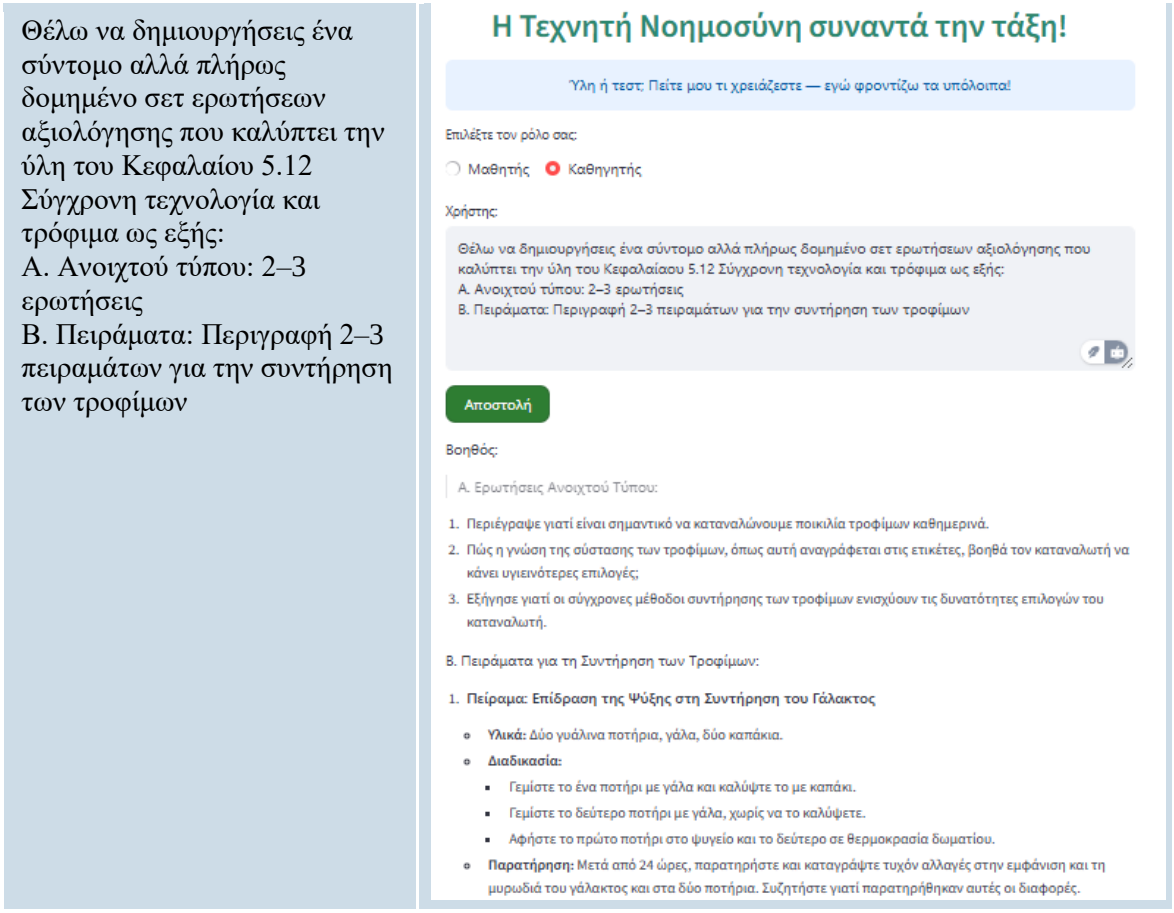


Figure 3: An example of Tutor mode S.T.A.R.T. BOT response – model gemini-1.5-flash-lite

5. Evaluation and Results

Student Mode

The evaluation in **Student Mode** centered on measuring the accuracy and semantic consistency of the generated responses relative to the official curriculum. The "**gold answers**" extracted from the official teacher's guide for the Home Economics course served as the ground truth for this assessment.

Semantic Similarity Analysis

Quantitative evaluation was conducted using Semantic Similarity metrics. The results were derived from a comparative study of 10 curriculum-based questions submitted to the three models: Gemini, DeepSeek, and the SLM Gemma.

Key Findings

- The small language model **Gemma** demonstrated significant competitiveness, achieving a mean score of **0.753**. This performance is remarkably close to the larger models, Gemini (0.773) and DeepSeek (0.764).
- In several instances, such as Q1 and Q3, Gemma outperformed the LLMs, reaching similarity scores as high as **0.914**. This highlights the efficacy of SLMs when supported by a well-structured RAG architecture.
- Qualitative analysis confirmed that the system maintained high fidelity to the official content. For example, when asked to describe a family's purchasing

activity, Gemma produced a comprehensive response covering all curriculum-specified stages—needs identification, information search, and price comparison—while providing precise citations to the source textbooks

Question	Gemini	DeepSeek	Gemma
1	0,741	0,776	**0,856**
2	**0,939**	0,928	0,875
3	0,811	0,815	**0,914**
4	0,586	0,574	**0,640**
5	0,650	**0,738**	0,588
6	**0,883**	0,756	0,698
7	0,886	0,872	**0,894**
8	**0,900**	0,865	0,822
9	0,755	**0,779**	0,679
10	**0,575**	0,537	0,561
Mean	**0,773**	**0,764**	**0,753**

Table 1. Student Mode - Semantic Similarity Results

Tutor Mode (LLM-as-a-Judge).

Evaluation Methodology

To ensure an objective and scalable assessment test generated in Tutor Mode, the study employed the **LLM-as-a-Judge** framework. The state-of-the-art model **GPT-5.1 pro** was utilized as an expert to evaluate the assessment tests produced by the three candidate models (Gemini, DeepSeek, and Gemma).

The evaluation process was structured around a specialized "**Evaluation Prompt**" that instructed the judge model to analyze the generated content based on three key dimensions:

1. **Coverage Rate:** Examination of the extent to which the generated test covers the core concepts of the specific instructional unit.
2. **Relevance to Material:** Evaluation of how closely the questions align with the provided RAG context from the Home Economics textbooks. Verification of the artifact's format, including the logical flow of questions and the inclusion of diverse assessment types (e.g., experiments, open-ended questions).
3. **Quality of question formulation** in relation to comprehension by a high school student.

Our study minimized human bias and provided a standardized comparison across different model architectures. The judge model provided both qualitative feedback and quantitative scoring, allowing for a rigorous analysis of how effectively each model can serve as an instructional partner for educators.

Performance Comparison and Model Reliability

A significant finding during the experimental phase was the complete failure of the DeepSeek model to generate any output for the requested assessment tests in either of the two selected chapters. This lack of responsiveness indicates a potential limitation in the model's reliability or its ability to handle complex, persona-driven instructions within the Greek educational context. Consequently, the comparative analysis focused on the performance of Gemini and the SLM Gemma.

TEST 1	Coverage rate	Quality of the formulation of the questions	Relevance to the educational material
Gemini	65 – 75 %	Οι ερωτήσεις είναι γενικά **καλογραμμένες, σαφείς και σε σωστό γλωσσικό επίπεδο** για Γυμνάσιο. Το μόνο πραγματικό παιδαγωγικό «γκρίζο» σημείο είναι η **Α3**, λόγω αδυναμίας σύνδεσης με το συγκεκριμένο απόσπασμα και υψηλότερου επιπέδου αφαίρεσης.	Η πλειονότητα των ερωτήσεων είναι σαφώς σχετική και «πατάει» πάνω στο κείμενο. Μικρή «διαρροή» σε άλλη υποενότητα (Γ4) και μία ερώτηση πιο γενική (Α3).
Gemma	60 – 70 %	Η γλωσσική ποιότητα είναι **καλή** και φιλική προς τον μαθητή. Γενικά καθαρή και κατάλληλη για μαθητές Γυμνασίου, με 2–3 σημεία που χρειάζονται καλύτερη σύνδεση με τη φρασεολογία του βιβλίου.	Οι περισσότερες ερωτήσεις είναι καλά ευθυγραμμισμένες, αλλά ορισμένες (κυρίως Α2 & Α4) πατούν πιο πολύ σε «λογική/εμπειρική» γνώση παρά σε ρητό κείμενο.

Table 2. Assessment Test 1: Family Budget

Assessment Test 1: Family Budget

In the first test, which covered the "Family Budget" unit, both active models demonstrated strong pedagogical alignment. Gemini achieved a coverage rate of 65% – 75%, producing clear and linguistically appropriate questions for the target age group. It showed superior overall coverage in sub-units related to budgeting, income, and planning. Gemma (SLM) followed closely with a 60% – 70% coverage rate, maintaining high linguistic quality and a student-friendly tone. Notably, Gemma excelled in generating items related to payment methods, though it occasionally relied on general logic rather than explicit textbook phrasing.

While the BookTest1 (derived directly from the textbook) remained the "gold standard" with 100% compatibility, Gemini was identified as the top-performing AI model for this specific unit due to its structured academic phrasing and minimal deviations from the curriculum.

TEST 2	Coverage rate	Quality of the formulation of the questions	Relevance to the educational material
Gemini	50 – 60 %	Γλωσσικά καθαρό και κατανοητό. Τα πειράματα είναι καλά ως μορφή, αλλά το 2ο δεν αναδεικνύει σωστά την αποστείρωση. Δύο ανοικτές ερωτήσεις (ποικιλία, ετικέτες)	Η πλειονότητα των ερωτήσεων είναι σαφώς σχετική και «πατάει» πάνω στο κείμενο. Μικρή «διαρροή» σε άλλη υποενότητα (Γ4) και μία ερώτηση πιο γενική (Α3).

		δεν «κουμπώνουν» με το συγκεκριμένο κείμενο.	
Gemma	60 – 70 %	Πολύ ικανοποιητική – γλώσσα απλή, σαφής, με ξεκάθαρο τι ζητείται και με καλή δομή στα πειράματα.	Καλή μόνο για μέρος του υλικού (σημασία συντήρησης, σύγχρονες μέθοδοι, δύο βασικές μέθοδοι ψύξης/ξήρανσης). Αδύναμη έως χαμηλή για αρκετά βασικά στοιχεία (ετικέτες, ειδικές μέθοδοι, μικροοργανισμοί/ ένζυμα, συντηρητικά, ζύμωση).

Table 3. Assessment Test 2: Modern Technology and Food

Assessment Test 2: Modern Technology and Food

The second test focused on more technical content regarding food preservation and technology. Gemma (SLM) emerged as the superior AI performer in this category, achieving a 60% – 70% coverage rate and receiving high praise for its simple, clear language and well-structured experimental descriptions. It provided an excellent pedagogical transcription of theory into practical experiments. Gemini showed a lower coverage rate of 50% – 60%. While its language was clear, the evaluator noted that its questions tended toward general nutritional advice rather than the specific technical details of the instructional unit, such as food labeling or specific preservation methods.

Summary of Findings: The results from the Tutor Mode highlight a nuanced trade-off between model architectures. While Gemini provided a more "academic" and strictly aligned structure for economic concepts, the SLM Gemma demonstrated superior pedagogical creativity, particularly in designing classroom experiments and maintaining a friendly tone for young learners. Crucially, the experiments confirm that Small Language Models can effectively serve as instructional assistants, often rivaling or exceeding the performance of larger models in specific creative teaching tasks.

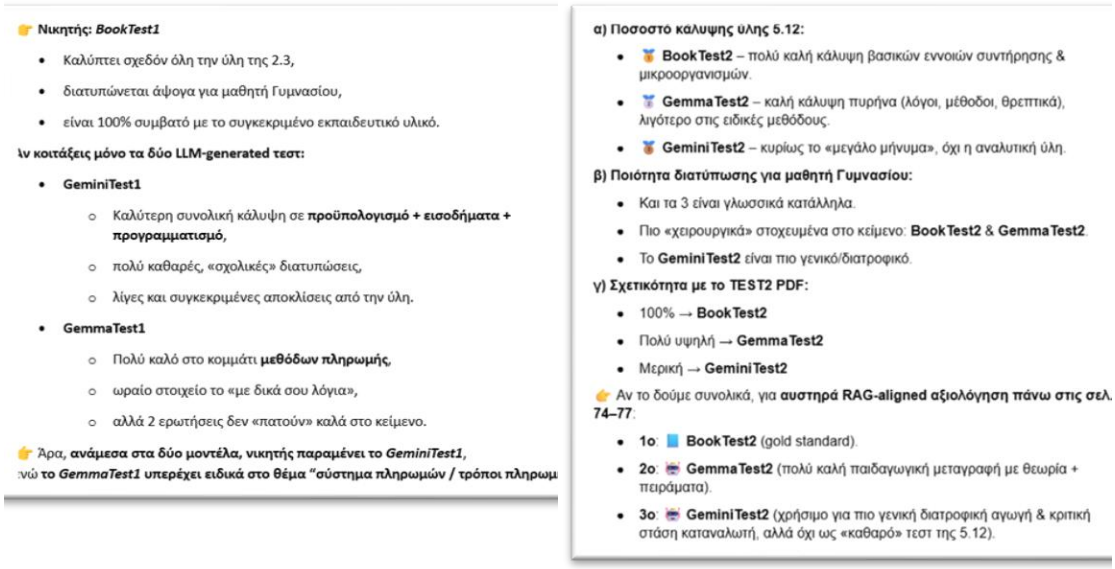


Figure 4: GhatGPT as a Judge - Summary of Findings

6. Conclusion

The development and evaluation of the S.T.A.R.T. BOT demonstrate that the integration of Generative AI within a structured Retrieval-Augmented Generation (RAG) framework can significantly enhance the educational process in the Greek secondary sector. The study successfully implemented a Pedagogical Persona Switching mechanism, proving that a single AI model can effectively transition between the roles of a learning guide for students and an instructional partner for teachers. Regarding the core research questions, the experimental results provide compelling evidence that Small Language Models, such as Gemma, can decisively compete with significantly larger models like Gemini and DeepSeek in specialized educational tasks. In both Student and Tutor modes, the SLM demonstrated high semantic alignment with the official curriculum, often matching or even exceeding the performance of LLMs in pedagogical creativity and linguistic clarity.

A primary conclusion of this research is the distinct suitability of SLMs for deployment within closed educational environments. Unlike LLMs, which typically require cloud-based processing and API calls to external servers, SLMs can be hosted on-premise or on local school infrastructure. This architectural advantage ensures that sensitive educational data and student interactions remain local, eliminating the risk of information leakage to the public internet and aligning with strict data privacy and GDPR requirements.

Furthermore, the study highlights the efficiency of SLMs in terms of reduced hardware requirements. While LLMs demand immense computational power and high-end GPU clusters, SLMs are designed to operate effectively with significantly fewer resources. This low computational footprint makes them a sustainable and cost-effective solution for large-scale integration into national education systems, where hardware budgets may be constrained.

In conclusion, the S.T.A.R.T. BOT framework establishes a reliable, secure, and pedagogically grounded foundation for the future of AI in education. By leveraging the power of SLMs and RAG, we can provide teachers and students with advanced digital assistants that are not only intelligent and curriculum-aligned but also private, localized, and technologically accessible.

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AI into Foreign Language Learning: Pathways to Innovation and the Challenge of Integrity

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract—Artificial intelligence (AI) is reshaping the landscape of foreign language education, offering new pathways for learner engagement, instructional innovation, and teacher development. This presentation synthesizes recent empirical and review studies on the integration of generative AI tools, particularly ChatGPT, into foreign language learning and teacher education. Findings demonstrate that AI-mediated instruction enhances language achievement, supports self-regulated learning, and fosters learner motivation through personalized feedback and authentic conversational practice. Systematic reviews further reveal that AI is increasingly embedded in teacher training programs, prompting both pedagogical opportunities and critical discussions around ethics, assessment, and professional preparedness. In addition, teaching on computer-assisted language learning (CALL) highlights AI's role in customizing instruction and expanding access to language resources. On the contrary, the systematic unwise exploitation of AI raising questions when it comes to ethics and the creation of a lazy generation. Recapitulating, these findings reveal that AI has significant promise in store for advancing foreign language learning and teaching, though challenges remain in ensuring equitable access, maintaining academic integrity, and preparing educators to critically integrate AI into their syllabus. This synthesis contributes to emerging debates about the future of language education in an era of smart technology.

Keywords: foreign language teaching, AI, language learning

1. Introduction

The landscape of foreign language education is undergoing a seismic shift. As noted in the opening of this study, Artificial Intelligence (AI) is no longer a peripheral technological luxury but a core transformative force reshaping learner engagement and teacher development. In 2026, the integration of generative AI tools, most notably Large Language Models (LLMs) such as ChatGPT, has transitioned from experimental curiosity to a foundational element of the curriculum.

The primary objective of this article is to synthesize recent empirical data and review studies to demonstrate how AI-mediated instruction enhances language achievement. However, as the abstract highlights, this technological advancement is a double-edged sword. While it supports self-regulated learning (SRL) and offers personalized feedback, it also necessitates a rigorous discussion regarding "unwise exploitation" and the potential emergence of a "lazy generation." This paper argues that the future of Foreign Language Teaching (FLT) depends on a critical synthesis of smart technology and human pedagogical oversight.

2. Theoretical Framework: From CALL to Intelligent CALL (ICALL)

The evolution of Computer-Assisted Language Learning (CALL) has been documented extensively, but the leap from traditional software to AI represents a paradigm shift. According to Levy (1997), CALL was initially limited to deterministic programs. Today, we operate in the era of Intelligent CALL (ICALL), where AI systems utilize Natural Language Processing (NLP) to provide a non-linear learning experience.

As Chun (2016) emphasizes, the hallmark of modern language learning is AI as “the meditator." Unlike older programs that offered binary (right/wrong) feedback, generative AI can understand the intent behind a student's error. This aligns with Long’s Interaction Hypothesis (1996), which suggests that language acquisition is most effective when learners must modify their output to be understood. AI tutors act as tireless interlocutors, forcing learners to clarify their thoughts and refine their linguistic structures in real-time.

3. Enhancing Language Achievement through AI

Recent empirical studies demonstrate that AI-mediated instruction significantly boosts language achievement across all four skills (Reading, Writing, Listening, Speaking). According to Zhai et all, “the AI technique was utilized as a development tool for the construction of a smart learning environment, which can be subclassified as focusing on the development of algorithms including classification, matching, recommendation, and deep learning for teaching and learning purposes”.

3.1 Personalized Feedback and Scaffolding

One of the most critical findings in recent literature is the role of AI in providing instantaneous, formative feedback. In a traditional classroom, a teacher cannot provide immediate correction to 25 different essays simultaneously. AI bridges this gap. Research by Zhai et al. (2021) underscores that AI’s ability to analyze specific syntax errors and suggest corrections aligns with the principles of the Zone of Proximal

Development (Vygotsky). By receiving feedback tailored to their current proficiency, learners internalize rules more effectively.

3.2 Authentic Conversational Practice and Motivation

Language learning thrives on interaction, yet many students suffer from Foreign Language Anxiety (FLA). Dörnyei and Ryan (2015) argue that motivation is the primary engine of acquisition. AI tools, such as voice-activated LLMs, provide a "safe space." Learners can practice ordering food in a virtual café or conducting a business meeting in their target language without fear of embarrassment. This "low-stakes" environment fosters learner motivation and encourages the "willingness to communicate" (WTC).

4. AI in Teacher Education and Professional Development

The abstract of this study identifies AI's role in "instructional innovation and teacher development." By 2026, teacher training programs have shifted from teaching with technology to teaching about technology

4.1 Pedagogical Opportunities

Teachers are leveraging AI to generate levelled content. For example, a single news article can be adapted into three different versions for A2, B2, and C1 levels within seconds. This allows for differentiated instruction, ensuring that no student is left behind. UNESCO (2023) notes that AI literacy is now a core competence for educators, requiring them to understand "prompt engineering" to create high-quality rubrics and lesson plans.

4.2 Professional Preparedness

The integration of AI into teacher education also prompts critical discussions about the role of the educator. The teacher is no longer the sole "source of knowledge" but a facilitator of learning. Programs now emphasize how to integrate AI into the syllabus while maintaining academic rigor and ensuring that technology serves pedagogical goals rather than replacing them.

5. The Ethical Paradox: "Unwise Exploitation" and the "Lazy Generation"

Perhaps the most significant contribution of this synthesis is the warning against the "systematic unwise exploitation of AI."

5.1 Cognitive Laziness and Prosthetic Knowledge

There is an emerging concern that over-reliance on AI leads to "cognitive laziness." If a student uses AI to write an essay from scratch, the deep processing required for language acquisition is bypassed. Hockly (2023) warns of the "black box" effect, where learners produce perfect output without internalizing the grammar or vocabulary used. This creates what some researchers call "Prosthetic Knowledge"—knowledge that exists in the tool but not in the mind of the user.

5.2 Cultural Competence and Pragmatics

While AI is proficient in syntax, it often struggles with the "pragmatics" of language—the subtle cultural nuances that define human interaction. Stockwell (2022) points out that AI models are often trained on datasets that favor Western perspectives, potentially leading to a "cultural homogenization" of language. Learners must be taught to critically evaluate AI output for cultural and contextual accuracy.

6. Equitable Access and the Digital Divide

The promise of AI to democratize education is contingent upon equitable access. As the UNESCO (2023) report highlights, the "Digital Divide" remains a significant barrier. Students in remote or underprivileged areas may lack the hardware or high-speed internet required to access premium AI tools. Ensuring that AI serves as a tool for equality rather than a catalyst for further disparity is a central challenge for policymakers in 2026.

7. Conclusion and Future Directions

Recapitulating the findings, AI holds significant promise for the future of foreign language education. It democratizes access to personalized tutoring and provides immersive environments that were once impossible. However, the path forward requires a balanced approach. As proposed in this synthesis, we must ensure academic integrity and prepare educators to critically integrate AI into their syllabus.

The goal for the coming years is to develop a "Critical AI Literacy" among both students and teachers. Technology should enhance human potential, not diminish the cognitive effort essential for true linguistic mastery. By fostering a "wise exploitation" of these tools, the language classroom of 2026 can become a space where innovation and human intellect coexist harmoniously.

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Leveraging an AI-Based Digital Assistant: A Pilot Implementation in Early Childhood Communities of Learning and Practice within the Directorate of Primary Education of the Third District of Athens

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract —This paper presents the results of a pilot intervention implemented in early childhood education of the Directorate of Primary Education of Athens during the academic years 2023–2024 and 2024–2025. The aim of the study was to investigate how the use of digital assistants can support inclusive and personalized learning in early childhood education. The conception of the intervention was also informed by the researcher's experience through participation in an official European Commission initiative focusing on the systematic integration of innovative digital tools into educational practice. This experience contributed to the design of an intervention that combined pedagogical principles, digital practices, and the everyday needs of kindergarten teachers.

A mixed-methods research approach was employed to evaluate the intervention, incorporating both quantitative and qualitative data. In the initial phase, online informational and training sessions were conducted in order to familiarize kindergarten teachers with the functionalities of the digital tools and their pedagogical potential. Subsequently, the tools were organically integrated into the daily classroom routine, mainly in activities related to the organization of the school day, transitions between activities, and the enhancement of participation for all children, particularly those requiring additional support to meet the demands of the school environment.

The implementation was accompanied by continuous feedback, addressing both practical issues and teachers' reflective engagement with the use of digital assistants. Quantitative data were collected through a questionnaire administered after the completion of the intervention, focusing on perceived usefulness, ease of use, pedagogical value, and the extent to which the tools supported classroom organization. Qualitative data were derived from teachers' reflective records and open-ended questionnaire responses.

The analysis of the data provided insight into how teachers experienced the process and the changes they observed in children's participation and attitudes. The findings indicated that kindergarten teachers responded positively to the implementation of digital assistants, perceiving them as significantly contributing to more effective classroom organization and the management of daily routines. At the same time, teachers reported that children responded with enthusiasm, while the visual support and clear structuring of activities were particularly beneficial for students who require stable and predictable learning environments.

Overall, the study highlights that the use of digital assistants in early childhood education can function as a supportive mechanism for promoting inclusion and personalized learning, especially when accompanied by appropriate professional development and systematic support. The findings are aligned with the broader directions of the European Commission regarding the digital transformation of education and underscore the need for further research with larger samples and across diverse educational contexts.

A concise and factual abstract is required (maximum length of 500 words). The abstract should state briefly the purpose of the research, the principal results and major conclusions. References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Keywords— inclusive education, personalized learning, digital assistants, early childhood education

Introduction

The integration of Artificial Intelligence (AI) into education constitutes a key dimension of contemporary digital transformation, with a growing emphasis on differentiation, personalization, and inclusive learning. At the European level, policy frameworks developed by the European Commission highlight the importance of pedagogically grounded digital innovation, with a strong focus on inclusive education, teacher professional development, and the responsible use of emerging technologies (European Commission, 2021).

Early childhood education represents a critical stage in children's educational trajectories, as foundational cognitive, social, and emotional skills are developed during this period. Research consistently demonstrates that the quality of early learning environments is closely linked to later school adjustment and engagement (Shonkoff & Phillips, 2000). In particular, the organization of daily routines and transitions between activities plays a central role in shaping children's participation, emotional regulation, and sense of security, especially for those who require stable and predictable learning contexts (Dettmer et al., 2000).

From an inclusive education perspective, meaningful participation is achieved not merely through children's physical presence in mainstream settings, but through pedagogical practices that are responsive to diverse needs and that foster engagement and belonging (Ainscow, 2020; Florian, 2014). Tools that support visual structure, clarity, and organization of learning experiences may therefore contribute substantially to inclusive practices in early childhood classrooms.

Within this context, AI-based digital assistants have emerged as tools of particular pedagogical relevance. Unlike more complex AI systems that primarily target academic performance, digital assistants can be embedded in everyday classroom practices, supporting the organization of the school day, transitions between activities, differentiated support, and participation for all children (Hwang et al., 2020; Pedró et al., 2019). Despite their potential, empirical research on the systematic use of digital assistants in early childhood education remains limited, particularly in authentic classroom settings.

The purpose of the present study is to investigate how the pilot use of digital assistants can support inclusive and personalized learning in early childhood education. The study draws on a pilot intervention implemented in kindergartens schools of the Directorate of Primary Education of Athens during the academic years 2023–2024 and 2024–2025 and adopts a mixed-methods research design. It focuses on the integration of digital assistants into the daily classroom routine, with particular attention to classroom organization, transitions between activities, and the enhancement of participation for all children.

Methodology

The digital tool: My First Calendar

The digital tool My First Calendar is a visual calendar application and daily organizer designed specifically for children in early childhood and early primary education. It

was developed by the Finnish company MiTale, which specializes in serious games and educational applications with a strong focus on interactive storytelling and pedagogically grounded digital experiences. The application was designed in collaboration with Finnish speech therapists, with the initial aim of supporting language development, storytelling, and children's understanding of daily routines.

From a pedagogical perspective, My First Calendar aligns with research emphasizing the importance of structure, predictability, and visual support in early childhood learning environments, particularly within inclusive education contexts (Ainscow, 2020; Florian, 2014). The application makes use of visual symbols, a simple interface, and structured entries that enable children to comprehend the flow of the day and actively participate in planning and reviewing activities. Such features are consistent with findings suggesting that digital tools can support personalization and participation when meaningfully embedded in classroom practice (Hwang et al., 2020).

For teachers, My First Calendar functions as a flexible pedagogical tool that can be integrated into everyday classroom routines. It supports calendar entries using text, images, or voice recordings, allowing teachers and children to organize activities, tasks, and events in a visually clear and developmentally appropriate manner. The ability to store and revisit entries supports consistency and predictability in learning experiences, elements that are particularly important in early childhood and inclusive educational settings.

The application supports more than 20 languages, including Greek, making it suitable for multilingual and multicultural educational contexts. It is freely available via Google Play and the App Store, while additional features—such as photo and drawing tools, calendar synchronization, and PIN protection—can be unlocked through educational access codes. This ensures that children are not exposed to in-app purchases and allows schools to use the full functionality of the tool in a safe educational environment.

The pilot implementation of the tool took place within the testing phase of the European Digital Education Hub – Accelerator, an initiative of the European Commission aimed at supporting the evaluation and improvement of educational digital solutions in authentic European educational settings. Participation in this framework enabled the systematic collection of feedback from teachers and students, focusing on both usability and pedagogical value.

Pilot implementation in educational practice

The pilot implementation of the digital assistant was carried out in kindergarten schools of the Directorate of Primary Education of Athens during the academic years 2023–2024 and 2024–2025. The intervention was designed to support the organic integration of the digital tool into everyday educational practice, rather than its use as an isolated or supplementary digital activity.

During the initial phase of the intervention, online informational and training sessions were conducted for kindergarten teachers. These sessions focused on the core functionalities of My First Calendar, its pedagogical potential, and examples of its use in early childhood classrooms. Particular emphasis was placed on connecting the tool

to daily classroom routines and to the needs of children who benefit from clear structure and predictability.

Subsequently, teachers integrated the digital assistant into the daily classroom flow, primarily in activities related to the organization of the school day, transitions between activities, and the enhancement of participation for all children, particularly those requiring additional support to meet classroom demands. The use of My First Calendar took place both at a whole-group level (e.g., collective review of the daily schedule) and within specific activities, depending on classroom needs.

The implementation was accompanied by ongoing feedback and support, enabling teachers to reflect on their use of the digital assistant and to adapt their pedagogical practices accordingly.

Data collection and analysis

Data were collected using a mixed-methods approach, combining quantitative and qualitative sources in order to capture both teachers' overall perceptions and their reflective experiences during the pilot implementation.

Quantitative data were gathered through a structured questionnaire completed by participating kindergarten teachers after the completion of the pilot intervention. The questionnaire included closed-ended items focusing on perceived usefulness, ease of use, pedagogical value, and the extent to which the digital assistant supported classroom organization and daily routines. Responses were recorded using Likert-type scales and were analyzed using descriptive statistics. Given the pilot nature of the study, the analysis focused on identifying descriptive trends rather than conducting inferential statistical testing.

Qualitative data were derived from open-ended questionnaire items and written reflective comments provided by the teachers. These data offered insights into teachers' experiences with the digital assistant, their observations regarding children's engagement, and perceived changes in classroom routines and participation. Qualitative data were analyzed through thematic analysis, allowing for the identification of recurring patterns related to classroom organization, transitions, and inclusive participation.

The integration of quantitative and qualitative findings enabled a more comprehensive understanding of the pilot implementation and supported the interpretation of results in relation to the aims of the study. The structure of the questionnaire and the main evaluation domains are summarized in Figure 1.

Domain	Focus
Usability	Ease of use, clarity
Pedagogical value	Support for learning
Classroom routines	Organization & transitions

Children's engagement	Participation & response
Feedback	Suggestions for improvement

Figure 1. Structure of the study / Questionnaire domains

Results / Findings

The results of the study provide insight into how kindergarten teachers experienced the pilot implementation of *My First Calendar* and how they perceived its contribution to classroom organization and children's participation. Given the pilot nature of the study, findings are presented in a descriptive manner, combining quantitative indicators from the questionnaire with qualitative evidence drawn from open-ended responses and reflective teacher accounts.
Overall, teachers reported a positive evaluation of the digital assistant, particularly in relation to its perceived usefulness and ease of use. Responses to the questionnaire indicated that the application was considered intuitive and accessible, allowing teachers to integrate it into daily classroom routines without the need for extensive technical support. The visual structure of the tool and the clear representation of daily activities were consistently identified as key strengths.

In terms of classroom organization, teachers reported that the use of *My First Calendar* supported the structuring of the school day and facilitated smoother transitions between activities. The visual overview of upcoming activities helped children anticipate changes during the day, contributing to reduced uncertainty and improved classroom flow. This aspect was described as especially beneficial for children who require stable and predictable learning environments.

Qualitative findings further revealed that children responded with enthusiasm to the use of the digital assistant. Teachers observed increased engagement during the collective review of the daily schedule and noted that children were more willing to participate in discussions about upcoming activities. The use of icons and visual symbols appeared to support shared understanding within the group and enhance children's sense of participation.

Regarding pedagogical value, teachers emphasized that the digital assistant functioned primarily as a supportive organizational tool rather than as a standalone instructional application. Its contribution was most evident in supporting daily routines, facilitating transitions, and reinforcing inclusive practices by enabling all children to follow the structure of the day.

At the same time, teachers identified certain limitations and areas for improvement, including the need for greater flexibility in activity categories and practical constraints related to device use, such as screen size when the tool was used in whole-group settings.
The relationship between the core features of *My First Calendar* and their pedagogical functions, as reflected in the findings, is summarized in Figure 2.

Core feature of *My First Calendar*	**Pedagogical function in kindergarten practice**

Visual daily schedule	Supports predictability and understanding of the daily routine
Clear representation of activities	Facilitates smoother transitions between activities
Use of icons and visual symbols	Enhances comprehension and inclusion for all children
Shared review of the daily plan	Promotes participation and collective engagement
Teacher-mediated use of the tool	Supports personalization and adaptation to classroom needs

Figure 2. Mapping My First Calendar features to pedagogical functions

Discussion and Conclusions

The present study sought to investigate how the pilot use of a digital assistant could support inclusive and personalized learning in kindergarten settings. The findings indicate that the integration of *My First Calendar* into everyday classroom practice was perceived positively by participating kindergarten teachers and contributed primarily to the organization of classroom routines, smoother transitions, and enhanced participation of children.

A key finding of the study concerns the role of structure and predictability in early childhood learning environments. Teachers emphasized that the visual representation of the daily schedule supported children's understanding of the flow of the day and reduced uncertainty during transitions. This finding aligns with research highlighting the importance of stable routines and clear expectations for young children's emotional security and self-regulation (McClelland & Cameron, 2019; Rimm-Kaufman & Sandilos, 2015). In this sense, the digital assistant functioned as a supportive organizational scaffold rather than as a content-delivery tool.

The enthusiastic response of children, as reported by teachers, further underscores the value of visual and participatory digital tools in early childhood education. The use of symbols, shared review of activities, and collective discussion around the daily plan appeared to foster engagement and a sense of participation within the group. Similar findings have been reported in studies emphasizing that well-designed digital tools can support children's meaning-making and participation when embedded in socially mediated learning contexts (Fleer, 2018; Plowman & McPake, 2013).

Importantly, the findings highlight the central role of teacher mediation in the effective use of digital assistants in kindergarten classrooms. Teachers did not perceive *My First Calendar* as a replacement for pedagogical interaction, but rather as a tool that supported their instructional decisions and classroom management strategies. This resonates with research stressing that young children's engagement with digital technologies is shaped primarily through guided, intentional, and pedagogically informed use by educators (Edwards, 2016; Kervin et al., 2019). In the present study, teachers remained actively involved in introducing, contextualizing, and adapting the tool to the needs of their classroom communities.

From an inclusion perspective, the study suggests that digital assistants that emphasize clarity, visual support, and flexible use may contribute to reducing barriers to participation for children who benefit from predictable learning environments. Although the study did not explicitly adopt a Universal Design for Learning framework, the reported practices reflect principles associated with inclusive design, such as multiple means of representation and flexible engagement (Al-Azawei et al., 2016). This finding is particularly relevant in diverse kindergarten settings, where differences in developmental pace, language background, and self-regulation skills are common.

The importance of professional development and ongoing support also emerged as a critical factor in the successful implementation of the digital assistant. The initial training sessions and continuous feedback opportunities enabled teachers to integrate the tool meaningfully into their daily routines. This observation aligns with broader discussions on the responsible integration of digital technologies in education, which emphasize the need for teacher empowerment and pedagogically grounded innovation (UNESCO, 2022).

Several limitations of the study should be acknowledged. The pilot nature of the intervention and the limited sample size restrict the generalizability of the findings. In addition, the results are based on teachers' perceptions and reflective accounts rather than direct measures of children's learning outcomes. Nevertheless, the mixed-methods approach provided rich insights into authentic classroom practices and highlighted promising directions for further exploration.

In conclusion, the study demonstrates that the pilot use of a digital assistant such as *My First Calendar* can support inclusive and personalized learning in early childhood education when it is thoughtfully integrated into daily classroom routines and mediated by teachers. The findings contribute to ongoing discussions on the pedagogical role of digital assistants in kindergarten settings and align with wider international calls for the development of supportive, inclusive, and human-centered digital learning environments. Future research could extend this work by involving larger samples, diverse educational contexts, and longitudinal designs to further examine the impact of digital assistants on children's participation and learning trajectories.

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Case Adaptive e-Learning Systems for Sustainable Healthcare: Personalized Green Lean Six Sigma Training for Hospital Staff

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Abstract —This paper proposes a conceptual framework for designing adaptive e-learning systems that support hospital personnel in developing competencies in Green Lean Six Sigma (GLSS). GLSS is an integrated methodology that combines Lean process optimization, Six Sigma quality improvement, and environmentally sustainable operational practices. As hospitals confront the growing need to enhance clinical efficiency while reducing their ecological footprint, they require training approaches capable of equipping diverse professional groups with the skills needed to address these dual priorities. The aim of this study is to demonstrate how artificial intelligence (AI)–enabled educational technologies can personalize GLSS learning pathways, strengthen learner engagement, and increase the transfer of knowledge and skills to everyday clinical contexts.

The framework is structured around three main components. The first component involves detailed learner profiling and an initial diagnostic assessment to establish baseline knowledge, identify role-specific requirements, and capture individual learning preferences. The second component uses real-time learning analytics to dynamically adapt instructional materials by adjusting difficulty levels, modifying activity sequences, and calibrating the level of scaffolding in response to learner performance and progression. The third component integrates AI-driven assistants built on retrieval-augmented generation (RAG), which deliver tailored feedback, case-based explanations, error analyses, and contextually grounded examples drawn from actual hospital workflows. Through these mechanisms, the system aims to promote core GLSS capabilities, including waste recognition, root-cause analysis, process redesign, and environmentally responsible decision-making.

The instructional design includes micro-learning modules, interactive clinical scenarios, simulation-based exercises, and applied activities using anonymized hospital datasets. These elements are intended to help learners connect GLSS principles with everyday responsibilities, such as reducing unnecessary consumption of materials, improving patient flow, and supporting sustainable resource use. Ethical considerations are embedded throughout the system's architecture, particularly in relation to data transparency, responsible AI use, and strategies to minimize algorithmic bias in adaptive personalization.

Expected outcomes of the proposed approach include increased learner motivation, measurable gains in GLSS-related knowledge, and observable improvements in sustainability practices across clinical departments. By tailoring content to learners' roles and progress, the system has the potential to shorten training time while enhancing relevance and practical applicability for various healthcare professionals. The evaluation plan incorporates pre- and post-training assessments, detailed analytics on learner interactions, and operational metrics such as waste reduction indicators and measures of environmental impact.

Overall, this abstract outlines how adaptive e-learning technologies-when integrated with GLSS principles-can support the transition toward more sustainable healthcare systems. The combination of adaptive instructional design, AI-based personalization, and data-driven feedback represents a coherent model for preparing healthcare staff to address environmental challenges while improving operational performance. Future research will focus on developing a working prototype, assessing its educational effectiveness, and examining its influence on sustainability outcomes in real clinical environments.

Keywords: Adaptive e-Learning, Green Lean Six Sigma, Sustainable Healthcare, Learning Analytics, Artificial Intelligence in Education

Introduction

Healthcare institutions worldwide are under growing pressure to enhance clinical efficiency while simultaneously reducing their environmental footprint. Achieving these dual objectives demands a workforce equipped with the knowledge and skills to streamline processes, improve quality, and adopt sustainable operational practices. Green Lean Six Sigma (GLSS) provides an integrated methodology that combines Lean process optimization, Six Sigma quality improvement, and environmentally responsible strategies. However, traditional GLSS training often struggles to address the diverse professional backgrounds, learning needs, and contextual challenges found within hospital environments.

This study aims to design a conceptual framework for an adaptive e-learning system that leverages artificial intelligence (AI) to support hospital personnel in developing GLSS-related competencies. By incorporating adaptive instructional design principles and AI-driven personalization, the proposed framework seeks to tailor learning experiences to individual roles and performance levels. Through the use of real-time learning analytics, diagnostic assessments, and intelligent tutoring components, the system aspires to promote efficient knowledge acquisition, sustained engagement, and practical skill transfer in real clinical contexts. This approach aligns with the broader objective of fostering a culture of sustainable healthcare operations and continuous quality improvement.

1. The Role of Sustainable Improvement in Healthcare

Modern healthcare systems face a dual challenge: maintaining high standards of quality and efficiency while simultaneously minimizing environmental impact. Hospitals consume significant quantities of energy, water, and disposable materials, producing large volumes of waste-from biomedical residues to plastics and paper. As sustainability becomes an imperative rather than a choice, the health sector must integrate environmental responsibility into every aspect of operations.

The Green Lean Six Sigma (GLSS) methodology offers a comprehensive approach to this problem by combining three distinct yet complementary principles: Lean Thinking, which focuses on eliminating waste and maximizing patient value; Six Sigma, which reduces variation and errors; and Green Management, which ensures the environmental sustainability of processes. Together, they form a robust framework for continuous improvement.

However, effective implementation of GLSS in hospitals is hindered by the heterogeneity of staff roles and learning needs. Doctors, nurses, technicians, and administrative personnel differ widely in background and daily responsibilities. A one-size-fits-all training approach is therefore inadequate. This is where adaptive e-learning systems, powered by artificial intelligence (AI), offer transformative potential. They enable personalized learning pathways that adapt to the learner's role, prior knowledge, and learning pace, making the process both efficient and engaging.

2. Conceptual Framework: The Three Pillars of Adaptive GLSS Education

The proposed framework is organized around three interconnected pillars that ensure training is individualized, progressive, and directly applicable to clinical contexts.

Pillar 1: Learner Profiling and Initial Diagnostic Assessment

Before training begins, the system conducts a diagnostic evaluation to identify baseline knowledge of Lean, Six Sigma, and environmental management principles. It also maps the learner's professional role and specific learning preferences-whether visual, auditory, or kinesthetic.

For example, a laboratory technician receives modules emphasizing proper equipment maintenance (Lean) and reduction of reagent consumption (Green). A nurse focuses on process efficiency in patient care, while a procurement officer learns sustainable sourcing and waste minimization strategies. These contextual adjustments ensure relevance and immediate applicability.

By collecting these individualized data points, the system creates a comprehensive learner profile, forming the basis for personalized content delivery and adaptive progression.

Pillar 2: Dynamic Adaptation through Learning Analytics

The second pillar introduces real-time Learning Analytics (LA) to enable dynamic content adaptation. Unlike static e-learning systems, this model continuously monitors learner behavior, progression speed, and error patterns.

If a user struggles with root-cause analysis tools from Six Sigma, the system automatically provides additional exercises and simplified visualizations. Conversely, learners who excel are directed to advanced simulations. The order of modules may also change according to individual interest-for instance, prioritizing "Green" content for those more engaged in sustainability.

This iterative adaptation transforms the learning process into a feedback-rich ecosystem that nurtures both competence and confidence, reinforcing engagement and retention.

Pillar 3: AI-Enhanced Feedback Using Retrieval-Augmented Generation (RAG)

The third pillar integrates Retrieval-Augmented Generation (RAG) technology, which combines generative AI with access to domain-specific hospital data. This allows the system to provide contextualized feedback grounded in real operational examples.

When a learner misidentifies a source of waste in a simulated clinical process, the AI retrieves a relevant real-world case, such as excessive waiting times in hematology departments, and challenges the learner to propose an improvement. Similarly, in quality control scenarios, the AI not only points out mistakes but explains their systemic impact-on safety, efficiency, and environmental cost.

Through these adaptive interactions, RAG-driven feedback fosters experiential learning, enhancing the transfer of knowledge to practical settings. It also cultivates

higher-order thinking skills by linking abstract GLSS concepts with tangible, data-driven hospital realities.

3. From Theory to Practice: Applied Learning Scenarios

The system operationalizes GLSS principles through micro-learning modules and simulation-based activities.

Lean Module: Learners participate in a "Visual Waste Hunt," identifying inefficiencies in virtual hospital scenes-such as unnecessary patient movement, redundant supply transfers, or idle waiting areas. AI feedback explains how each correction reduces time and energy waste.

Six Sigma Module: A medication management simulation trains learners to detect potential errors in pharmaceutical workflows, apply Pareto analysis, and use fishbone diagrams for root-cause identification.

Green Module: Exercises involve comparing disposable versus reusable materials, calculating environmental cost savings, and evaluating CO_2 reductions achieved through digital or electric transport transitions.

These activities not only reinforce conceptual understanding but also simulate authentic clinical decision-making, ensuring that learning outcomes directly translate into operational improvements.

4. Ethical and Technical Considerations

Developing such an adaptive system requires strict adherence to ethical principles of data governance. Transparency in data collection is paramount: learners must know what information is gathered, how it is used, and for what purpose.

Furthermore, the system must actively mitigate algorithmic bias, ensuring equitable learning opportunities for all staff regardless of role, seniority, or digital literacy. Anonymization of hospital data is also essential when using real-world examples, maintaining compliance with privacy and confidentiality standards.

These ethical safeguards embody the principle of "Ethics by Design", embedding fairness and trustworthiness into the very architecture of AI-driven education.

5. Evaluation and Expected Benefits

To assess effectiveness, several performance indicators are proposed:
Motivation and engagement levels (e.g., completion rates, time on task).
Knowledge and skill gains, measured through pre- and post-assessments.

Operational impact, such as reduced material waste, shorter patient throughput times, and improved recycling rates.

Expected outcomes include enhanced learner motivation, measurable improvement in GLSS-related competencies, and tangible sustainability gains within hospital

departments. By tailoring training to individual roles, the system can shorten learning time while improving practical relevance and adoption.

Ultimately, this adaptive GLSS e-learning framework positions hospitals as learning organizations-entities capable of self-improvement through data-driven insight, continuous education, and ethical AI application.

Conclusion

The proposed adaptive e-learning framework provides a structured approach to integrating GLSS principles into hospital training through AI-enabled personalization and data-driven feedback mechanisms. By aligning instructional content with learners' roles, performance, and progression, the framework has the potential to enhance motivation, shorten training time, and improve both knowledge retention and the application of sustainability practices in clinical settings.

Expected outcomes include measurable gains in GLSS-related competencies, improved resource utilization, and reductions in environmental impact across hospital departments. Beyond immediate training benefits, the framework contributes to the strategic transformation of healthcare organizations toward more sustainable, efficient, and data-informed operations.

Nonetheless, several limitations remain. The framework's effectiveness depends on the availability of high-quality learning analytics data, robust AI models capable of minimizing bias, and strong institutional support for digital learning integration. Future research will focus on developing and testing a prototype system, evaluating its educational impact, and assessing its influence on operational sustainability outcomes in real-world clinical environments.

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Evaluating Gamma App as an AI-Powered Authoring Tool for Educational Content Creation

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Abstract —This study investigates teachers' acceptance and post-training use of Gamma App—an AI-powered platform for educational content creation—among secondary education teachers who attended a related professional development seminar. A total of 18 teachers from various subject areas participated, evaluating both the training and the tool's educational value, while key constructs grounded in the Technology Acceptance Model (TAM) were also measured. Results indicate that most participants perceived the seminar as clear and satisfactory, although some rated the duration and/or post-training support as only moderate. Following the seminar, approximately 38.9% of participants (7 out of 18) reported using Gamma App in their teaching practice, primarily for creating lesson presentations, on a weekly or monthly basis. These users reported high perceived usefulness and perceived ease of use (mean scores 4.33/5 and 4.55/5, respectively), along with positive satisfaction and a strong intention to continue using the tool. Internal consistency for the perceived usefulness and perceived ease-of-use scales was high (Cronbach's $\alpha > .90$), indicating reliable measurement.

In contrast, 11 teachers did not use Gamma App after the seminar. The most prominent barrier was lack of time, followed by technical constraints and infrastructure limitations. Perceived lack of support, ethical concerns, and perceived relevance to the subject area were rated as less influential barriers. Moreover, most participants expressed interest in further professional development on AI tools, suggesting a willingness to pursue ongoing growth in digital competencies.

Overall, Gamma App was evaluated positively by teachers who actively tried it; however, time availability, sustained support, and enabling conditions appear necessary to facilitate broader adoption in everyday educational practice.

Keywords— AI authoring tools, Technology Acceptance Model (TAM), perceived usefulness, perceived ease of use, teacher professional development

Introduction

The rapid development of Artificial Intelligence (AI) in recent years has begun to transform the educational landscape, offering new tools for content creation, learning personalization, and instructional support. In particular, AI-powered educational authoring applications such as Gamma App enable teachers to quickly produce interactive presentations, lesson plans, and other instructional materials tailored to learners' needs. The integration of such tools into teaching practice has the potential to enhance both instructional effectiveness and personalization. At the same time, important challenges and open questions emerge regarding teachers' acceptance of these tools, the factors shaping their intention to use them, and the barriers that may hinder their adoption.

Teachers' acceptance of technology is a critical condition for the successful implementation of any educational innovation in classroom settings. Even highly promising technologies may fail to be integrated if teachers do not adopt them in practice. Consequently, research attention has increasingly focused on the determinants of teachers' intentions and behaviors regarding the adoption of AI tools in education. Recent studies suggest that, although teachers acknowledge the potential value of AI technologies (including tools based on large language models) for teaching and learning, a considerable proportion still refrains from using them, citing factors such as insufficient support, limited time, and unclear guidance from institutional stakeholders. In parallel, concerns have been raised regarding ethical risks and teachers' readiness to incorporate such technologies. Frequently reported barriers include the reliability of AI-generated content, algorithmic bias, and the adequacy of teacher professional development.

Within this context, the present study focuses on evaluating Gamma App as an AI-based tool for educational content creation, primarily through quantitative indicators of acceptance (perceived usefulness, perceived ease of use, satisfaction, and continuance intention). Gamma App was introduced to a group of teachers through a targeted professional development seminar at the Laboratory Center of Lagadas, after which the study examined whether participants used the tool in their teaching practice and how they perceived it. Although small-scale and essentially pilot in nature, the study provides initial evidence regarding teachers' attitudes toward AI-driven content authoring tools. The findings contribute to a better understanding of the factors that may encourage or discourage the adoption of Gamma App—and similar tools—offering useful implications for the effective integration of AI into educational practice.

Finally, evaluating the effectiveness of professional development interventions and user experience in digital platforms constitutes a key dimension for the sustainable adoption of educational technologies by teachers. In comparable teacher professional development contexts (e.g., LMS-focused training), user experience and perceived usefulness following the intervention have been linked to teachers' willingness to implement the platform in practice (Papantoni, Pierrakeas, & Dragogiannis, 2019).

Theoretical Framework

The theoretical framework of this study is primarily grounded in the Technology Acceptance Model (TAM), which has been established as one of the most widely used approaches for interpreting users' acceptance of technological innovations in educational contexts. TAM was proposed by Davis (1989) and posits that users' behavioral intentions to use a system are primarily determined by two key perceptions: perceived usefulness (PU)—the extent to which the tool is perceived to enhance performance or effectiveness in one's work—and perceived ease of use (PEOU)—the extent to which using the tool is perceived as effort-free. Moreover, TAM assumes that perceived ease of use positively influences perceived usefulness; that is, when a technology is easy to use, users tend to perceive it as more useful (Davis, 1989). The model has been extensively applied to explain the acceptance of educational technologies by teachers and students, providing a robust analytical lens for understanding why new tools are adopted or rejected.

Within education, contemporary meta-analytic approaches confirm the enduring explanatory power of TAM, highlighting the consistent relationship of PU and PEOU with usage intentions and, where measured, actual use (Or, 2024). In parallel, the application of TAM to generative AI environments has intensified in recent years, with studies developing and validating TAM-based survey instruments for tools such as ChatGPT. These studies underline the importance of scale reliability (e.g., Cronbach's alpha) and the empirical validation of key constructs (Barakat, Salim, & Sallam, 2025).

Beyond TAM, a more comprehensive understanding of continuance intention—namely, users' intention to continue using a tool after initial adoption—can be supported through the concepts of user satisfaction and expectation confirmation. These are derived from Bhattacherjee's (2001) Expectation Confirmation Model (ECM), which has been widely used in research on information systems continuance. According to ECM, users form expectations prior to use and subsequently compare these expectations against their actual experience, assessing whether the system met or exceeded what they anticipated. In turn, confirmation influences user satisfaction as well as post-adoption perceived usefulness, following the initial experience (Bhattacherjee, 2001). High satisfaction tends to increase continuance intention, whereas disconfirmation and dissatisfaction may lead to discontinuance. Applying these concepts to the present study, it is expected that teachers who used Gamma App would form judgments regarding the extent to which the tool met their expectations shaped by the training seminar. A positive experience (i.e., confirmation) is expected to enhance satisfaction and strengthen their intention to continue using the tool, whereas negative experiences or difficulties may reduce satisfaction and discourage future use.

Finally, the literature on AI tool adoption in education emphasizes that, beyond the core TAM constructs, issues of readiness and contextual barriers—such as limited time and restricted opportunities for professional development—are also critical. In large-scale studies, perceived usefulness has been identified as a key predictor of teachers' intention to adopt AI, while barriers such as AI-related anxiety and limited training opportunities are frequently reported (Granström & Oppi, 2025). Similarly, empirical research on teachers' adoption of AI technologies highlights the importance of understanding the determinants of adoption as a prerequisite for meaningful integration of AI in teaching practice (Zhao, Li, & Zhang, 2025). In higher education contexts, PU

is often reported as the strongest predictor of attitudes and usage intentions toward AI tools (Zhao, An, & Liu, 2025). For this reason, a comprehensive evaluation of Gamma App acceptance should consider not only perceived usefulness and perceived ease of use, but also external constraints and concerns expressed by teachers.

In summary, the present study draws on TAM and ECM to shape its analytical framework. We assume that PU and PEOU will be positively associated with teachers' intention to use Gamma App, while expectation confirmation and satisfaction following initial use will influence continuance intention. At the same time, participants' statements regarding exogenous factors (e.g., time, support, ethical concerns) are taken into account as potential barriers or facilitators affecting the integration of the tool into everyday teaching practice.

Methodology

Participants and context

Eighteen (18) teachers from the Laboratory Center of Lagadas participated in the study. All participants attended a two-hour professional development session on Gamma App during the 2024–2025 school year. A convenience sampling approach was used, including teachers from various national teaching specializations (PE codes), with the majority belonging to PE82 (61.1%). Teaching experience varied across participants: approximately 16.7% had ≤5 years of teaching experience, 22.2% had 6–10 years, 16.7% had 11–20 years, and 44.4% had more than 21 years of experience. Regarding gender, 11 participants were male and 7 were female (61.1% and 38.9%, respectively). Prior to the seminar, all participants completed a brief demographic survey and self-assessed their digital competencies for classroom use on a 1–5 scale. The mean self-assessment score was approximately 3.5 (maximum = 5), indicating moderately high familiarity with educational technology. In addition, 61.1% reported no prior experience with AI tools (e.g., ChatGPT or other AI applications).

Training procedure

During the professional development session, Gamma App and its key features (e.g., automated presentation generation) were introduced. The session included a demonstration of core functionalities, followed by opportunities for hands-on practice in small groups. Particular emphasis was placed on pedagogical applications, including adaptation of AI-generated materials to students' needs, as well as potential limitations of the platform (e.g., subscription requirements for certain features).

Data collection

Data were collected through an online questionnaire distributed to participants approximately two weeks after the training session. This interval was intentionally selected to allow teachers who wished to try Gamma App in their classrooms to do so and to report their initial experiences. The questionnaire was anonymous, and participation was voluntary. Of the 25 teachers who attended the training, 18 completed the questionnaire (response rate: 72%).

Instrument (questionnaire structure)

The questionnaire consisted of the following sections:

Training experience (Gamma App seminar)

Participants rated three aspects of the training—(a) clarity of presentation, (b) duration, and (c) post-training support—using a five-point Likert scale (1 = not at all satisfactory, 3 = neutral, 5 = completely satisfactory).

Post-training use of Gamma App

Participants indicated whether they used Gamma App after the training (Yes/No). Those who responded "Yes" completed additional questions: i) Purpose of use (e.g., creating presentations, worksheets, flipped classroom materials, etc.), allowing multiple selections and an open-ended "Other" option; ii) Frequency of use (e.g., rarely, monthly, weekly, daily).

Acceptance-related constructs

i) Perceived Usefulness (PU): 6 items; ii) Perceived Ease of Use (PEOU): 6 items; iii) Satisfaction: 2 general items; iv) Expectation Confirmation: 3 items; v) Continuance Intention: 3 items examining whether participants intended to continue using the tool.

Reasons for non-use (for non-users)

Participants who did not use Gamma App after training rated the importance of potential reasons for non-use ("How important are the following reasons to you?"). Reasons included lack of time, difficulty of use/learning, lack of support, technical constraints/infrastructure, ethical concerns, lack of relevance to the subject area, and "Other" (with an optional description). Each reason was rated on a five-point scale (1 = not important at all, 5 = extremely important). Non-users could also select multiple reasons from a list of the most prominent barriers.

Future needs and overall evaluation

All participants reported: i) whether they would like further professional development on AI tools ("Yes," "Maybe," "No"); ii) preferred format for future training (e.g., face-to-face workshops with coaching, short online micro-workshops, asynchronous online courses, etc.); and iii) two brief overall evaluations of Gamma App: general satisfaction (1–5 scale) and willingness to recommend the tool to a colleague (0–10 scale). Participants also rated the likelihood of using Gamma App or similar tools in the future on a five-point scale (1 = not likely at all, 5 = very likely).

Data Analysis

Statistical analysis was conducted using IBM SPSS. Given the small sample size (N = 18), emphasis was placed on descriptive statistics. Frequencies, percentages, and mean values were calculated for all variables. Closed-ended Likert-scale items were coded from 1 to 5 (or 0–10 where applicable) for analysis.

For multi-item scales (PU, PEOU, etc.), internal consistency was assessed using Cronbach's alpha, a widely used indicator of reliability in terms of internal consistency (Tavakol & Dennick, 2011). All scales demonstrated acceptable to high reliability ($\alpha >$ .70). For the continuance intention scale, reverse scoring was applied to the negatively worded item (the third statement), after which scale reliability was computed.

Due to the limited number of participants who used the tool after training (n = 7) and those who did not (n = 11), advanced inferential analyses (e.g., hypothesis testing for group differences or multivariate models such as regression or structural equation modeling) were not considered feasible. Instead, descriptive trends were compared between the two groups (users vs. non-users), and potential associations among key acceptance variables were explored. For example, Spearman's rho correlation coefficients were calculated among the mean scale scores for PU, PEOU, satisfaction, and continuance intention for the user subgroup, with interpretations provided at a qualitative level, considering that statistical significance testing was not emphasized due to sample size constraints.

Finally, open-ended responses (e.g., "Other" reasons for non-use and participant suggestions) were analyzed qualitatively to complement the quantitative findings.

Results

Evaluation of the professional development seminar

Participants evaluated the Gamma App professional development seminar very positively. Clarity of presentation received a mean score of 4.5, with 72.2% rating it as "completely satisfactory" (score 5). Only one participant expressed dissatisfaction (a single score of 1).

Similarly, training duration was rated positively overall, with a mean score of 3.89, although responses showed slightly greater dispersion. Approximately 72.2% assigned a score of 4 or 5 (satisfactory to completely satisfactory), whereas three teachers (16.7%) rated the duration as 1 or 2 (not at all or slightly satisfactory). Qualitative comments suggested that some participants would have preferred a longer session to allow more hands-on practice, while others considered the duration "appropriate."

The dimension with more moderate ratings was post-training support. The mean score was 3.83 (neutral to fairly satisfactory). Specifically, approximately 33.3% rated post-training support as completely satisfactory, another 33.3% rated it as neutral, and 27.8% rated it as fairly satisfactory. One participant (5.6%) reported complete dissatisfaction. This pattern suggests that, although the seminar itself was perceived as highly positive, several teachers felt that support after returning to their classrooms was insufficient. This was also reflected in qualitative comments, where participants proposed establishing a communication group (e.g., via a forum or social media) for sharing experiences and resolving questions during the school-based implementation of Gamma App.

Adoption and use of Gamma App after training

Out of the 18 teachers, 7 (38.9%) reported using Gamma App in their teaching during the weeks following the seminar. The remaining 11 (61.1%) did not use the tool beyond the initial exposure during training. This early adoption rate can be considered relatively satisfactory for a new tool, although it indicates that most participants did not immediately integrate Gamma App into everyday teaching practice.

Purposes of use. Among the 7 users, 6 teachers (85.7%) used Gamma App primarily to create digital lesson presentations, confirming that the platform's core functionality (automated presentation generation) resonated strongly with participants. In addition, 2 teachers (28.6%) used it to create worksheets and/or lesson scenarios, and one teacher reported using it to develop material for a flipped classroom approach. Overall, users highlighted the value of rapid creation of interactive content (e.g., slides with automatically suggested images and design elements), and some experimented with multiple material formats. One teacher noted: "It saved me time in building a well-designed presentation—I only added my own examples."

Frequency of use. No user reported daily use, which is expected given that the follow-up period was only two weeks. Three out of seven users (42.9%) used the tool weekly, while another three (42.9%) used it approximately once per month. One teacher reported using it only rarely, mainly in an exploratory manner. These results suggest that about half of the adopters moved toward more regular use, while the remainder tried the tool a limited number of times. Notably, even those with more limited use reported an intention to reuse Gamma App when an appropriate opportunity arises (see continuance intention below).

Users' perceptions of Gamma App (User subgroup, N = 7)

The seven teachers who used Gamma App evaluated the tool across several dimensions using 1–5 Likert-type scales (disagree/agree).

Perceived Usefulness (PU). Users reported very high perceived usefulness. The mean score across the six PU items was 4.33 (agree to strongly agree). The internal consistency of the PU scale was high (Cronbach's $\alpha = 0.91$), indicating that the six items coherently measured the same construct. This aligns with TAM-based expectations that perceived usefulness is a key driver of acceptance: teachers who tried the tool perceived tangible benefits for their work.

Perceived Ease of Use (PEOU). Perceptions of ease of use were similarly positive. The mean score across the six PEOU items was 4.55. Internal consistency was exceptionally high (Cronbach's $\alpha = 0.99$), suggesting highly consistent responses across all ease-of-use indicators and very limited dispersion. Overall, teachers perceived Gamma App as user-friendly, with minimal technical difficulty.

Satisfaction, expectation confirmation, and continuance intention were also positive. Satisfaction averaged 4.21 (α=0.71), confirmation averaged 4.14 (α=0.88), and continuance intention averaged 4.33 (α=0.86), indicating that most users felt the tool met expectations and intended to continue using it (Bhattacherjee, 2001).

Correlational patterns (User subgroup). Within the user subgroup (N = 7), relationships among PU, PEOU, satisfaction (SAT), confirmation (CONF), and intention (INT) were examined using Spearman's rho (ρ, two-tailed) due to the small sample size and the ordinal nature of measurements. The strongest—and statistically significant—positive correlation was observed between PU and CONF ($\rho = 0.963$, $p < 0.001$), indicating that higher perceived usefulness was associated with stronger confirmation of expectations. Other correlations were also positive and ranged from moderate to strong (e.g., PEOU–SAT: $\rho = 0.709$, $p = 0.075$; CONF–INT: $\rho = 0.634$, $p = 0.126$; PU–SAT: $\rho = 0.654$, $p = 0.111$), but did not reach statistical significance in this sample. Overall, the correlational pattern suggests conceptual coherence across constructs, while also highlighting the need for larger samples to test hypothesized relationships with adequate statistical power.

Reasons for non-adoption (Non-user subgroup, N = 11)

Non-users' ratings indicate that barriers were primarily practical. Lack of time was the most important factor (64% selected it; M=3.91), followed by technical constraints/infrastructure (M=3.09). Perceived relevance to the subject area showed mixed responses (M=3.0).

Other reasons were comparatively less influential: difficulty of use/learning (M=2.73), lack of support (M=2.55), and ethical concerns (M=2.55). Open-ended responses additionally mentioned paywalled features (e.g., PDF upload) and occasional mismatch with one's teaching approach.

Overall evaluation and future trends

At the end of the questionnaire, all participants (regardless of use) provided an overall evaluation and future-oriented responses: i) Overall satisfaction with Gamma App: mean 4.1 (1–5 scale). ii) Willingness to recommend to a colleague: mean 7.4 (0–10 scale). iii) Likelihood of future use (Gamma App or similar tools): mean 4.2 (1–5 scale).

Need for further professional development. Among non-users, 100% responded "Yes" or "Maybe" to the question of whether they would like additional training on AI tools (10 Yes, 1 Maybe). This indicates strong interest in continued development of AI-related competencies. Preferred formats included face-to-face workshops with coaching and short micro-seminars of 1–2 hours (online or in-person). Many participants selected a blended approach (e.g., an in-person workshop followed by asynchronous online materials), suggesting a preference for both hands-on support and flexible follow-up resources.

In sum, results depict a pattern in which teachers recognize the value of Gamma App and report intentions to use it, provided that practical barriers are addressed and sufficient support is available for meaningful classroom integration.

Discussion

The findings offer initial evidence on teachers' acceptance and early post-training use of Gamma App. First, in line with TAM and related contemporary research, teachers who adopted Gamma App perceived it as highly useful and easy to use, which appears

to support their intention to continue using it. The high PU and PEOU mean scores (above 4/5) and the almost unanimous positive stance among users indicate that the tool largely met the expectations established during the training seminar. This is an important signal: despite the small number of users, the fact that none of those who tried the tool reported disappointment or abandonment suggests that Gamma App has key characteristics required for acceptance in educational settings—namely, being user-friendly and perceived as beneficial. In practical terms, teachers reported that Gamma App saved them time in preparing instructional materials and enhanced the visual appeal of their lessons, both of which can strengthen motivation for sustained use.

Equally important is the high level of satisfaction and the positive expectation confirmation reported by users. Although the post-training usage period was limited (only a few weeks), teachers felt that the tool "delivered" on what was promised during training. This result is critical because, according to continuance models, satisfaction following initial use is a core determinant of whether users will continue to use a new technology (Bhattacherjee, 2001). In this study, early adopters not only intended to continue using Gamma App but were also willing to recommend it to others. This is an encouraging diffusion indicator: satisfied early users may act as "technology ambassadors" within their school environment, which can further strengthen adoption over time.

At the same time, the study also revealed a gap between favorable perceptions and actual implementation. Despite the generally positive overall stance, the majority of participants (11 out of 18) did not proceed to use the tool in practice. This pattern highlights the role of organizational and individual constraints. The most prominent barrier was lack of time—an issue repeatedly identified in the literature as a key impediment to classroom innovation. Teachers often operate under heavy workloads and may hesitate to invest time in learning and integrating a new tool unless immediate benefits are certain. In this respect, providing ready-to-use examples or lesson scenarios could be beneficial, enabling teachers to implement Gamma App with minimal preparation. For instance, following the training, participants could receive a set of sample Gamma-based lessons via email across different subject areas, which might encourage more immediate classroom use. Experience suggests that professional development should not end in the training room: follow-up materials, reminders, and structured support can increase the likelihood of experimentation. The moderate ratings for post-training support in the present study are consistent with this need, as several teachers indicated that they felt "on their own" after the initial seminar. One practical recommendation would be to establish a follow-up mechanism, such as an online community of practice or a second meeting one month later, to facilitate experience sharing, troubleshooting, and sustained engagement.

A second critical barrier identified was technical constraints and infrastructure limitations. This factor is external to the tool itself and relates to the conditions of the educational environment. If a school lacks stable Wi-Fi, adequate hardware, or reliable internet access, even highly motivated teachers may be unable to adopt an online platform such as Gamma App. The literature on technology integration often distinguishes between first-order barriers (e.g., infrastructure and organizational limitations) and second-order barriers (e.g., beliefs, attitudes, and knowledge). In the present study, first-order barriers (time and infrastructure) appear more decisive, whereas second-order factors (attitudes and perceived competence) were generally

favorable. Therefore, for adoption to increase, practical conditions need to be addressed: ensuring adequate infrastructure, allocating time for instructional preparation (e.g., through school-based workshops or designated innovation time), and potentially offering administrative incentives. If a school unit chooses to pilot Gamma App more systematically, it would be beneficial to provide prioritized support, such as access to computer labs, technical assistance from ICT staff, and recognition of teachers' effort.

Although ethical and pedagogical concerns did not emerge as major barriers in this study, they should still be addressed explicitly when introducing AI tools. Training can emphasize that teachers retain responsibility for critical evaluation and adaptation of AI-generated materials, and can clarify common concerns (e.g., reliability, bias, and appropriate classroom use) to build informed trust.

At a practical level, several factors may further support adoption. First, cost-related friction can discourage experimentation when key features are paywalled; educational access (licenses or discounted packages) may therefore facilitate use. Second, localized guidance and exemplars can reduce uncertainty: short, curriculum-aligned templates and subject-specific examples may help teachers quickly identify relevant classroom applications. Finally, clear guidance on responsible use (teacher oversight and verification of AI-generated materials) can strengthen trust and sustain continued use.

Limitations

Before moving to the conclusions, it is important to acknowledge several limitations of the present study. First, the sample size (N = 18) is small, which restricts the generalizability of the findings. The results should therefore be interpreted as indicative trends within this specific context rather than as broadly generalizable conclusions about teachers overall. Second, the sample was not random; it consisted of teachers who attended a specific professional development seminar and may therefore be more positively predisposed toward technology. This may introduce selection bias in favor of acceptance. Third, the measurement of certain constructs (e.g., continuance intention) is challenging with such a small N, and qualitative approaches (e.g., interviews or focus groups) may be needed to achieve a deeper understanding of teachers' perspectives. Finally, the observation window was short; thus, it remains unclear whether participants would continue using Gamma App after several months. Future research could include follow-up assessment (e.g., at the end of the school year) to examine whether adoption is sustained or fades over time.

Conclusions

This pilot study evaluated teachers' acceptance and early post-training use of Gamma App as an AI-based tool for educational content creation. Early adopters (38.9%) reported high perceived usefulness (M=4.33) and ease of use (M=4.55), alongside positive satisfaction and continuance intention.

Most participants did not implement the tool within the short follow-up period. Reported barriers were mainly practical—especially limited time and, to a lesser extent, infrastructure constraints—rather than strong negative attitudes. Participants also

expressed strong interest in further professional development, suggesting the value of structured follow-up support after introductory training.

Given the small sample and brief observation window, findings should be interpreted as preliminary. Future studies should include larger samples, longer follow-up, and mixed methods to examine how enabling conditions and support mechanisms influence sustained classroom adoption of AI authoring tools.

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Earthquaker-AI: A Retrieval-Augmented Generation Framework with Rubric-Based Assessment for Primary School Earthquake Education

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Abstract—This paper presents Earthquaker-AI, a hybrid educational framework that builds upon a previously implemented educational robotics project by integrating a conversational artificial intelligence assistant based on Retrieval-Augmented Generation (RAG), aiming to enhance earthquake preparedness and conscious action among primary-school students. The system extends the earlier award-winning STEM project Earthquaker, which received 3rd place in the Hellenic WRO Competition (2020), and moves from mechanical simulation through Lego WeDo2 activities to cognitive and metacognitive processing.

The robotics component, developed in the original Earthquaker project, employed Lego WeDo2-based automation to simulate seismic response, allowing students to interact with sensors and actuators that function as tangible representations of core protective actions. At the cognitive level, the conversational assistant adopts a Retrieval-Augmented Generation architecture, in which evidence retrieval precedes language generation, so that responses are grounded in official educational material and aligned with the intended pedagogical framework. The assistant serves a dual role: it operates as a guided learning mechanism that aligns students' responses with institutional safety guidelines, while simultaneously providing rubric-based verbal feedback that supports self-regulated learning and the development of calmness under emergency conditions.

Earthquaker-AI follows a progressive learning trajectory aligned with students' cognitive development across age stages. In the early grades, the emphasis is placed on basic recognition of earthquake-safety actions through simple multiple-choice questions, in which students select the most appropriate answer, supporting orientation toward the recommended behavior during seismic events. Assessment at this stage is conducted using a two-dimensional rubric focused on action recognition and emotional regulation. In middle grades, learning activities become more demanding, requiring students to identify the correct sequence of actions through multiple-choice questions, evaluated using a three-axis rubric that captures organized thinking and decision-making. In upper grades, the approach shifts from recognition to verbal production, with students providing short written responses assessed through a four-dimensional rubric. The additional dimension of clarity of expression reflects increasing

metacognitive maturity, as it requires structured reasoning, justification, and precise articulation.

The system also includes a dedicated dialogic module that leverages RAG to retrieve and synthesize evidence-based answers. Student queries are semantically matched with selected excerpts from official earthquake-safety guidelines, from which pedagogically safe and accurate responses are generated. Experimental evaluation demonstrates high answer groundedness (0.84) and accuracy (0.85), together with a low hallucination rate (0.07), indicating stable and evidence-aligned behavior under the evaluated experimental conditions.

Overall, Earthquaker-AI presents an integrated educational approach to earthquake preparedness, bringing together hands-on engagement, information processing, and reflective practice. The sequence of observation, physical interaction, interpretation, and verbal articulation provides a holistic learning experience. At the same time, the combined use of robotic processes, analytic rubrics, and artificial intelligence promotes technological literacy, self-regulation, and responsible use of digital systems in primary education, contributing meaningfully to earthquake preparedness and the early development of crisis-management skills.

Keywords— Artificial intelligence, Retrieval-Augmented Generation (RAG), large language models, educational robotics, formative assessment, disaster risk education

1. Introduction

Earthquake preparedness constitutes a critical component of safety education in primary schools. Despite the existence of official guidelines, earthquake education at the primary level often remains fragmented and predominantly theoretical, offering limited opportunities for experiential learning, structured reflection, and individualized feedback (Yeon et al., 2020). While STEM-oriented activities and educational robotics have been successfully employed to promote engagement and hands-on understanding of physical safety mechanisms, their impact frequently remains confined to mechanical simulation and does not systematically extend to the cognitive and verbal articulation of appropriate actions during an earthquake. Comparative research on earthquake training methods further indicates that interactive and game-based approaches can enhance engagement and learning outcomes compared to traditional instruction (Çoban & Göktaş, 2022).

The original Earthquaker project addressed the limitations of predominantly theoretical earthquake education by introducing a robotics-based STEM framework focused on the design and implementation of an automated school safety system for earthquakes. Inspired by ancient automation mechanisms, the original Earthquaker system enabled students to simulate seismic detection and automated responses such as door opening, utility shutdown, and occupancy counting. Through hands-on construction and physical interaction, students developed an experiential understanding of cause–effect relationships related to earthquake safety. However, while the robotic component effectively supported procedural awareness, it offered limited support for guided reasoning, justification of actions, and formative assessment of students' understanding.

Recent work has highlighted both the opportunities and challenges of integrating large language models into educational settings (Kasneci et al., 2023). In this context, Earthquaker-AI emerges as a natural evolution of this framework, extending earthquake education from the domain of mechanical causality to the cognitive and metacognitive dimensions of preparedness. The transition to Earthquaker-AI responds to the identified need for structured, evidence-based, and pedagogically controlled learning experiences that support not only correct actions, but also calmness, judgment, and verbal expression during emergency situations. To address this need, the system integrates experiential robotics with a dialogic artificial intelligence component designed to support scenario-based learning and structured evaluation.

Earthquaker-AI integrates a Retrieval-Augmented Generation (RAG) architecture within an educational setting. By design, all system responses are generated exclusively on the basis of retrieved excerpts from official earthquake safety guidelines, ensuring that learning interactions remain accurate, evidence-grounded, and constrained within verified instructional sources. This design aims to reduce risks typically associated with open-domain conversational agents and allows the system to function as a controlled educational assistant rather than a generic chatbot.

In parallel, Earthquaker-AI incorporates rubric-based formative assessment as a core pedagogical mechanism. Student interactions are structured according to age-appropriate scenarios, and responses are evaluated using explicitly defined rubrics aligned with students' cognitive development. This design supports pedagogical

continuity across educational levels and enables the provision of targeted, comprehensible feedback that fosters self-regulation and reflective learning.

The objectives of this study are threefold: (a) to present the design of Earthquaker-AI as a hybrid educational model situated within an existing robotics-based learning environment and extended with RAG-based dialogue, and rubric-driven assessment; (b) to evaluate the extent to which the RAG component produces accurate and evidence-aligned responses grounded in official earthquake safety guidelines; and (c) to examine the reliability and consistency of rubric-level formative assessment produced by language models across repeated evaluations and different educational grades.

2. Conceptual Positioning of Earthquaker-AI

Earthquaker-AI represents a natural pedagogical extension of the original STEM project Earthquaker: Design and Implementation of an Automated School Safety System for Earthquakes, transferring the logic of mechanical causality and physical simulation into a broader cognitive and pedagogical framework. In the initial project, students engaged in robotic constructions that simulated seismic detection and automated response mechanisms (e.g., door opening, utility shutdown, and occupancy counting), enabling them to develop an experiential and procedural understanding of fundamental safety principles. The transition toward Earthquaker-AI does not replace this experiential level; rather, it builds upon it, shifting the emphasis from physical execution to cognitive processing, verbal articulation, and informed decision-making, as highlighted in the system's design.

The need for this transition is grounded in an identified pedagogical gap: earthquake education in primary schools often remains largely theoretical and fragmented, with limited opportunities for individualized feedback. Despite the existence of official guidelines, students are rarely invited to actively process earthquake-related scenarios, justify their choices, or be assessed using clear, age-appropriate, and comprehensible criteria. Earthquaker-AI seeks to address this gap by relocating earthquake preparedness into the domain of guided inquiry and gamified learning, where knowledge is not passively reproduced but actively constructed through structured interaction.

3. Pedagogical and Developmental Foundations

The concept of pedagogical continuity (learning continuum) is established as a central theoretical axis of Earthquaker-AI. The system is designed as a progressive learning trajectory, aligned with students' cognitive and metacognitive development, in accordance with principles of developmental psychology (Piaget, 1970) and the spiral organization of the curriculum (Bruner, 1960). Learners are not approached as a homogeneous group; rather, differentiated cognitive processing capacities are assumed, necessitating the systematic gradation of cognitive demands and assessment tools. The robotic component of Earthquaker-AI is grounded in constructionist design principles, emphasizing learning through hands-on manipulation and iterative exploration (Resnick & Rosenbaum, 2013).

Within this framework, assessment rubrics function as the structural mechanism linking learning and assessment. As a formative assessment instrument, performance criteria and quality levels are made explicit, allowing expectations and evaluation procedures to be transparent and comprehensible to students (Andrade, 2000; Brookhart, 2013). In Earthquaker-AI, the use of rubrics is framed as non-punitive and non-comparative, with emphasis placed on supportive application and the provision of targeted, pedagogically adapted feedback.

The differentiation of rubrics across grade levels is aligned with students' cognitive development. In the early grades (Grades 1–2), assessment focuses on the recognition of basic actions and the maintenance of calm behavior, with reduced cognitive load and explicit support for self-regulation in crisis situations (Zimmerman, 2002). In the middle grades (Grades 3–4), the inclusion of action sequencing enables the assessment of organized thinking and systemic understanding, both of which are considered essential for earthquake preparedness and for integration with the project's robotics component. In the upper grades (Grades 5–6), emphasis is placed on verbal production, justification, and clarity of expression, which are treated as indicators of metacognitive maturity and conscious action (Flavell, 1979; Panadero & Jonsson, 2013). The feedback mechanism of Earthquaker-AI aligns with established models of formative feedback that support self-regulated learning and performance improvement (Hattie & Timperley, 2007).

This design choice is aligned with contemporary literature that highlights rubrics as powerful tools for self-assessment and learning regulation (Andrade & Du, 2005; Brookhart, 2017). At the same time, it enables the artificial intelligence system to operate not as an authoritative evaluator but as a pedagogical mediator, in which students' responses are compared against institutional standards, and feedback is returned in a comprehensible and actionable form.

Overall, the theoretical framework of Earthquaker-AI is articulated as a hybrid pedagogical model that integrates experiential robotics, structured knowledge, and formative assessment into a coherent learning scheme. The transition from mechanical simulation to cognitive processing, the use of Retrieval-Augmented Generation (RAG) for pedagogically controlled dialogue, and the staged application of rubrics collectively constitute a framework oriented not only toward the acquisition of correct actions, but toward conscious understanding, calmness, and students' metacognitive awareness in earthquake-risk situations.

4. AI & RAG Framework

A central component of the framework is the adoption of a Retrieval-Augmented Generation (RAG) architecture (Lewis et al., 2020). This approach combines natural language generation with semantic information retrieval from external, controlled, and institutionally validated sources. The retrieval component relies on semantic embeddings generated by a Greek-language Sentence Transformer model (dimitriz/st-Greek-media-Bert-base-uncased) and indexed with FAISS, following established retrieval approaches for open-domain question answering (Karpukhin et al., 2020). At the pedagogical level, the use of RAG ensures that generated responses are not derived from generalized or arbitrary model knowledge, but are grounded exclusively in retrieved excerpts from official earthquake safety guidelines. The system is designed to

operate within pedagogically controlled constraints, reducing the risk of misinformation and strengthening trust and reliability in the learning process (UNESCO, 2014). In this context, the adoption of RAG can be interpreted as a mechanism of epistemic control, ensuring that generative processes remain strictly bounded by verifiable institutional knowledge rather than unrestricted model priors.

5. System Design

Earthquaker-AI is implemented as an educational AI layer designed to support exploratory learning and structured formative assessment within the existing earthquake-preparedness environment. The system combines Retrieval-Augmented Generation (RAG) with rubric-based evaluation and guided pedagogical feedback, ensuring that all interactions remain strictly grounded in official earthquake safety guidelines and aligned with age-appropriate educational objectives.

5.1 Interaction Modes

Earthquaker-AI is structured around two complementary interaction modes, each addressing distinct pedagogical goals.

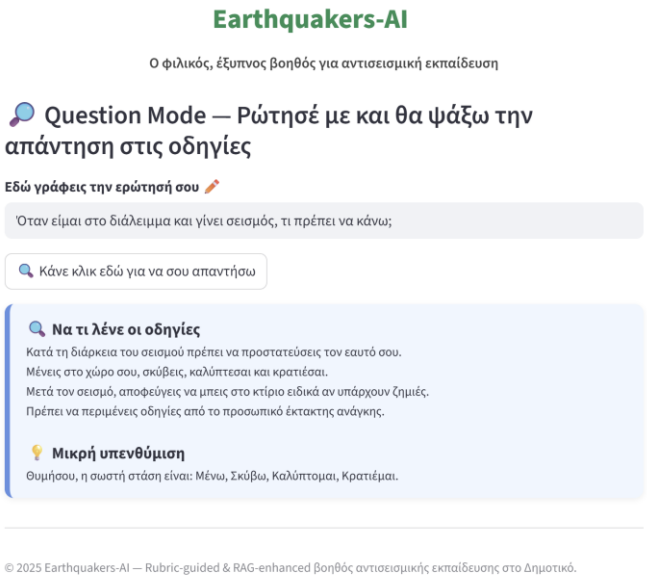


Figure 13. Example of the Question Mode interface, illustrating evidence-grounded answering based on retrieved excerpts from official earthquake-safety guidelines.

Question Mode allows students to freely ask questions related to earthquake safety. For every query, the system retrieves semantically relevant excerpts from the official earthquake safety corpus and generates an answer grounded in the retrieved material. This mode is designed to promote inquiry-based learning, while ensuring safety and factual reliability, since no response can be produced without explicit grounding in authoritative sources. An example of the Question Mode interface is presented in Figure 1.

Quiz Adventure Mode provides scenario-based questions tailored to the student's educational grade. Students respond either through structured selections (e.g., multiple-

choice) or through short open-ended answers, which are then evaluated using predefined, grade-specific rubrics. For each response, the system produces rubric-level scores and short, pedagogically adapted feedback, followed by a concise progress summary at the end of each session. This mode integrates learning and assessment, enabling students to reflect on their performance while receiving structured instructional guidance. An example of the Quiz Adventure interaction is shown in Figure 2.

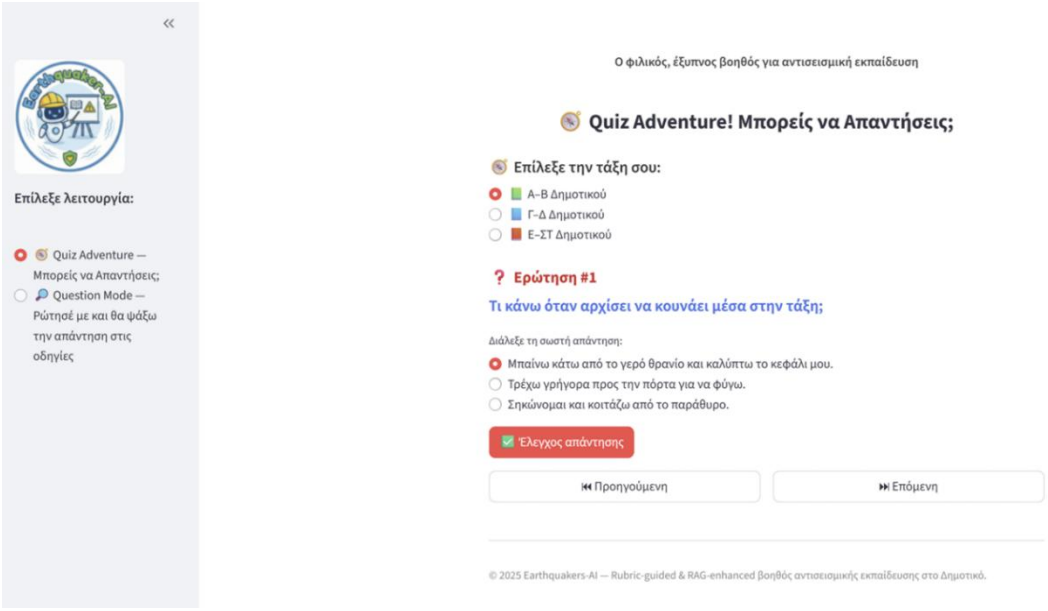


Figure 14. Example of the Quiz Adventure mode (Greek UI), illustrating scenario-based, grade-adapted interaction.

5.2 RAG–Rubric Evaluation Pipeline

All interactions in Earthquaker-AI are organized through a multi-stage evaluation pipeline, as illustrated in Figure 3. First, the system loads the question content, its interaction type, and the reference answer from a grade-specific structured repository. Second, it performs semantic retrieval over the official earthquake safety corpus to obtain the most relevant evidence passages, which serve as the basis for both response generation and evaluation. Third, a language model assigns rubric-level scores (1–3) for each assessment axis by comparing the student's response with the reference answer and the retrieved evidence. Fourth, the system generates pedagogically adapted feedback aligned with the assigned rubric levels and highlights strengths and areas for improvement.

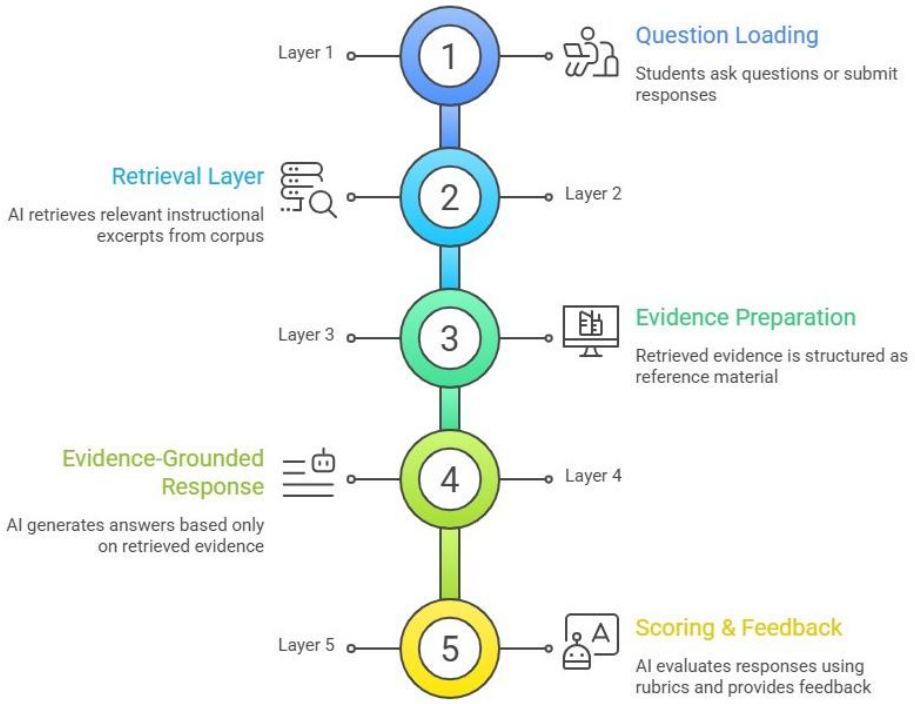


Figure 3. Overview of the Earthquaker-AI system architecture and RAG–Rubric evaluation pipeline

Figure 3 illustrates the overall architecture of the Earthquaker-AI system, including the RAG retrieval process, rubric-based evaluation, guided feedback generation, and final progress summarization. This architecture ensures that Earthquaker-AI does not function as an unrestricted conversational agent, but as a structured educational system, in which all answers, evaluations, and feedback are systematically anchored in verified instructional content and explicit assessment criteria.

Finally, after a set of questions has been completed, a concise, individualized progress summary is produced. An example of rubric-based feedback and the generated progress summary is presented in Figure 4.

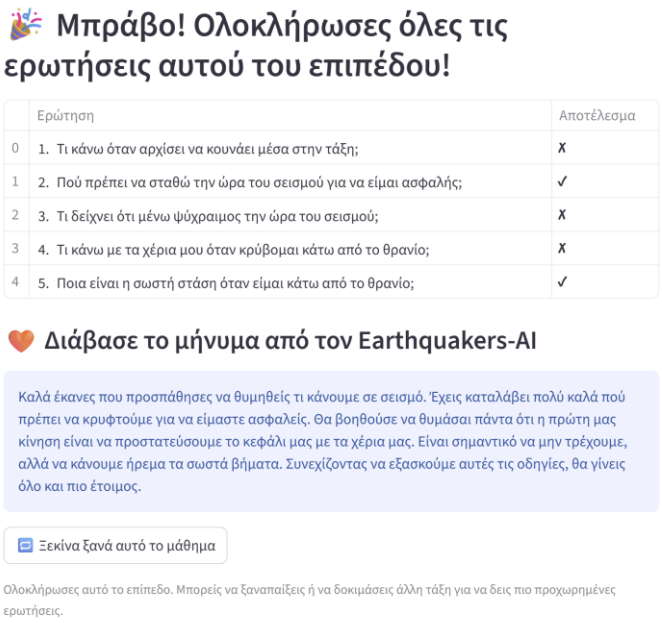


Figure 4. Example of rubric-based evaluation and individualized progress summary displayed to students after completing a question set.

6. Research Objectives and Research Questions

The Earthquaker-AI project is designed to support safe and evidence-based earthquake education for primary school students through structured AI-assisted interaction and formative assessment. Accordingly, this study pursues two specific research objectives: (a) to assess the factual accuracy and evidence grounding of answers generated by the RAG component, and (b) to evaluate the consistency and reliability of rubric-based formative assessment produced by AI models.

These objectives are operationalized through the following research questions:
RQ1: To what extent does Earthquaker-AI generate factually accurate and evidence-grounded answers that are explicitly supported by retrieved excerpts from official earthquake safety guidelines?
RQ2: To what extent does the AI-based assessment model (SLM/LLM) produce consistent and accurate rubric-level scores (1–3) under stochastic generation, across repeated evaluations of standardized student responses?

6.1 Methodology

The study adopts a two-stage experimental design, directly aligned with the defined research questions. The first stage (RQ1) evaluates the answer quality and grounding behavior of the Retrieval-Augmented Generation (RAG) component, focusing on factual accuracy and alignment with retrieved instructional evidence. The second stage (RQ2) examines the stability and accuracy of rubric-level scoring, comparing repeated evaluations of predefined standardized student responses produced by language models of different sizes.

6.2 Evaluation of RAG Answer Quality (RQ1)

To assess the reliability of the RAG component, a set of representative student-style questions was submitted to the system. For each question, the system retrieved semantically relevant excerpts from the official earthquake safety corpus and generated an answer based on these retrieved excerpts. The retrieval corpus remained fixed and unchanged across all experimental runs, ensuring controlled and reproducible evaluation conditions.

The generated answers were evaluated using an LLM-as-a-Judge approach, implemented using an independent Gemma 3 (4B) model. This evaluation strategy follows recent methodological practices in which large language models are employed as judges for assessing the quality and faithfulness of generated outputs (Zheng et al., 2023). The responses being evaluated were generated by the DeepSeek model within the RAG pipeline, while Gemma 3 (4B) was used solely as an independent evaluation model. The judge assessed each answer along four computationally defined criteria:

- Groundedness: the degree to which the answer is explicitly supported by the retrieved excerpts,
- Accuracy: the factual correctness of the answer with respect to the official earthquake safety guidelines,
- Completeness: the extent to which all relevant aspects of the question are adequately covered,
- Hallucination risk: the presence of information not supported by the retrieved evidence.

Each criterion was scored numerically, allowing the computation of aggregate indicators for overall RAG performance. These evaluation dimensions are conceptually aligned with recent automated frameworks for assessing Retrieval-Augmented Generation (Es et al., 2023). In addition, complementary embedding-based similarity metrics were computed between generated answers and retrieved evidence passages in order to provide a system-level, embedding-based assessment independent of the generation model.

6.3 Rubric-Based Assessment and Model Comparison (RQ2)

To evaluate the reliability of the rubric-based assessment mechanism, standardized evaluation scenarios were constructed. For each question, three types of predefined student-style responses were constructed, representing high-, medium-, and low-quality answers. Each response was associated with predefined expected rubric levels (1–3) for all assessment axes of the corresponding educational grade.

These scenarios were submitted repeatedly (five runs per scenario) to two language models of different sizes: a Small Language Model (Gemma 3, 4B) and a Large Language Model (DeepSeek). For each run, the model produced rubric-level scores (1–3) based on the student response, the reference answer, and the retrieved evidence.

Performance was evaluated using two primary indicators:

- Assessment accuracy, defined as the percentage of cases in which the predicted rubric level matched the expected level,
- Assessment consistency, measured both as absolute consistency (identical scores across all repetitions) and relative consistency (dominance of the most frequent score across repetitions).

This second stage allows us to examine the stability and internal reliability of AI-based formative assessment, as well as comparative behavior across language models of different capacities, within the Earthquaker-AI framework. In RQ2, rubric-level predictions were directly compared against predefined expected levels; no external LLM judge was used in this stage.

7. Experimental Setup

The experimental evaluation was conducted using a set of earthquake-safety questions and structured student-response scenarios, constructed on the basis of the official earthquake safety guidelines. The evaluation included 15 earthquake-safety questions across three grade clusters (A–B, G–D, and E–ST). For RQ1, student-style questions were submitted to the RAG-based system, which retrieved relevant evidence passages and generated grounded answers. This resulted in 15 RAG-generated responses, which were subsequently evaluated for groundedness, accuracy, completeness, and hallucination risk. For RQ2, three standardized student responses (high-, medium-, and low-quality) were created for each question and evaluated repeatedly. Each scenario was executed five times on two language models of different sizes: a Small Language Model (Gemma 3, 4B) and a Large Language Model (DeepSeek). Given 15 questions, three predefined response-quality levels per question, five stochastic repetitions, and two language models, the experimental design comprised 450 rubric-level evaluation instances. This design enabled the measurement of assessment accuracy and evaluation consistency across repeated stochastic runs.

8. Results

8.1 Results for RQ1 – RAG Answer Quality

To address RQ1 (“To what extent does Earthquaker-AI provide accurate and evidence-aligned answers grounded in retrieved official earthquake safety guidelines?”), the evaluation was conducted at two complementary levels: (a) system-level assessment of retrieval-supported generation within the RAG pipeline, and (b) semantic evaluation of the generated answers.

8.1.1 System-Level Evaluation of RAG Retrieval

As shown in Table 1, system-level computational metrics indicate that the RAG pipeline consistently retrieves semantically relevant excerpts from the official earthquake safety corpus. High similarity between retrieved evidence and generated responses, together with adequate coverage of instructional content, indicates strong alignment with the retrieved source material.

The system-level hallucination_ratio does not measure factual fabrication, but rather the dispersion of answer content across multiple retrieved chunks, serving as an indicator of retrieval distribution rather than unsupported generation. These results indicate that the RAG pipeline provides a reliable retrieval foundation for evidence-grounded answer generation.

Metric	Mean
Support from most relevant retrieved source (sim_best_evidence)	**0.78**

Average semantic similarity with retrieved chunks (mean_chunk_similarity)	**0.62**
Coverage of key safety points (coverage_ratio)	**0.81**
Hallucination indication at system level (hallucination_ratio)	**0.37**
Average answer length (tokens)	**65.9**

Table 3. System-level computational metrics evaluating the behavior of the RAG retrieval pipeline.

8.1.2 Semantic Evaluation of Generated Answers

At the semantic level, answer quality was evaluated using an LLM-as-a-Judge approach (Gemma 3, 4B).

Metric	**Mean**
Groundedness (answer supported by retrieved excerpts)	**0.84**
Accuracy (alignment with official guidelines)	**0.85**
Completeness (coverage of required information)	**0.78**
Hallucination (unsupported information)	**0.07**

Table 4. LLM-as-a-Judge (Gemma 3, 4B) evaluation of RAG-generated answers across groundedness, accuracy, completeness, and hallucination risk.

As reported in Table 2, the system achieved high groundedness (0.84) and accuracy (0.85), while maintaining a low hallucination rate (0.07). These results indicate that the RAG configuration effectively constrained generation within the retrieved evidence, supporting reliable answer production under the evaluated conditions.

Overall, the results indicate that Earthquaker-AI provides accurate and evidence-grounded answers, addressing the requirements of RQ1.

8.2 Results for RQ2 – Rubric-Based Assessment Reliability

The second research question examined the reliability and stability of rubric-level scoring produced by language models of different sizes.

8.2.1 Rubric-Level Accuracy

As shown in Table 3, the Large Language Model (DeepSeek) achieved higher rubric-level accuracy than the Small Language Model (Gemma 3, 4B). In particular, the LLM more frequently assigned rubric scores that matched the predefined expected levels for medium- and high-quality response scenarios, while the SLM exhibited lower agreement in these categories. This pattern highlights the influence of model capacity on rubric-level assessment accuracy within the defined experimental setup.

Model	**Rubric-Level Accuracy (%)**
Gemma (SLM)	54.7
DeepSeek (LLM)	73.7

Table 5. Rubric-level assessment accuracy across models.

8.2.2 Assessment Consistency Across Repeated Evaluations

Assessment stability was evaluated using both absolute and relative consistency metrics.
As reported in Table 4, both models demonstrated high absolute consistency across repeated evaluations, indicating that identical rubric levels were assigned across repeated runs in the majority of cases. The LLM exhibited slightly higher absolute consistency values.

In addition, Table 5 shows that relative consistency remained very high for both models, with the LLM achieving the highest dominance of the most frequent rubric score across repetitions.

Model	Absolute Consistency (%)
Gemma	87.5
DeepSeek	89.7

Table 6. Absolute assessment consistency across repeated evaluations.

Model	Relative Consistency (%)
Gemma	95.7
DeepSeek	97.2

Table 7. Relative assessment consistency across repeated evaluations.

Overall, these results indicate that while both models provide stable rubric-based evaluations, model capacity appears to influence assessment accuracy, with the LLM consistently outperforming the SLM. At the same time, high consistency values across both models suggest that AI-based rubric evaluation demonstrates reproducible behavior under the defined experimental conditions and when guided by explicit rubrics. These results suggest that while smaller models may provide stable evaluations, higher-capacity models are better suited for fine-grained rubric-level discrimination.

9. Ethical, Legal and Data Protection Considerations

Earthquaker-AI was designed in alignment with ethical and legal requirements for educational use in primary school settings. The system does not collect, process, or store personal data of students and operates exclusively on anonymized, scenario-based inputs. All knowledge sources are restricted to official earthquake safety guidelines retrieved through a closed RAG corpus.

This design ensures that the system does not expose students to uncontrolled or unsafe content, in contrast to open-domain conversational agents. Under current Greek and European regulatory frameworks, the experimental and supervised use of AI systems for educational purposes is permitted, provided that data protection, safety, and pedagogical oversight are ensured.

In addition, the system supports deployment in a fully local execution setting for educational use. In the experimental configuration, the Small Language Model (Gemma 3, 4B) was executed locally via the Ollama framework for the assessment experiments, without any external API calls or data transmission to third-party servers. This local execution design is intended to support GDPR-aligned deployment in primary-school

contexts, as all interactions, evaluations, and generated outputs remain confined to the local computational environment. Such architecture is particularly appropriate for primary-school contexts, where minimizing data exposure and ensuring institutional control over educational AI systems is a critical ethical requirement. No real student data were used in the experimental phase; all evaluations relied exclusively on predefined scenario-based inputs.

10. Limitations

The present study is subject to certain limitations. The experimental evaluation was conducted in a controlled, scenario-based setting and did not involve real-time interaction with students in classroom environments. In addition, the assessment focused on answer quality and rubric-level consistency, rather than on long-term learning outcomes or behavioral change. These limitations define the scope of the findings and motivate future classroom-scale and longitudinal studies.

11. Conclusion

This study presented Earthquaker-AI as a hybrid educational model that builds upon an existing robotics-based learning environment by integrating Retrieval-Augmented Generation (RAG) and rubric-based formative assessment to support earthquake preparedness in primary education. By combining experiential STEM activities with AI-mediated, evidence-grounded dialogue and structured evaluation, the system addresses limitations of purely theory-driven approaches by integrating experiential and dialogic learning components.

The results for RQ1 indicate that, under the defined experimental configuration, the RAG architecture enables the system to generate responses that remain closely aligned with retrieved official earthquake safety guidelines. The observed levels of groundedness and accuracy, combined with low hallucination rates, suggest that constraining generation to verified instructional sources can enhance reliability in safety-critical educational contexts. These findings highlight the potential of RAG as a pedagogically bounded mechanism for AI-assisted interaction within controlled educational settings.

The results for RQ2 show that AI-based rubric scoring can provide stable and reproducible formative assessment, with model capacity influencing performance. The Large Language Model (LLM) achieved higher rubric-level accuracy than the Small Language Model (SLM), while both models exhibited high consistency across repeated evaluations. These findings indicate that, when guided by explicit rubrics and evidence, language models can support structured educational assessment rather than producing unstructured or inconsistent grading outputs.

Overall, the findings indicate that an evidence-based AI architecture can support structured learning interactions and rubric-based evaluation in primary-school earthquake education. The combination of RAG-grounded dialogue, rubric-driven evaluation, and age-appropriate feedback provides a scalable and transparent framework for the use of artificial intelligence in disaster-preparedness education. In line with recent discussions on both the opportunities and risks of LLMs in education, the present study demonstrates that constraining generative models through evidence

retrieval and explicit rubrics can support pedagogically controlled deployment. Future work will focus on classroom-scale experimentation and the longitudinal examination of learning outcomes across different educational levels.

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AI and AE: Aristotelian Virtue Ethics at the Core of the Ethical Use of Artificial Intelligence in Lower Secondary Education

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Abstract—The rapid integration of Artificial Intelligence (AI) into education constitutes not merely a technological development but a profound anthropological and pedagogical transformation reshaping learners' relationships with knowledge, truth, judgment, agency and community. Although contemporary institutional frameworks (AI Act, EU Guidelines, National Documents) emphasize risk mitigation, human oversight, fundamental rights, they largely remaining external to ethical formation in lived school practice.

This study addresses a clear scientific gap: the absence of a coherent pedagogical model capable of foregrounding how AI ethics is understood and explicitly enacted in classrooms. It is, thus, situated within the genre of conceptual research as it advances theory through normative reasoning, philosophical analysis and interpretative engagement with institutional and educational discourse rather than empirical investigation.

The main aim of the study is to propose a reflective, virtue-based pedagogical and philosophical model for AI Ethics Education in secondary education that integrates critical understanding of AI into the core of the educational process addressing AI ethical dilemmas and supporting the holistic development of the school community. It seeks to: a. synthesize Aristotelian virtue ethics with contemporary AI ethics discourse and pedagogical theory, b. propose the *in situ* co-creation of an Internal School Code of Digital Ethics (ISCDE) as a humanistic guide for cultivating Digital Phronēsis-Prudence, c. elucidate the Code's pedagogical logic as a tool for responsible AI use, teacher professional empowerment and collective ethical culture formation.

The model integrates Aristotelian virtue ethics -*mesotēs, hexis proairetikē and phronēsis*- (virtue as mean, habituation by deliberative choice, practical prudence) drawing on Aristotle's *Nicomachean Ethics (NE)*. This foundation is extended through Techno-moral virtues theory, Critical Pedagogy, Multiple Intelligences, Social Constructivism, Holistic Learning and the methodological use of Critical Discourse Analysis and Thematic Analysis. Two school textbooks -the *Anthology of Philosophical Texts* and *Euripides' Helen* serve as pedagogical anchors. The above Aristotelian theory alongside the ontological dilemma of *εἶναι–φαίνεσθαι* (being-appearing) in *Helen* is reinterpreted in relation to AI verisimilitude, demonstrating the central role of humanities subjects in cultivating ethical judgment within digital education.

Methodologically, the model follows a three-phase conceptual process: Critical Discourse Analysis of official AI texts by teachers as institutional moral literacy; thematic synthesis of values re-signified as virtues; classroom "scenarios" enabling experiential AI habituation. Institutional values are transformed into digital virtues articulated as means between AI deficiency and excess and embodied in the ISCDE, a

co-created ongoing pedagogical artifact. An example is given on Digital Liberality, where prompt sharing and attribution practices shift AI use toward communal epistemic contribution.
Expected outcomes are multilevel: students cultivate Digital Prudence, moral judgment, balanced AI use and critical agency; teachers develop institutional literacy and professional confidence; schools foster a shared ethical culture of AI governance.
Policy recommendations to the Institute of Educational Policy involves advocating the institutionalization of AI Ethics Education as a cross-curricular priority, the integration of Aristotelian ethics and humanities-based reflection into curricula and the strengthening of teacher institutional literacy. The originality of the study lies in defining Digital Phronēsis as a new educational competence for human-centered education in the AI era.
Keywords—AI, ethical dilemmas, School Code, Aristotelian Ethics, mesotēs-mean, digital prudence, CDA, conceptual paper, Greek secondary education

1. Introduction

Rationale, Main Aim, Objectives

The rapid integration of Artificial Intelligence (AI) into educational environments constitutes not merely a technological development but a profoundly anthropological and pedagogical event reshaping the relationship of the stakeholders with knowledge, truth, and community (Gouseti et al., 2025; Nguyen et al., 2022). Contemporary institutional discourse increasingly acknowledge the ethical dilemmas and challenges associated with AI use in education. Education is explicitly classified among "high-risk" domains due to AI implications for fundamental rights, non-discrimination, data protection and human oversight (Eur.Com., 2021, pp. 6-9; Eur.Parl., 2024, Annex III, Floridi et al., 2018). Although the National Opnion and Report texts emphasizes the distinction between AI education and education *for* AI charting AI ethical axes (HNBTC, 2025a,b), most policy-institutional approaches remain oriented toward regulation and risk management, lacking to integrate the ethical formation and pedagogical meaning of AI use in school practice explicitly (Ghimire & Edwards, 2024; Stamboliev & Christiaens, 2024). Such approaches frequently detach technology from the meaningful purposes of learning as they fail to cultivate students' sense of responsibility and critical consciousness (Selwyn, 2019). Within this context, a re-orientation of pedagogical discourse becomes necessary: a shift from regulation toward the internal cultivation of ethical judgment and responsible action through the educational process itself (Freire, 1998).

On the other hand, as for the Secondary Education where students simultaneously shape cognitive autonomy, moral judgment, psycho-emotional maturation and digital competence, research reveals phenomena of youth's moral blindness (Bougia, 2024) and students' naïve assumptions regarding AI objectivity (Gouseti et al., 2025) as well as risks of intellectual atrophy, surface learning and the fossilization of practices (Smyrnaiou et al., 2023; Mylonaki, 2025). Such conditions, when exist, threaten Holistic Learning (cognitive, critical, ethical, psycho-emotional, social) undermining balance and interconnectedness (Miller, 2019) as well as interpersonal and intrapersonal intelligence (Gardner, 1999). At the same time, it is argued that students and teachers's freedom of action and thought can be affected by the use of AI (Arvanitis & Papadopoulou, 2024). Teachers, confronted with the complexity of intelligent technologies, report insufficient training (Varmazi & Kaskalis, 2024) and high levels of anxiety and insecurity due to difficulties managing emerging ethical challenges (Mylonaki, 2025). Further evidence confirms a significant gap in AI ethics education in schools worldwide, in particular, how AI ethics is understood and enacted in classrooms underscoring that ethics must be taught explicitly rather than assumed (Gouseti et al.; Dabbagh et al., 2024).

Contemporary debates in AI Ethics stress that in contexts of uncertainty and rapid change technical safeguards alone are insufficient. An ethical framework is required that foregrounds judgment and the ethical agency of all participants in the learning process by cultivating techno-moral virtues (Vallor, 2016). It is further argued that a balanced approach informed by classical philosophical thought could enable an ethically grounded transformation of education (Karpouzis, 2024).

From this "double" perspective, the present paper is expressly situated within the framework of conceptual papers, as it presents neither field research nor a systematic literature review. Conceptual studies aim to advance theory by integrating normative reasoning, philosophical analysis and interpretative engagement with existing discourses in order to propose new models or frameworks (Jaakkola, 2020). Thus, seeking to address a clear scientific gap, this approach proposes a conceptual and

reflective synthesis of a systematic model for AI Ethics Education in schools that interfaces institutional discourse about AI ethics with in-school ethical formation. Rather than sterile regulation or prohibition, it proposes the *in situ* co-creation by teachers and students of an Internal School Code of Digital Ethics (ISCDE) for AI use as a pedagogical tool for navigating ethical dilemmas and supporting holistic learning practices. It is strongly grounded on Aristotelian Virtue Ethics Theory further strengthened by contemporary Techno-Ethic Virtues Theory, Critical Pedagogy, Social Constructivism and Holistic Learning. The selection of these theories reflects the need for a coherent pedagogical and philosofical approach that connects knowledge with value and technology with the humanistic purpose of education (Biesta, 2010).

Additionally, the choice of co-creating an In-school Code of Ethics is fully aligned with contemporary european and national orientations for AI in education. Current policy frameworks emphasize that effective AI integration requires strengthening human agency and cultivating critical engagement among both teachers and learners (UNESCO, 2023; HNBTC, 2025a). Within this perspective, the ISCDE does not function as a static regulatory text but as a process which "builds shared language around values and establishes participatory norms through the very act of jointly constructing expectations and responsibilities into lived school practice" (UNICEF, 2023:2; Stárek, 2020).

Accordingly, a central tenet of the present study is the premise that AI ethics cannot be taught as an external set of rules but must instead be acquired *in situ*, within real school settings, as a process of ongoing collective meaning-making and reflection (Vallor, 2016; Vygotsky, 1978). Within this context, our educational model is indeed pedagogically coherent with the existing curriculum since its philosophical grounding draws upon two taught textbooks: the ***A**nthology of **P**hilosophical **T**exts* and the *Dramatic Poetry: Euripides' Helen.* Aristotle's doctrine of the mean/*mesotēs*, *phronēsis* and *hexis proairetikē* in *Nicomachean Ethics* (Stefanopoulos et al. n.d; Aristotle, *NE,* II.6, 1106b36-1107a2*)* alongside the ethical dilemma of "being and appearing" (*εἶναι-φαίνεσθαι*) in *Helen* (Desypris et al., n.d) offer a diachronic cognitive tool for exploring core principles of human life, virtue, truth and moral action as a conscious and responsible choice oriented toward *eudaimonia*/*εὖ ζῆν* (flourising). The present model states that the re-interpretation of these Ancient Greek concepts within the contemporary AI digital environment will enable the formulation of the notion of "*Digital Phronēsis*" as a central *virtue* for the responsible use of AI in school contexts (Kristjánsson, 2024).

Therefore, the main aim of this paper is to propose a reflective, virtue-based pedagogical and philosophical model for AI Ethics Education in secondary education, which integrates a critical understanding of AI into the core of the educational process so as to effectinely address the ethical dilemmas and challenges emerging in the AI-mediated school environment and achieve, thereby, the holistic development of the school community.

The study pursues the following interrelated objectives:

1. To present a coherent conceptual framework that synthesizes the Aristotelian ethical discourse on Virtue with the contemporary scholarly discourse of AI ethics and pedagogical principles.
2. To propose and described the *in situ* co-creation by teachers and students of a virtue-based Internal School AI Code of Ethics-to-be, associated with institutional and ancient greek moral discourse, as a humanistic guide for fostering AI Digital Phronēsis (prudence) in education (*NE* II–VI; Vallor, 2016).

3. To elucidate the code's internal logic as a pedagogical tool that supports AI responsible use for students' holistic development, teachers' professional empowerment and the collective transformation of the school community on the basis of the new digital ecosystem (HNBTC, 2025a).

2. Conceptual Framework of the Proposal - Literature Review

2.1. Aristotelian Virtue Ethics and *Helen* as Normative Foundation

Aristotelian virtue ethics theory is foregrounded as the most timely "operating framework" for navigating the complexity of contemporary education (Mary et al., 2025). Aristotle states that morality is not rule compliance but the cultivation of stable dispositions (hexeis/ἕξεις)) oriented toward human flourishing (eudaimonia) (*NE* II.5, 1105b25-1106a13). Virtue is defined as a state concerned with choice, lying in a mean relative to us, determined by reason and by the person of practical prudence, phronisis (*NE* II.6, 1106b36-1107a8). Ethical evaluation of AI use, thus, concerns whether it supports or undermines the learner's development as a moral and intellectual agent (*NE* I.7, 1098a16-18).

Habituation further highlights the pedagogical dimension: virtues are formed through repeated practice within a community rather than abstract instruction (*NE* II.1, 1103a14-25). Accordingly, the proposed In-school Code of Ethics functions not as regulation but as a pedagogical structure for cultivating digital virtues. Responsibility remains with the human agent, not with the AI systems, as Aristotle would argue (*NE* VI.5, 1140b20-23).

In particular, *Mesotēs, phronēsis* and *hexis prohairetikē* provide the ethical grammar for AI use. Virtue as *«ἕξις προαιρετική ἐν μεσότητι οὖσα»* (a stable disposition that involves conscious choice and lies in the mean) resides between excess and deficiency and clarifies that ethical action involves reasoned choice grounded in character (*NE* II.6, 1106b36-1107a8; III.2, 1112a15-20). In parallel, the notion of *phronēsis* (practical prudence) highlights the need for responsible, reflective decision-making under conditions of moral complexity oriented toward the ultimate end (*telos*) of *eudaimonia* (*NE* VI.5, 1140a25-b5; 1140b20-25). Unlike technē or epistēmē, it doesn't produce objects or necessary truths but regulates action in contingent contexts. These concepts gain particular relevance in the digital age, where algorithmic objectives often diverge from human teleological aims, as "AI systems… lack fundamental aspects… such as the capacity to acquire virtues… including practical prudence, justice, and courage" (Ober & Tasioulas, 2024, p. 33). From this point of view, the Code of Ethics operationalizes these concepts: mesotēs identifies extremes, phronēsis guides interpretation in context and hexis captures the enduring formation of responsible inclinations. Therefore, it provides a conceptual lens for avoiding both technophobic rejection and uncritical technological excess through morally reasoned choice.

Aristotle's conception of virtue as *mesotēs* offers a normative structure for navigating ethical extremes in technologically mediated contexts (Mary et al., 2025). This framework becomes especially salient when it comes for the extrime premises like Vaccari and Chadwick's (2020) on deepfakes and Lodge et al.'s (2023) on the verisimilitude (*alēthofaneia*) of language models, that educational reality is at risk of

being colonized by synthetic artifacts that mimic reality so persuasively that the distinction between 'appearance' (digital representation) and 'reality' (empirical truth) becomes increasingly arduous for students. A striking literary prefiguration of this condition appears in Euripides' *Helen*. In the drama, the Trojan War is waged not for Helen herself but for an *eidōlon*, a persuasive phantom sent to Troy while the real Helen remains elsewhere. Euripides, thus, stages an ontological rupture collapsing the distinction between φαίνεσθαι (seeming) and εἶναι (being) and demonstrating how collective action may be organised around representations lacking ontological truth (Euripides, *Helen*, vv. 31-36, 582-88). This dramatic logic anticipates the epistemic threat posed by deepfakes and synthetic media, where hyper-realistic audiovisual artefacts undermine the reliability of visual evidence and produce tangible social consequences despite their fabricated status (Chesney & Citron, 2019; Rini, 2020). Where Euripides exposes the ontological "shock" of deceptive appearance, Aristotle provides the ethical mechanism for navigating such instability. In a deepfake environment, therefore, digital *mesotēs* does not simply imply technological minimalism but purpose-oriented engagement -avoiding both technophobic refusal (deficiency) and naïve trust in algorithmic outputs (excess), a stance consistent with virtue-oriented approaches to technology ethics (Vallor, 2016).

2.2. Vallor: Virtue Ethics for Technology

Digital Ethics or Techno-ethics is framed as an essential 21st-century competence, together with metacognition, adaptability, creative observation and the capacity for multitasking (Smyrnaiou et al., 2023). Vallor (2016) extends Aristotelian virtue ethics to technological environments arguing that rule-based ethics is insufficient under AI-driven uncertainty. Technology shapes character; thus, *ethical agency* (capacity to act, moral sensitivity, development by means of practice) depends on cultivating techno-moral virtues (Vallor). She emphasizes practical prudence as the capacity to balance competing goods and highlights education's responsibility in sustaining this cultivation. Virtues emerge within communities of practice. The ISCDE, therefore, functions as a collective educational artifact, aligning the school with the Aristotelian *polis* oriented toward the common good (*NE* I.2, 1094b7-10). This perspective supports the shift toward digital virtue formation.

2.3.

2.3.1. Freire: Critical Pedagogy and Moral Agency

Freire's critical pedagogy frames AI Ethics Education as moral agency rather than passive reception. The "banking model" fosters epistemic dependence while dialogical education cultivates critical consciousness (Freire, 1998). Learners must "interrogate" AI system and assume responsibility for ethical choices. Dialogue legitimizes the co-creation of the Code of Ethics, positioning teachers and students as co-investigators. Freire, thus, provides the emancipatory pedagogical conditions for exercising phronēsis and prohairesis (Attwood, 2025).

2.3.2. Holistic Learning, Multiple Intelligences and Social Constructivism as Pedagogical Bridges

Howard Gardner's theory of Multiple Intelligences complements the ethical framework by emphasizing the plurality of human cognitive capacities and rejecting reductionist conceptions of intelligence. Learning unfolds through diverse modalities -linguistic, logical, interpersonal, intrapersonal- supporting holistic development (Gardner, 1999). This is crucial for AI Ethics Education, which must engage the full spectrum of human capacities rather than privileging purely technical skills.

Gardner further emphasizes that education must foster cognitive and moral growth holistically. Within this model, AI use is situated in a framework of human flourishing, supported by socio-constructivist pedagogy. Vygotsky (1978) similarly argues that knowledge is socially co-constructed; moral understanding emerges through collective reflection rather than rule transmission.

These perspectives ground the co-creation of the Code of Ethics as a dialogical and communal process, aligned with Freire's pedagogy and Aristotelian habituation (Freire, 1998; *NE*, II.1, 1103a14-25). The Code functions as a scaffold for internalizing moral dispositions, enabling learners to integrate AI into the pursuit of eudaimonia tsansforming regulatory compliance.

2.3.3. Coherence of the Integrated Ethical-Pedagogical Framework

The above framework integrates philosophical ethics and educational theory into a unified model. Aristotelian ethics provides the normative foundation through mesotis, prohairesis and phronēsis, oriented toward eudaimonia. Vallor extends this to technological contexts by emphasizing techno-moral virtues for navigating AI-related uncertainty. Freire contributes the emancipatory dimension, cultivating moral agency through dialogue and critical consciousness. Gardner and Social Constructivism supply the pedagogical architecture for holistic learning.

Together, these perspectives legitimize the ISCDE as a pedagogical artifact translating ethical principles into lived norms. Therefore, ethical engagement with AI extends beyond "proper use" and becomes a collective practice of reflection, through which teachers and students discuss AI ethical dilemmas, analyze them underlying values and critically re-signify them pedagogically (Wodak & Meyer, 2015; Braun & Clarke, 2006). In the end, it moves toward the sustained cultivation of the virtue of *digital phronēsis* (prudence).

2.4. Conceptual Proposal

2.4.1. Conceptual Method - The Role of Critical Discourse Analysis (CDA) and Thematic Analysis in Shaping the Code of Ethics

The present study adopts a conceptual and reflective synthesis rather than an empirical research design. It seeks to construct a transparent chain of reasoning linking AI institutional governance discourse, Ancient Greek virtue ethics and contemporary pedagogical theory and practice. The methodology adopted in this study is outlined in three phases as follows:

Initially, the ISCDE is preceded by two phases in which Critical Discourse Analysis (CDA) and Thematic Analysis operate as professional practices of ethical

interpretation. In Phase I: CDA is proposed to function as a form of institutional moral literacy enabling educators to examine how AI potencial and ethical values are constructed and hierarchized in AI policy texts (Panagiotou, 2025). Drawing on the discourse-historical approach (Wodak & Meyer,), teachers analyze four institutional documents as normative artifacts (Table I): *Ethics Guidelines for Trustworthy AI (Eur.Com., 2021), AI Act (EPCEU, 2024), Opinion of the Hellenic National Bioethics and Technoethics (HNBTC, 2025a), Report on the applications of artificial intelligence in Greek schools (HNBTC, 2025b)*. Policy texts require "active interpretation and translation by practitioners during enactment, rather than functioning as neutral directives" (Bagley & Shiekh, 2018, p. 2). Here, CDA supports critical judgment beyond formal regulation (Fairclough, 2013) generating theoretical framings of ethical issues.

In Phase II: a thematic synthesis of value claims follows in line with Braun and Clarke (2006). The themes emerged are introduced to students in the classroom and re-signified through Aristotelian teleological ethics (*mesotis, hexeis, phronēsis*) and *Helen's* concept of *true* moving the focus to the cultivation of virtues oriented toward *eudaimonia* (NE, II–VI). In this way, institutional discourse of ethics is transformed into the pedagogical core of the ISCDE, since it is bridged with the articles and principles of the Code which are co-created by the educational community.

In Phase III: Once the students have theoretically conceived the significance of digital prudence, it is proposed that 'scenarios' be designed and implemented in the classroom to foster digitally prudent students (Smyrnaiou et al., 2023). This involves enriching the Code of Ethics with articles, principles and solutions derived directly from the students' own experiences and attitudes towards AI.

In the context of the present study OpenAI's ChatGPT and Google's Gemini were employed with due diligence to construct explanatory tables. These models were prompted with relevant scientific content as detailed in the following sub-sections.

2.4.2. Structure and Logic of the Code of Ethics

The structure of the proposed ISCDE is explicitly grounded in the Aristotelian architecture of virtue complemented by *Helen's True*, organizing each article as a "mean" between two extremes -excess and deficiency. Each article follows a tripartite format: first, it names the moral virtue/mean; second, it identifies the opposing extremes that threaten balance; third, it formulates the digital virtuous mean as a pedagogical practice. In this way, the Code functions as a dynamic moral compass that renders tensions visible and discussable. It explicitly operationalizes the intellectual virtue *phronēsis*, enabling students and teachers to interpret principles in light of circumstances rather than apply them mechanically (Gillespie, 2002).

Pedagogically, this approach aims at the gradual formation of *hexeis proairetikai*, stable dispositions grounded in reasoned choice rather than impulsive behavior or external compulsion (*NE,* III.2, 1112a15-20). Students are guided to understand why certain uses of AI support autonomy. The Code is, thus, conceived as a living, revisable artifact that bridges philosophical ethics with everyday practice and lived experiences, ensuring that AI is integrated not as a threat but as a technological mediator (Vagelatos et al., 2025) consistently oriented toward human flourishing (Aristotle's *eudaimonia*).

2.4.3. Unified Value Matrix Derived from Institutional AI Governance Discourse

After identifying the potential of AI tools (eg. Personalization and Engagement, Accessibility and Inclusion, Teacher Effectiveness, Innovative Teaching Methodologies, and Scientific Research in Table 1a,b), the construction of the ISCDE begins with consolidating ethical values identified through CDA into a unified value matrix. This matrix (Table 1b) functions as an intermediate conceptual layer between institutional norms and their pedagogical articulation ensuring both normative legitimacy and educational relevance. Across the AI Act, HLEG-AI, EETH Opinion and Report a convergent set of ethical values, dilemmas and challenges emerges despite differing discursive registers:

Institutional Text	Key Ethical Challenges & Dilemmas (CDA)	Dominant Ethical Principles / Axiological Positions	Emerging Value-Based Themes (Thematic Analysis)	Pedagogical Translation (Basis for the Code)
EU Artificial Intelligence Act (2024/1689)	Education as a "High Risk" sector; tension between innovation and protection of minors; risks of automated decision-making	Protection of fundamental rights, non-discrimination, human oversight, accountability	Dignity, Justice/Equity, Human Oversight, Responsibility.	Necessity to cultivate critical judgment and phronēsis regarding AI use in schools
Ethics Guidelines for Trustworthy AI (HLEG, 2021)	Ethical trade-offs between principles; shift from compliance to continuous ethical judgment	Human agency, prevention of harm, transparency, fairness	Autonomy, Transparency, AccountabilityBeneficence	Transformation of principles into embodied pedagogical practices and virtues
Opinion of the EETH for AI in Greek Schools (2025)	Risk of heteronomy; weakening of critical thinking; instrumentalization of learning	Human dignity, pedagogical responsibility, ethical agency	Dignity, Critical Thinking, Pedagogical Responsibility.	Empowerment of the educator's role as an ethical mediator
Report of the EETH: AI in Greek Schools (2025)	Privacy, inequalities, loss of pedagogical meaning	Equity, transparency, inclusivity	Inclusion, Transparency, Collectivity.	Need for in-school, participatory ethical frameworks

Table 1a: Critical Discourse Analysis. AI potencial; From Institutional Texts to the Value-Based Themes of the In-school AI Code of Digital Ethics

Advantage Category	Institutional Source	Specific Reference / Section	Interpretation
Personalisation & Learner Participation	EU *Ethical Guidelines for Educators on using AI and data in teaching and learning*	Guidelines mention *adaptive learning technologies* and *individualised teaching for pupils with differentlevels of knowledge* relevant to personalised support for learners (e.g., tailored essay assessment, adaptive chatbots)	This reflects *personalisation* as an educational benefit: AI enables teaching to be responsive to individual learners' needs.
Accessibility & Inclusion	Council of Europe: *Artificial*	AI "has the potential to play a transformative role in achieving accessible, inclusive	Highlights how AI can support diverse learners and reduce exclusion

	Intelligence and Education	and equitable education for all learners."	
Instructional Efficiency for Educators	EU Commission *Ethical Guidelines for Educators on using AI and data in teaching and learning*	Guidelines support teachers (especially with little experience) in *ethical and practical use of AI*, implying time savings and pedagogical support	Implicit relief to teachers' workload and improved pedagogical support
Innovative Teaching Methods & Research	Council of Europe *Artificial Intelligence and Education*	Council emphasises *real-time feedback* and *innovative methodologies* in education via AI systems	Recognises advanced teaching practices and pedagogical innovation enabled by AI
Digital Skills & Competence Formation	EU *AI Act*	Deployment of AI systems *promotes high-quality digital education and allows learners to acquire digital skills* necessary for participation in society	Explicit link between AI use, acquiring digital competence and broader social participation
Ethical & Safe Use with Trustworthiness	EU *AI Act* / Trustworthy AI principles	The Act's overall aim is promoting trustworthy, safe and human-centric AI across sectors, including education, which supports ethical AI adoption.	Establishes an ethical, rights-based context for AI integration into education, which enables responsible pedagogical use rather than unfettered risk.

Table 1b: AI potencial in education. Other EU texts

Human dignity protects students from instrumentalization (Smyrnaiou, & Psarri, 2016); autonomy addresses the risk of cognitive displacement by algorithmic systems; justice and non-discrimination respond to algorithmic bias; transparency and explainability enable critical engagement; accountability preserves human responsibility; human oversight, prudence and proportionality resonate with Aristotelian mean and practical prudence. Within this framework, institutional values are transformed into principle-articles of the Code, articulated hexeis.

2.4.4. From Values to Virtues: The Logic of Ethical Transformation

Mapping Institutional Values to Articles of the In-school Code of Ethics

The transition from the unified value matrix to the In-school Code of Ethics follows a deliberate ethical–philosophical transformation grounded in Aristotelian virtue ethics:

Sphere of Action or Feeling	Deficiency (The Less)	Mean (The Virtue)	Excess (The More)
Fear and Confidence	**Cowardice** *(Deilos)*	**Courage** *(Andreia)*	**Rashness** *(Thrasos, (Excess of confidence)*
Pleasures and Pains	**Insensibility** *(Anaisthetos)*	**Temperance** *(Sophrosyne)*	**Self-Indulgence / Licentiousness** *(Akolasia)*
Getting and Spending (Minor)	**Meanness / Illiberality** *(Aneleutheria)*	**Liberality** *(Eleutheriotes)*	**Prodigality** *(Asotia)*

Getting and Spending (Major)	**Niggardliness / Pettiness** *(Mikroprepeia)*	**Magnificence** *(Megaloprepeia)*	**Vulgarity / Tastelessness** *(Apeirokalia / Banausia)*
Honor and Dishonor (Major)	**Pusillanimity / Small-mindedness** *(Mikropsychia)*	**Magnanimity / Great-souledness** *(Megalopsychia)*	**Vanity** *(Chaunotes)*
Honor and Dishonor (Minor)	**Unambitiousness** *(Aphilotimos)*	**Proper Ambition** *(Unnamed mean)*	**Ambition / Over-ambition** *(Philotimos)*
Anger	**Inirascibility / Spiritlessness** *(Aorgesia)*	**Good Temper / Patience** *(Praotes)*	**Irascibility** *(Orgilos)*
Social Intercourse (Truth)	**Mock Modesty / Irony** *(Eironeia)*	**Truthfulness** *(Aletheia)*	**Boastfulness** *(Alazoneia)*
Social Intercourse (Humor)	**Boorishness** *(Agroikia)*	**Wittiness** *(Eutrapelia)*	**Buffoonery** *(Bomolochia)*
Social Intercourse (Friendliness)	**Cantankerousness / Surliness** *(Duseris / Duskolos)*	**Friendliness** *(Philia)*	**Obsequiousness** *(Areskos - with no ulterior motive)* **Flattery** *(Kolax - for gain)*
Passions (Shame)	**Shamelessness** *(Anaischyntos)*	**Modesty** *(Aidemon)*	**Bashfulness** *(Kataplex)*
Feelings regarding others' fortunes	**Malice / Spitefulness** *(Epichairekakos)*	**Righteous Indignation** *(Nemesis)*	**Envy** *(Phthoneros)*

Table 2a. Aristotle's Mesotēs (*NE*, II.6, 1106b36-1107a8)

The model re-articulates the ethical themes emerged by the official documents as virtues understood through the logic of mesotēs. Each value, thus, undergoes a twofold translation (Table 2b). First, values are re-conceptualized as moral dispositions; for instance, autonomy becomes the cultivated capacity for reflective choice, while human oversight is reframed as the exercise of phronēsis.

Institutional Value Theme	Ethical Tension (highlighted in institutional texts)	Aristotelian Mean (Digital Virtue)	Deficiency (Ellipsis)	Excess (Hyperbole)	What it regulates in the school context
Human Dignity	Risk of student instrumentalization by algorithmic systems	Digital Courage (Andreia)	Resignation from personal thought – intellectual dependence on AI	Arrogant self-sufficiency, refusal to cooperate	Cultivates responsible intellectual effort and moral agency
Autonomy / Human Oversight	Tendency to delegate judgment to the	Digital Practical Prudence	Blind trust in algorithmic outputs	Technophobic rejection	Supports context-sensitive moral judgement before

Institutional Value Theme	Ethical Tension (highlighted in institutional texts)	Aristotelian Mean (Digital Virtue)	Deficiency (Ellipsis)	Excess (Hyperbole)	What it regulates in the school context
	machine	(Phronesis)			AI use
Justice/Non-discrimination	Algorithmic bias and unequal access	Justice as a Habit of Communitarian Measure	Indifference to inequalities	Indiscriminate hyper-egalitarianism	Balances equal opportunities with personal responsibility
Transparency / Explainability	System opacity	Truthfulness as an Ethical Stance	Passive acceptance of outputs	Irrational suspicion	Encourages epistemic questioning: "How do I know?"
Accountability	Diffusion of responsibility between human and machine	Responsibility (Voluntary Action)	Shifting responsibility to AI	Excessive self-blame	Reinforces conscious assumption of responsibility
Safety / Protection	Protection of minors vs. innovation	Temperance (Sophrosyne)	Digital illiteracy	Digital overconsumption	Regulates proportional AI use
Privacy	Data exploitation	Modesty/Shame (Aidos – Moral Self-Restraint)	Indifference to personal data	Paralysis of fear	Cultivates respect for personal and communal boundaries
Human-Centricity	Replacement of human judgment	Magnanimity as Pedagogical Responsibility	Underestimation of the human role	Excessive anthropocentrism	The educator's role as a guide
Critical Thinking	Superficial learning through AI	Intellectual Diligence	Cognitive sloth	Over- analysis without action	Active cognitive engagement
Common Good / Community	Individualistic use of AI	Civic Friendship (Politike Philia)	Isolation	Collectivist conformity	Collaborative ethical learning

Table 2b.Thematic Synthesis:Transformation into Aristotelian Virtue Framework

Human Dignity as Digital Respect for the Person: A dignity-centered approach treats students as moral agents, promoting balanced AI use that supports learning while safeguarding integrity, privacy, and their developmental vulnerability.

Autonomy as Digital Self-Governance: Autonomy is expressed as reflective self-governance. The mean lies between cognitive outsourcing and technophobic rejection, framing AI as support for, not substitution of student effort and responsibility.

Justice and Fairness Digital Equity: Justice becomes digital equity. Avoiding both biased deployment and blanket prohibition, the mean promotes proportionate, inclusive AI use aligned with equal opportunity.

*Transparency as Intellectual Honesty and Explainability:*Transparency becomes intellectual honesty about AI, encouraging disclosure and critical interpretation, avoiding blind reliance or rigid rejection through reflective, responsible engagement.

Accountability as Responsibility for Judgment: Accountability becomes responsibility for judgment, rejecting both algorithmic authority and disengagement. Moral responsibility remains with human agents.

Human Oversight Digital Phronēsis: Human oversight is reframed as digital phronēsis -context-sensitive practical prudence regulating AI use between overregulation and permissiveness.

Crucially, by linking institutional ethics to pedagogy via the Aristotelian mean, the Code serves education's *telos*: forming autonomous moral judgment. AI use is judged by its role in learner flourishing as a moral agent (*NE* I.7, 1098a16-18; Vallor, 2016). Institutional values, thus, cease to function only as "ready-given" rules and become internalized orientations cultivated through practice.

Second, each virtue is articulated as a mean (*mesotēs*) between two extremes. The virtuous mean as a pedagogically attainable mode of AI use represents an ideal condition relative to educational purpose and context (*NE*, II.6, 1106a26-b7). This structure ensures that the Code operates as a pedagogically actionable orientation seeking deliberation on proportionality (Table 3).

Aristotelian Mean (Digital Virtue)	In-school AI Ethical Code Article	Article Content (Principle)	Prevented Deficiency	Prevented Excess	Pedagogical Function in School
Digital Courage (*Andreia*)	**Article 1 – Principle of Intellectual Effort**	AI does not substitute thought; it is used only after personal cognitive effort.	Flight from effort, cognitive passivity	Self-sufficient isolation	Cultivation of resilience, perseverance, cognitive autonomy
Digital Practical Wisdom (*Phronesis*)	**Article 2 – Principle of the Mean in AI Use**	Every AI use presupposes judgment of purpose, context, and consequences.	Blind trust in AI	Technophobic refusal	Development of practical wisdom and ethical judgment
Justice (Communitarian)	**Article 3 – Principle of Equity and Inclusion**	AI use must ensure equal learning opportunities.	Indifference to inequalities	Leveling egalitarianism	Reinforcement of social justice
Truthfulness as an Ethical Stance	**Article 4 – Principle of Transparency and Critical Interpretation**	AI outputs are examined, substantiated, and questioned.	Passive acceptance of outputs	Irrational suspicion	Epistemic literacy, critical thinking
Responsibility	**Article 5 – Principle of Assumption**	The AI user bears responsibility	Shifting responsibility to the system	Excessive self-blame	Ethical agency and accountability

Aristotelian Mean (Digital Virtue)	In-school AI Ethical Code Article	Article Content (Principle)	Prevented Deficiency	Prevented Excess	Pedagogical Function in School
(*Voluntary Action*)	**of Responsibility**	for the result and its use.			
Temperance (*Sophrosyne*)	**Article 6 – Principle of Regulated Use**	AI is used with measure, not constantly or irrationally.	Digital ignorance	Digital overconsumption	Balance of digital and analog learning
Modesty/Shame (*Aidos*)	**Article 7 – Principle of Privacy Protection**	Personal data of all community members are protected.	Indifference to data	Paralysis of fear	Ethical digital self-control
Magnanimity (Pedagogical)	**Article 8 – Principle of the Educator's Role**	The educator remains the ethical and pedagogical guide.	Underestimation of the human role	Authoritarian control	Pedagogical leadership
Intellectual Diligence	**Article 9 – Principle of Active Learning**	AI supports, does not replace, active cognitive participation.	Cognitive sloth	Overanalysis without action	Deep learning
Civic Friendship (*Politike Philia*)	**Article 10 – Principle of the Common Good**	AI use serves the collective benefit of the school community.	Individualism	Conformity	School as a learning community

Table 3. Aristotelian Means Articles of the In-school AI Code of Ethics

2.5. Aristotelian Ethics - Deepening the Principles of Aristotelian Mean & Prudence in AI-Mediated Education with "senarios-built" articles

An essential part of the ISCDE is the co-creation of articles and solutions-rules through 'scenarios' implemented in the classroom. For the development of an example we drew upon Book IV I (1120a–1121b) of the *Nicomachean Ethics*, in which Aristotle introduces the virtue of Liberality (*eleutheriotēs*) as the *mean* between Illiberality (*aneleutheria*) and Prodigality (*asōtia*). This passage is of particular significance for contemporary discussions concerning intellectual property, open source, knowledge sharing-generosity of spirit and the cost of access to AI technologies (Reddy et al., 2025). At this point, a concise illustrative example of *Digital Liberality* is presented to render Tables 4a-b-c more readily comprehensible: The "Creative Commons" Principle (giving and receiving/*δοῦναι καὶ λαβεῖν*). Aristotle states that the liberal person takes only *"from where one ought"* (*ὅθεν δεῖ*) and gives *"to those to whom one ought"* (*οἷς δεῖ*). The Problem: A "predatory" mindset: taking from AI without acknowledgment and taking from classmates or colleagues without respecting others' work. The pedagogical *praxis*-practice as a Rule: Instruction in licensing practices and proper attribution. Students learn that knowledge constitutes a chain of giving. If one draws

upon AI, this must be acknowledged as this represents the ethically appropriate course of action. A classroom "Prompt Bank" is proposed, where students deposit the effective prompts they have identified for the common benefit.

As can be detected in Tables 4a-b-c, the Code renders the tensions and distortions visible operating *collectively*, linking individual's *praxis* with the ethical community of the *polis* (*NE*, I.2, 1094b7-11).

Aristotelian Distinction	Ancient Greek Rendering	English Rendering	Significance for AI (Connection)
Liberality (Mean)	Μεσότης περὶ χρήματα... μᾶλλον ἐν τῇ δόσει	Mean regarding wealth... primarily in giving	In AI, "wealth" is information/knowledge. The liberal person (Open Source contributor, Wikimedia editor) is one who gives knowledge (prompts, code, experiences) to the community, not one who only takes.
Illiberality (Deficiency)	Μᾶλλον ἢ δεῖ περὶ χρήματα σπουδάζουσι	They take more interest in money/wealth than they ought to	The stance of "closed" systems (Paywalls) or students who keep knowledge to themselves ("I won't tell you how I did it"). They fear sharing; they are stingy with knowledge.
Prodigality (Excess)	Φθείρειν τὴν οὐσίαν... ἀπώλειά τις αὐτοῦ	Destroying one's substance... a sort of self-destruction	The mindless waste of resources (time, data, energy) on AI without benefit. The student who pays for expensive AI tool subscriptions without needing them or "burns" their mind (their substance) on pointless prompts.
Usage (Giving & Taking)	Χρῆσις... δαπάνη καὶ δόσις	Use is spending and giving	True use of AI is not about "taking" (download/consume), but "giving" (upload/create). Whoever only takes merely "possesses" (ktēsis), they do not use correctly (chrēsis).
Love for the Liberal	Φιλοῦνται... ὠφέλιμοι γὰρ	They are loved... because they are useful/beneficial	Students who share their findings with the class ("I found this cool prompt") are beneficial and liked. They build community (Holistic connection).

Table 4a. Ελευθεριότης/Liberality, Prodigality & Illiberality in the Digital Age

Aristotelian Ethical Category	Conceptual Definition	Reinterpretation in AI-Mediated Epistemic Environments	Characteristic Distortion in Educational Practice	Pedagogical Counter-Practice	Normative Educational Function
Liberality (Virtuous Mean)	The virtuous disposition governing the right circulation of resources through appropriate giving	Knowledge, strategies, and prompts function as epistemic capital; learning becomes participatory rather than extractive	Instrumental use of AI as an answer-delivery mechanism	Structured Prompt Sharing: disclosure of process, not only outcome	Reconfigures learners from consumers of cognition to contributors to a shared epistemic ecology
Illiberality (Deficiency)	Restrictive attachment to one's resources; failure in giving	Withholding prompts, methods, or insights; privatization of learning	Epistemic secrecy and competitive individualism	Institutionalizatio n of transparency norms and collaborative knowledge practices	Cultivates epistemic trust and dismantles knowledge-hoarding behaviors

Aristotelian Ethical Category	Conceptual Definition	Reinterpretation in AI-Mediated Epistemic Environments	Characteristic Distortion in Educational Practice	Pedagogical Counter-Practice	Normative Educational Function
		processes			
Prodigality (Excess)	Misuse leading to depletion of one's substance	Cognitive outsourcing without reflection; indiscriminate data exposure	Uncritical surrender of personal data and intellectual agency	Education in data stewardship and digital self-regulation	Preserves learner autonomy and conceptualizes data as moral–educational substance
Use (Giving & Receiving)	Ethical use entails both expenditure and proper giving	AI use is ethical only when embedded in reciprocal knowledge practices	Extraction of AI outputs or peer work without attribution	Teaching attribution ethics, licensing logic, and responsible reuse	Establishes reciprocity as the structural principle of digital knowledge exchange
Being Loved for Usefulness	The liberal person is valued because they benefit others	Epistemic generosity enhances collective intelligence and classroom cohesion	Hyper-individualized performance culture	Development of shared prompt repositories and communal knowledge pools	Reorients learning from competitive accumulation to cooperative flourishing
Motive (The Noble Good)	Action performed for the sake of the noble (τὸ καλόν)	Knowledge sharing grounded in communal benefit rather than metrics	Performative or grade-oriented sharing	Ethical framing of contribution as service to the learning community	Aligns AI-mediated practice with moral purpose rather than instrumental gain
Joy in Giving	Giving with willingness rather than reluctance	Collaboration as a stable disposition rather than compliance	Minimal or coerced participation	Reflective practices reinforcing intrinsic value of contribution	Supports the internalization of generosity as an intellectual virtue
Proper Receiving (Integrity)	Taking only from appropriate sources	Recognition of intellectual origin in AI-assisted work	Normalization of uncredited AI assistance or peer appropriation	Explicit acknowledgment protocols for AI contribution	Anchors digital learning in integrity and accountability

Table 4b. Digital Liberality/Eleftheriotēs, *NE*

Component	Description
The Concept	From "Taking" to "Giving"
	Aristotle states that the characteristic of the liberal person (eleutherios) is to give rather than to take.
The Problem	AI as a "Taking Machine"
	AI is utilized merely as a mechanism for receiving/extracting answers (passive consumption).
The Solution	The Practice of "Prompt Sharing"

Component	Description
	We require students not only to produce the result but to share with the class how they achieved it (i.e. their prompt).
The Ethical Goal	"Grant Knowledge to Your Peers"
.	This practice cultivates liberality (eleutheriotes) and combats illiberality (manifested as secretiveness or hoarding of knowledge)

Table 4c. Open Source: The Transition from "Taking" to "Giving"

3. Conclusion

3.1. Expected Outcomes

The ISDCE is depicted throughout all four tables above. Its ethical guidelines drawn by Aristotle's Ethics offer a framework where AI systems must not merely be powerful but understandable, controllable and aligned with educational ethics (Varmazi & Kaskalis, 2024). The Code is not static, since the school community changes year by year. It warrants rigorous ongoing critical examination so as for the stakeholders to achieve at least the following expected outcomes:

Level	What is Cultivated (Ethical Competence / Hexis)	Pedagogical Outcome	Transformation in Practice	Theoretical Anchoring
Students – Cognitive Level	**Digital Phronesis** (critical AI evaluation)	Capacity to interpret, control, and make sense of AI outputs	From passive acceptance → active cognitive mediation	Aristotle, *NE* VI; Vallor,
Students – Ethical Level	**Meanin AI Use**	Balanced use between dependence and refusal	From technolatry/technophobia → virtuous use	Aristotle, *NE* II
Students – Psycho-emotional Level	**Aidos & Self-restraint**	Respect for privacy and boundaries	From over-exposure → digital self-regulation	Aristotle, *NE* IV
Students – Social Level	**Civic Friendship / Common Good**	Collaborative learning with ethical responsibility	From individualistic AI use → communal learning	Aristotle, *NE* VIII–IX; Freire
Students – Critical Consciousness	**Ethical Agency**	Capacity to question algorithmic authority	From technocratic dependence → ethical reflection	Freire
Educators – Pedagogical Role	**Pedagogical Phronesis**	From tool users → ethical mediators	Empowerment of professional judgment	Aristotle; Schön (reflective practice)
Educators – Professional Confidence	**Digital Competence with a Critical Stance**	Reduction of anxiety and technological insecurity	From fear of replacement → role of a guide	Smyrnaiou et al.; Vallor
Educators – Reflection	**Institutional Literacy**	Understanding of AI policy ethical frameworks	From compliance → pedagogical interpretation	Wodak & Meyer; Braun & Clarke
School –	**Ethical**	Shared language of	From anarchic	AI Act;

Level	What is Cultivated (Ethical Competence / Hexis)	Pedagogical Outcome	Transformation in Practice	Theoretical Anchoring
Institutional Level	**Governance of AI**	values	practices → cohesive ethical culture	HNBTC
School – Learning Community	**Community of Civic Friendship**	Participatory ethical culture	From individual practices → collective responsibility	Aristotle; Freire

Table 5. Expected Pedagogical Outcomes of the AI Ethics Education Model

At the student level, the proposed model is expected to cultivate moral judgment, critical agency and digital *phronēsis* in AI-mediated learning environments. Through engagement with the ISCDE students are gradually guided to understand AI not as a neutral or autonomous system but as one whose outputs require interpretation, evaluation and moral responsibility, leading to strong attitudes favoring accountable AI use (Saklaki & Gardikiotis, 2024). This process mitigates the risk of moral disengagement supporting learner's autonomy and adaptability (Arvanitis & Papadopoulou, 2024) and the development of *Digital Phronēsis*, understood as the capacity to deliberate about appropriate action in concrete technologically mediated situations.

By explicitly framing AI use through the principle of the mean, students can become aware of the affordances of intelligent technologies and, consequently, the foundational ethical challenges they give rise to (about virtue, inclusion, responsibility and truth) and to internalize proportionate practices of AI use. This orientation strengthens moral action and critical thinking in building on academic integrity and authorship through transparency-of-use norms and shared responsibility structures (Macfarlane et al., 2014)

The model is further expected to support students' holistic development by integrating cognitive, ethical, social and emotional dimensions of learning (Smyrnaiou et al., 2020). By embedding moral reflection into everyday classroom practice, students learn to articulate reasons for their choices, justify their use of AI tools and recognize the broader consequences of technological action for themselves and others. Such outcomes align with human-centered approaches to AI Ethics Education that prioritize autonomy, dignity and agency over mere technical proficiency (Vallor, 2016).

For teachers, the proposed framework is expected to support professional empowerment and reflective practice (Schön, 1987). Through CDA they develop institutional literacy, critically interpreting ethical requirements rather than experiencing them as simple sentences (Wodak & Meyer, 2015). Effective teaching requires adaptive interpretation of principles informed by context and professional judgment (Walsh & Wyatt, 2014). They develop increased confidence in engaging with AI digital technologies since the co-creation of the Code of Ethics positions them as co-designers in the classroom (Smyrnaiou & Psarri, 2016). They consolidate their role as facilitators and as moral agents for the responsible and healthy integration of AI tools into everyday educational practice. In the end, the emphasis on *phronēsis* encourages the modelling of practical prudence contributing to long-term professional growth and well-being (Vallor, 2016).

At the school level, the model is expercted to foster a shared ethical culture of AI governance. The Code functions as a unifying reference, transforming the school into a community of moral deliberation in the Aristotelian sense of *koinōnia* (*NE* I.2, 1094b7-11). The participatory process strengthens trust and cultivates a human-centered digital ethos aligned with institutional principles (EU AI Act, Annex III; HNBTC, 2025b). Finally, the model offers a sustainable framework for the adaptive integration of future technologies, reinforcing the school as a learning organization oriented toward human flourishing.

3.2. Contribution and Originality of the Study

This study contributes to AI Ethics in Education by proposing a virtue-based conceptual model grounded in Aristotelian ethics and Critical Pedagogy, repositioning AI from a regulatory system to a pedagogical mediator of ethical deliberation.

Its originality lies in four dimensions. First, it advances a normative shift from rule compliance toward the cultivation of moral dispositions and phronēsis oriented to human flourishing. Second, it reconceptualizes Critical Discourse Analysis and thematic analysis as reflective professional practices through which educators interpret institutional AI governance and translate abstract values into pedagogical orientations. Third, it introduces the In-school Code of Ethics as a co-created artifact structured by mesotēs, transforming principles into virtue-based practices. Finally, the model reasserts the role of humanities-based ethical reflection, showing how classical philosophy and teaching subjects can guide responsible engagement with AI in secondary education.

Limitations of the Conceptual Proposal

This conceptual model lacks empirical validation prioritizing normative clarification over measurement. Additionally, implementation necessitates high teacher reflection potentially hindered by workload constraints (HNBTC, 2025b). Last but not least, a more extensive analysis of both official and ancient greek texts is required to enhance generalizability of the model's internal logic.

Future Research and Policy Proposals

Although conceptual, this study suggests future research paths: piloting the Code's co-creation investigating attitudes and analyzing school culture using qualitative tools (Wodak & Meyer, 2015). Futhermore, a variety of AI "senarios" for schools is about to be published by the author concerning all Aristotelian ethical and intellectual virtues. Policy recommendations for the Institute of Educational Policy include institutionalizing AI Ethics Education as a cross-curricular priority treating School Code of Ethics as a pedagogical tool. Furthermore, integrating Aristotelian Ethics into curricula, strengthening teacher institutional literacy through CDA, fostering humanities–digital ethics synergies and promoting flexible, context-sensitive regulation to embed a living ethical framework within educational communities.

General Conclusions

This study advances a conceptual and pedagogically grounded model for AI Ethics Education in secondary education proposing a shift from prohibition toward cultivating moral judgment at the core of educational practice. It integrates Aristotelian Ethics, particularly the mean/*mesotēs* and prudence/*phronēsis,* with contemporary pedagogy and institutional discourse as a foundation for cultivating *digital phronesis* addressing, thus, the ethical dilemmas and challenges emerging in AI school environments. A central contribution is the Internal School Code of Digital Ethics conceived as a living pedagogical artifact, co-created and dialogically revised (Kotsari & Smyrnaiou, 2025). The Code functions as a scaffold both translating abstract institutional values, such as dignity and accountability, into actionable norms through the logic of the mean and engaging students in collective ethical praxis through scenario-based co-creation guided by practical prudence.

This process is supported by Critical Discourse Analysis and Thematic Analysis, re-conceptualized as reflective practices. CDA reveals value hierarchies while Thematic Analysis pedagogically reframes principles. By framing AI use in light of human flourishing, the model affirms that AI cannot replace human judgment and responsibility, which are rooted in practical prudence and the formation of dispositions (Aristotle, *NE* II.1; VI.8; Vallor, 2016). At the same time, the approach aligns with institutional concerns about AI risks advancing human-centered governance through pedagogical practice.

The Internal School Code of Digital Ethics developed within the school environment introduces our own AI Ethics curriculum and advances a participatory approach in which students and teachers act as *co-designers* of school life. This condition is expected to contribute to teachers' professional fulfilment and emotional empowerment, as it enables them to cultivate learners who are not merely operators of machines but digitally prudent citizens, individuals capable of discerning truth within digital representations and placing technology at the service of human flourishing. Ultimately, this framework seeks to foster the exercise of ethical reasoning and critical agency for the healthy integration of AI into education. It does so through a model of holistic education and learning that embeds classical ethical concepts within the contemporary curriculum, thereby highlighting the enduring significance of the humanities in everyday school life.

In conclusion, the key educational question is not whether AI should be permitted in schools but how schools can cultivate learners and teachers capable of using AI tools with prudence, proportionality and responsibility and concider them as mediators supporting holistic learning practices, guided by humanistic values (Dep.Phil., 2021; Chatzivasileiou, 2023). Future work should examine the model's implementation in real school contexts, explore design-based iterations of Code co-creation and assess how cultivating digital *phronēsis* and *mesotēs* shapes student agency, teacher professionalism and the school's ethical culture.

Level of Analysis	Function at this Level	Methodological Tool	Theoretical Foundation	Produced Output	Added Originality
1.Institutional Discourse	Analysis of AI governance texts (AI Act, EU Guidelines, EETH, National	Critical Discourse Analysis (CDA)	Wodak & Meyer	Identification of value themes and ethical tensions	Transformation of CDA from a research method into a tool for professional

Level of Analysis	Function at this Level	Methodological Tool	Theoretical Foundation	Produced Output	Added Originality
	Strategy)				teacher reflection
2. Axiological Organization	Grouping of thematic values	Thematic Analysis	Braun & Clarke	Catalog of institutional values (dignity, transparency, accountability, etc.)	Linking thematic analysis with pedagogical sense-making
3. Ethical Transformation	Transformation of values into virtues	Aristotelian Teleological Ethics	Aristotle-*NE* (II–VI)	Digital Means (Digital Phronesis, Courage, Temperance, etc.)	Transition from rules → character in AI Ethics Education
4.Codification	Embodiment of virtues into Code articles	Pedagogical Recontextualization	Virtue Pedagogy	In-school Ethical Code	First model conceptualizing the Code as a pedagogical tool rather than a regulatory document
5. Pedagogical Praxis	Application in the school environment	Critical Pedagogy & Constructivism	Freire, Gardner	Participatory co-creation by students and teachers	Transformation of AI Ethics into experiential moral education
6.Educational Outcome	Cultivation of ethical competences	Character Formation	Vallor + Aristotle	Digital Phronesis	Definition of a new educational competence: Digital Phronēsis
7. Systemic Outcome	Transformation of the school community	Community Ethics	Aristotelian Political Friendship (Politike Philia)	School as a community of ethical practice	Connecting AI Ethics with democratic school culture

Table 6. Summary Contribution Matrix

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AI as a Tool for Inclusion: Supporting Differentiated Learning in Foreign Language Classrooms

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Abstract – Heterogeneity of learners, existing social inequalities and divergent learning requirements affect how foreign languages are taught in modern education systems. In most situations, such as the Greek system of education, language achievement gaps are strongly interconnected with socioeconomic status and a possibility of additional out-of-school education. Differentiated instruction within this context can be described as a pedagogical reaction that tries to deal with the differences in the abilities, styles of learning and educational backgrounds of learners.

The recent developments in the sphere of Artificial Intelligence (AI) provide new opportunities to facilitate differentiated learning in the field of foreign language teaching. AI-driven technologies help to support individual learning process, adaptive feedback and flexible learning systems, which react to individual learner profiles. The adaptive learning platforms, conversational agents, and learning analytics can be used to promote learner engagement, autonomy, and language development at the same time and help teachers to track progress and modify instructions.

The introduction of AI to language education attracts critical issues, despite the advantages. The challenges of data privacy and ethics of use, digital divide, and unequal access to technological opportunities might be exploitative of the current inequalities in education unless mitigated by knowledgeable pedagogical planning and policy improvements.

This paper will discuss the possibilities of Artificial Intelligence as an educational support system to support differentiated learning in foreign language education, both its pedagogical worth and its shortcomings in inclusive and equitable education systems.

Keywords: Artificial Intelligence, differentiated learning, foreign language education, educational inequality, inclusive pedagogy.

1. Introduction

The study of foreign languages is one of the central priorities of the modern European educational policy, closely interconnected with multilingualism, social integration, and educational and professional mobility of learners. It is also true that the European EU has been advocating early and systematic education of at least two other foreign languages since the Barcelona European Council (2002), with communicative competence and transversal skills taking priority (European Commission, 2003; Eurydice, 2017). Greek educational system has more or less been following these directions of the policy, as it has shown to have high levels of participation in foreign language education especially in lower secondary education and primary education (Eurostat, 2022). Nevertheless, the quantitative measures of participation are not always associated with the same qualitative results of the learning process, which exposes systemic restriction and ongoing social disparities in language education (European Commission, 2012).

Another issue that has been a major concern in foreign language classrooms is the growing heterogeneity of student population. Students are greatly disparate in linguistic ability, learning style, socioeconomic status, and access to extra private schooling (Tomlinson, 2014). Educational inequalities in the Greek environment are intensified by the widespread use of a private language education, which makes language acquisition highly dependent on the economic means of families and is often not related to the effectiveness of single schooling in this respect (KANEP/GSEE, 2023; European Commission, 2012). In this respect, differentiated instruction turns out to be a pedagogical need instead of an optional one. Differentiation instruction aims to support the diversity of learners and inclusive learning by means of content, learning process, learning outcomes and learning pace (Tomlinson and Imbeau, 2010). However, it is often limited in its systematic application to the area of public teaching due to the high student-teacher ratios, time, and the growth of teachers in planning and assessment (OECD, 2018).

The recent developments in Artificial Intelligence (AI) bring in new opportunities to facilitating differentiated learning in teaching a foreign language. The use of AI-based technologies facilitates individualised learning experiences, feedback systems, and data-driven teaching, which adds to more adaptable and learner-centred learning (Luckin et al., 2016; Holmes et al., 2019). Concurrently, the incorporation of AI brings important issues of data privacy, the ethical use thereof, digital divide, and equitable access, which should be thoroughly addressed pedagogically and policy-wise (Williamson and Eynon, 2020).

This article seeks to analyze how Artificial Intelligence may be used to facilitate differentiated learning in the teaching of the foreign language. It will provide the European and Greek educational background followed by a discussion of the pedagogical principles of the differentiated instruction and then look into the affordances, constraints, and implications of the AI-assisted practices in inclusive and equitable language education.

2. Foreign Languages teaching in Greece and Europe

a. European Policies in Multilingualism

The desire to multilingualism is an issue that an educational policy of the European Union has pursued over 20 years, as a sign of cultural diversity, social cohesion, and economic competitiveness. Another important step in this direction was the Barcelona European Council (2002), which officially set the strategic objective of empowering the European citizens to know at least two foreign languages to speak besides their native language. This policy orientation defined learning foreign language not only as an academic field of study, but as a key life-long learning, mobility, and active citizenship competence (European Council, 2002; European Commission, 2003). In the contemporary era, these competencies are being redefined to include AI-assisted translation and communication tools as part of a modern "AI-literate" multilingualism (Hockly, 2024; UNESCO, 2024).

Along this goal, the majority of the European education systems have implemented mandatory teaching of foreign languages at a very early age, usually when one is in the primary level. The need to study at least one foreign language has become virtually international in the EU member countries, and a second foreign language is gradually being introduced in lower secondary school (Eurydice, 2017; Eurydice, 2023). The goal of these policies is to provide wide and equal access to language learning opportunities even though the level and length of instruction in countries differs widely. Recent strategic frameworks emphasize that such access must now encompass digital equity to ensure that AI-driven language tools do not create a new "technological divide" between European learners (OECD, 2021; European Commission, 2024).

It is in this multilingual system whereby English has become the most popular first foreign language in Europe. In the lower secondary education, over 90 percent of the students learn English, which makes it the most important lingua franca in academic, professional, and transnational communication (Eurostat, 2022). Although such superiority promotes effectiveness of communication and international movement, it has also created issues of language diversity and marginalization of other European and world languages (Grin, 2005). Current research suggests that while Generative AI could theoretically support minoritized languages, its current training data often reinforces the hegemony of English in digital spaces (Williamson & Eynon, 2020).

The European language policies are closely related to the Common European Framework of Reference in Languages (CEFR) to standardise learning outcomes and be able to compare educational systems. Several nations set minimum standards of proficiency of the required education, with B1 or B2 most frequently being the expected level of competence in the first foreign language at the end of lower or upper secondary education (Council of Europe, 2020). These standards focus on practical communicative proficiency and not simply grammatical expertise, which further supports an outcome-based and learner-centered method of language teaching. As AI continues to evolve, the Council of Europe has begun exploring how "digital mediation" through AI agents should be integrated into future CEFR descriptors (Council of Europe, 2024).

b. The Greek Schooling Environment.

The Greek system of education has officially responded to the European policies regarding multilingualism, as it provides foreign language training in all the levels of

mandatory education. Primary education introduces foreign language learning where English is the first foreign language which is continued methodically up to lower secondary education. In this secondary level, the teaching of foreign languages is still mandatory, but the amount of teaching hours and the focus on the curriculum is considerably different based on the school type (Eurydice, 2017; Eurydice, 2023).

On the first tier, there are new reforms that have increased exposure to foreign languages especially English which are part of general trends in Europe of exposure to foreign languages at an earlier age. In lower secondary school (Gymnasium), students must take at least two foreign languages, mostly English as the first foreign language and French or German as the second. The given structure places Greece among Europeans with the highest rates of learning a foreign language at this level of education (Eurostat, 2022).

In spite of these high participation rates, quantitative data also shows significant differences in access and learning outcomes. The results of the European Survey on Language Competences (ESLC, 2011/2012) have shown that around 50 percent of Greek learners attain the independent user level (B1-B2) of the first foreign language by the lower secondary education. Nevertheless, the percentage of those students who have reached the basic or below-basic proficiency levels (A1 or lower) is still high (40 or more), causing some worries as to the effectiveness of the public language education when given to the students without any support (European Commission, 2012). Current pedagogical debates in Greece emphasize that the integration of AI-driven personalized tools could provide the necessary scaffolding to support these lower-performing groups (Nikolopoulou, 2024).

In upper secondary school, these issues are aggravated as great structural inequalities arise between the general and vocational tracks. The teaching of foreign languages remains in the case of General Upper Secondary Education (GEL), and an estimated two-thirds of the students also learn two or more foreign languages, which is also near the European average (Eurostat, 2022). Contrary to that, in Vocational Upper Secondary Education (EPAL), exposure to a second foreign language is highly minimal. The Eurostat data show that less than 1 percent of EPAL students attend school where they study two or more foreign languages, which leaves Greece at the bottom of the list of EU countries in this category (Eurostat, 2022).

The poor availability of the foreign language education in the vocational schools adds to the disparity in learning opportunities and limits the academic and career mobility of the students. Besides, the prevalent use of the use of individual language instruction has a significant impact on the general effectiveness of foreign language instruction in Greece. A big percentage of students are enrolled in the private language schools to cover the lack of instruction time and to attain internationally recognised certifications. This parallel structure supports the socioeconomic disparities because the language achievement of students is frequently reliant on the family resources but not on the ability of the public schooling in isolation (KANEP/GSEE, 2023).

The cumulative implication of these findings is that although Greece shows quantitative achievement in terms of foreign language provision, there is no qualitative achievement that is even tangible. The issues of structural constraints, distinction of access in educational tracks and reliance on personal education still serve as obstacles to the

ideals of equity and efficacy in the learning of foreign languages. Addressing these gaps in 2026 requires a systemic shift towards AI-enhanced differentiated learning to ensure that high-quality language support is available to all students, regardless of their socioeconomic background (OECD, 2024).

3. Educational Inequalities in the Foreign Language Learning due to Private Sector.

The role of the private sector in the achievement of foreign language learning in Greece is predominant since the sector runs parallel to the state education system and largely determines the linguistic achievements among the students. Language schools *(frontistiria xenon glosson*) have been an important part of language learning, offering intensive training, exam preparation and international language certifications. Consequently, foreign language education in Greece usually exists in a dual system, whereby the state school system exists alongside a vast amount of privatization (European Commission, 2012; KANEP/GSEE, 2023).

The economic statistics indicate the magnitude and the continuity of personal investment in foreign language studies. Recent statistics show that the household spending on foreign language learning in Greece is higher than EUR 750 million a year, which is more than spending on general private tutoring of core academic subjects (KANEP/GSEE, 2023). A sizeable percentage of this spending involves the learners at primary and lower secondary education implying that families spend on private language training long before they set certification as a clear objective. This tendency indicates a general attitude that the state system of education is not capable of providing high rates of language proficiency, especially higher levels (B2-C1) of it (Birbili, 2015).

This dependence on individual language education is what has been termed as high performance with an asterisk. Surveys conducted internationally, like the European Survey on Language Competences (ESLC) show that the Greek students are average in terms of in the first foreign language compared to their European counterparts. Nevertheless, such outcomes cannot be related solely to the public schooling as a significant percentage of students get the systematic kind of the assistance on a privative basis (European Commission, 2012). In turn, the seeming national achievement in language proficiency hides the presence of large inequalities between the students who can invest in extracurricular education and those students who use the school-based approaches to learning only.

These processes have far-reaching social and pedagogical implications. Socially, independent language education strengthens the existing socioeconomic disparities, with the children belonging to the families with low income being disadvantaged structurally in their access to the high-quality language learning opportunities. Closely connected to the educational progression, employability, and mobility, language proficiency becomes unevenly distributed among the socioeconomic groups (OECD, 2018). Pedagogically, the prevailing dominance of exam-driven private teaching affects the perception of learners towards language education, in such a way that they value certification more than communicative proficiency and significant interaction with the language.

Furthermore, the coexistence of the public and the private systems exert more pressure on the education of teachers in the public schools, who have to deal with the most heterogeneous classes, where the level of proficiency of students is not evenly distributed because they are not equally exposed to external support. This makes instructional planning and assessment difficult and it restricts the ability of the public education system to act as an equalising force. In that regard, systematic actions that promote the quality of the public teaching of foreign languages and decrease the reliance on the individual one should be concerned with the mitigation of the educational disparities in this area. Modern research suggests that the strategic integration of AI in public schools could act as a structural equalizer, providing the high-level support traditionally found in the private sector to all learners.

4. Differentiated Learning in Foreign Language Education

a. Theoretical Framework

The concept of differentiated learning is based on the understanding that learners are extremely diverse in terms of their background knowledge, learning ability, learning styles, interests and learning motivation as well as social cultural backgrounds. Unlike homogeneous, one-size-fits-all models of instruction delivery, differentiated instruction attempts to scale up and down the process of teaching and learning to address the diversity of learners and ensure equal opportunities to access meaningful learning opportunities (Tomlinson, 2014). In teaching foreign languages, the idea of differentiation is especially applicable to it because the language classrooms are by their very nature heterogeneous, i.e., they include learners of different proficiency, exposure and linguistic capital.

Differentiated instruction is based on theoretical foundations, with references to constructivism-based theories of learning and inclusive education models, which focus on active engagement of learners, scaffolding, and sensitivity to individual needs (Vygotsky, 1978; UNESCO, 2017). Differentiation is not interpreted to mean the one to one lesson to every learner, but a flexible style of teaching that provides various ways of learning in a common curricular model (Tomlinson & Imbeau, 2010).

One of the most popular concepts of differentiation is a model which dwells upon four interconnected dimensions of differentiation: content, process, product, and learning pace. Differentiation of content is the process of adapting what learners are exposed to such as the complexity of texts, vocabulary load and theme. This can take the form of provision of graded reading, multimodal input or the provision of diverse linguistic support according to the proficiency of the learners in the foreign language classrooms (Lightbown & Spada, 2013). Differentiation of process is concerned with the way the learners interpret and respond to the input of language. These are differences in instructional practices, task organization, groupings, and scaffolding levels. As an example, a learner can perform communicative activities in both collaborative and guided practice and independent research, depending on his/her readiness and the learning preferences (Richards, 2017).

Product differentiation concerns how the learners can show their learning and language proficiency. Differentiation instruction gives learners the chance to create different kinds of evidence, which may be oral presentations, written texts, digital artefacts, or

multimodal projects, as opposed to the standardized scoring of evidence. It is a way to encourage learner agency and respect multiple strengths and yet have shared learning goals (Tomlinson, 2014). Lastly, differentiation of learning pace is the acknowledgement of the fact that learners do not progress at the same rate and would need time to internalise linguistic structures and develop communicative competence at varying rates. Differentiated foreign language instruction is thus necessitated by adaptable pacing, revision, and more practice especially in heterogeneous classes (OECD, 2018). Recent developments in AI have further operationalized these dimensions, allowing for real-time adjustments in content complexity and process scaffolding through generative models.

b. Differentiation as a Response to Learner Heterogeneity

Collectively, these dimensions place differentiated learning as a pedagogical intervention to the diversity of learners and the inequality in education. Differentiation in the teaching of foreign languages helps in assisting inclusive practices in that all learners are able to interact well in the language learning process, irrespective of their initial achievement or capability of accessing external help.

Heterogeneity of learners is one of the characteristics of the modern foreign language classrooms. Not only are students linguistically different, their cognitive styles, motivation, cultural background, experience in learning and access to external education varies. In that regard, differentiation is a pedagogical reaction meant to accommodate diversity without offering the common goals of learning and curriculum coherence (Tomlinson, 2014).

One of the major concepts in differentiated teaching is that of learner profiles. Learner profiles include various personal aspects and may include learning preferences and interests, level of readiness, and sociocultural influences that define the way students approach language learning activities (Tomlinson & Moon, 2013). Learner profiles in the foreign language education are especially complicated because learners can have their development of all language skills (listening, speaking, reading, writing) which vary and different levels of exposure to the target language beyond the school. Learner profile differentiation will help teachers to create flexible learning trails to help them engage all learners without compromising academic standards. Differentiated instruction also has close association with inclusive education and support of learners with special educational needs and disabilities (SEND).

Learning needs, such as dyslexia, attention deficit hyperactivity disorder (ADHD), or specific learning impairments, can negatively affect students learning a foreign language in particular, particularly in the environment with high-preferred standards of pace and standards of assessment (European Agency for Special Needs and Inclusive Education, 2018). The input, task organization, scaffolding and assessment formats can be modified with differentiation, hence students with various needs will receive a chance to learn a language and they will not be stigmatized and segregated.

Besides individual learning needs, differentiation plays a very important role in promoting inclusion and equity in education. The inclusive foreign language education will equip a maximum number of learners regardless of their background and ability with a chance to participate in the learning process and become communicatively

competent (UNESCO, 2017). Differentiation supports this aim by recognizing diversity as pedagogical resource rather than a weakness and fighting structural inequalities due to socioeconomic disparities and disproportionate access to the addition of instruction.

The research hypothesizes that inclusive and differentiated practice will have a beneficial influence on the motivation of learners, their self-efficacy, and the overall interest in language learning of the learner in the long term (OECD, 2018; Florian and Black-Hawkins, 2011). Together, the differentiation is one of the strategies that can be selected to address the heterogeneity in the foreign language classrooms.

Differentiation instruction supports the needs of special education learner, profiles and also further the principle of inclusiveness and equity by responding to needs of the students as well as social and educational goals of the whole society. However, it must be planned efficiently, professionally designed, and supported by the conditions of learning, which, in its turn, may be promoted with the help of the strategic use of technological tools, like the Artificial Intelligence.

5. The Artificial Intelligence and its use in Differentiated Learning.

a. AI Technologies of Language Learning.

The current developments in the sphere of Artificial Intelligence (AI) have expanded significantly the range of possible pedagogical tools to employ in the process of differentiated learning in teaching a foreign language. Unlike traditional learning technologies, AI-based ones are characterised by the property of the dynamical reaction to the behaviour of learners, ability to process large quantities of data and provide individualised support in mass. All these features precondition the particular applicability of AI to heterogeneous language classrooms in which the learning needs, the proficiency level, and the learning progress of learners vary greatly.

The use of AI in language learning can be viewed as adaptive learning systems, which are one of the most common applications of AI. These systems apply machine learning algorithms to analyze the performance, interaction patterns and patterns of errors of learners to increase or decrease the difficulty of content, its sequence and instructional support in real time. Adaptive platforms can be used to provide adjustable input and practice based on the level of preparedness of individual learners to benefit flexible pacing and reduce cognitive load (Luckin et al., 2016; Holmes et al., 2019). These systems are specifically applied in the context of foreign language learning where students are often at different levels of vocabulary acquisition, grammar and reading comprehension development at dissimilar rates.

Conversational AI, which includes chatbots and language tutors, is another rapidly developing area. The tools are employed to imitate the human interaction and enable the learners to engage in written or spoken discussions in the target language outside the classroom boundaries. Conversational agents will ensure more practice time and instant feedback, as well as decrease anxiety, particularly in learners who might otherwise be afraid to talk with real people (Fryer and Carpenter, 2006).

Chatbots allow differentiated learning, where students can learn at their own pace and level, which helps learners to have a sense of autonomy and provide a personalised interaction. The other significant aspect of AI that has helped in the differentiated

language learning is automatic feedback. The feedback systems with AI capabilities can provide immediate feedback on some linguistic output by the learners (grammar, vocabulary use, pronunciation, and coherence). It has been demonstrated that timely and focused feedback is very important in second language learning especially when it is adaptive and well in relation to the level of development of the learner (Nicol and Macfarlane-Dick, 2006). Even though automated feedback is not able to substitute pedagogically informed teacher feedback, it could serve as a very useful addition to classroom teaching, which gives constant formative feedback.

Lastly, learning analytics and AI-based tools of data analysis can provide the prospect of a systematic collection and interpretation of learner interaction data. Teachers can use these tools to understand the progress and the engagement pattern, as well as the area of weakness in learners, influencing the decision-making of an instructional process. The analysis of learning can also help educators in differentiated classes by recognizing students with special needs, creating specific assignments, and assessing the success of teaching methods (Siemens and Long, 2011; Viberg et al., 2018).

Combined, these AI technologies lead to the development of differentiated learning spaces that involve personalised learning processes, flexible speeds, and pedagogy powered by data. However, their pedagogical worth will eventually be subject to their inclusion into cohesive pedagogical systems, as well as the capacity of teachers to read and mediate the findings of AI-based tools, which will be discussed in the subsequent sections.

b. AI Pedagogical Benefits in Differentiation and language learning.

There is a significant pedagogical connotation of artificial intelligence when it comes to differentiated learning in the foreign language education, especially when it comes to the heterogeneity of learners and the inequality in their access to the learning resources. With proper application to sound pedagogical principles, AI-based technologies can be used to improve personalisation, learner agency, uninterrupted practice and learning support, thereby increasing more inclusive and effective language learning.

Among the most glaring pedagogical benefits of AI is the fact that it enables individualised learning. AI-powered systems are capable of changing the content of learning, the level of challenge in a task and the feedback based on the level of proficiency, learning history, and pattern of performance exhibited by the learners. This personalisation is quite similar to the ideas of differentiated instruction as it facilitates the delivery of various learning options within a shared curricular framework and allows the scholars to work at their own pace (Tomlinson and Moon, 2013). According to the latest studies, nowadays, the generative models can customize these pathways on the fly, and according to the cognitive style of a particular learner (Kasneci, et. al., 2023).

AI also is important in enhancing learner independence. AI tools facilitate self-regulation and metacognitive awareness offering learners an increased accountability of their learning through opportunities to practice, receive feedback, and monitor any progress (Nicol and Macfarlane-Dick, 2006). The autonomy of learners is especially important in those situations when the classroom time is small and when the exposure

of the target language among the students is significantly different. In AI systems, the learner control can be increased by dashboards, progress indicators and adaptive tasks where the learner can track their progression and make suitable decisions regarding their learning journeys (Ghafouri, 2024).

The next important pedagogical benefit of AI is the opportunity to have an unlimited and endless practice. Both conversational and AI-driven platforms allow the learners to engage with the target language outside of the classroom and rehearse anytime and anywhere (Hockly, 2024). Such a one to one communication is particularly useful in building fluency and strengthening language structure especially with those learners who have no chance to practice the language in real life outside the classroom. In differentiated learning viewpoint, constant practice enables learners to learn at their own pace, repeat some of the learning materials where need be and to prolong learning where they have their personal goals and interests.

Besides assisting learners, AI technologies are of significant assistance to teachers. Learning analytics and AI-generated insights assist educators to see trends in student engagement, learners progress, and learning issues in order to instruct them based on that and differentiate their instructions (Siemens and Long, 2011). Instead of taking over the teacher, AI is used as a pedagogical assistance tool to increase the ability of teachers to address the diversity of learners and make decisions based on the data (Tomlinson and Imbeau, 2010). Moreover, AI has the potential to decrease the administration cost of evaluation and monitoring and liberate teaching hours to specific pedagogical interventions.

In general, the pedagogical benefits of AI are not just in the automation dimension of AI, but in the fact that it can lead to differentiated, learner-centred, and inclusive language learning. The successful application of AI needs to be pedagogically mediated critically and, in such a way, technological affordances should be educational demands and not prescriptions (UNESCO, 2023).

6. Application of Artificial Intelligence in Foreign Language Teaching.

Pedagogical implementation of the Artificial Intelligence in teaching foreign languages demands a keen correlation with the objectives of instruction, the aspect of classroom realities, and the concepts of inclusive education. Instead of being a solution on its own, AI needs to be seen as an auxiliary resource that promotes differentiated instruction via intentional pedagogical planning. Efficient implementation is based on practical instruction methods, teacher activities, and a combination of both technological affordance and human pedagogical judgment.

a. The Teaching Practices With AI Support

There are various ways AI can be implemented in foreign language instruction in the classroom and supplementary practice. Adaptive learning applications can be employed to offer differentiated grammar, vocabulary training based on the level of the learner to enable the student to develop at his/her own pace in achieving collective curricular goals. AI conversational tools like chatbots have the potential to facilitate speaking and writing because students can practice speaking and writing by following a prompt,

engaging in role-play, and providing feedback in a supportive setting, especially students who need more practice or less performance anxiety.

During writing and pronunciation tasks, one might also use AI-based feedback tools to receive formative feedback immediately, which will help with revision and self-correction. Such tools are part of formative assessment practices when they are embedded in teacher-guided tasks without substituting pedagogical evaluation.

b. The Role of the Teacher

Although the capabilities of the AI systems are on the rise, the teacher will still play a central role in the learning process. To the educator, the role is to choose the right tools, create meaningful learning activities, interpret AI generated data, and to mediate pedagogically. It is the role of the teachers to place AI feedback into context, consider the affective and motivational needs of learners and make sure that differentiation serves curricular goals instead of supporting deficit-based practices (Luckin et al., 2016).

The use of AI in heterogeneous classrooms is especially important, as professional judgment is essential in that case, and the knowledge of teachers about the social, emotional, and cultural background of their learners is to be taken into consideration. In this respect, AI is a decision-support system but not a decision-maker.

c. AI in conjunction with Human Pedagogical Judgment

The successful application of AI in different language teaching relies on the symbiotic association between technological systems and human pedagogical knowledge. Whereas AI is capable of detecting trends, anticipating challenges, and automating feedback, it is not able to make sense of learning as a whole or even with moral values. Teachers should thus be critical with AI outputs, modify instruction plans, and make sure that educational choices are based on pedagogical values and equity (Williamson and Eynon, 2020). This is a necessity to avoid mindless use of AI tools, to see that technology is used to support learning and not to influence it.

d. Application in Educational Situations

The use of AI in the public school context can be used as a way to support differentiated instruction by correcting the shortage of instructional time and high classes. Automated feedback and low-stakes adaptive practice have the potential to expand the classroom-based learning experience and still ensure teacher control. AI tools in mixed ability classes help in flexible groupings and personalized tracks allowing learners with divergent abilities to be able to interact substantially on the same thematic material.

These types of practices decrease the pressure of the homogenous pacing and facilitate inclusive participation. The judicious use of AI tools can help eliminate educational gaps in resource-constrained settings especially in schools that have limited access to privately offered educational assistance. Scalable solutions can be achieved through open-access platforms and low-bandwidth applications that can expand learning opportunities, although infrastructure and teacher training is done at a systematic level (OECD, 2021). In general, the pedagogical usefulness of AI in foreign language

teaching is not in the technological sophistication, but in how it can be used wisely as it is integrated with differentiated, inclusive and context-sensitive teaching.

7. Artificial Intelligence (AI) in Differentiated Language Learning: Research Evidence

In the last 10 years, the role of Artificial Intelligence in language teaching has been investigated in an increasing body of international research, especially in relation to its ability to facilitate personalised and differentiated learning. Research shows that AI-driven applications may positively affect the results of the language learning process, particularly when these applications are included in pedagogically-grounded instructional strategies instead of being applied as technological solutions in isolation (Zawacki-Richter et al., 2019; Holmes et al., 2019).

The findings of this research believe that it is possible to achieve significant improvements in language performance of learners, especially vocabulary learning, grammar correctness, and reading comprehension, with the help of adaptive learning systems and intelligent tutoring environments. The results of meta-analyses and large-scale reviews indicate moderate and consistent positive improvements in achievement with the use of AI-based tools to complement, as opposed to substitute, classroom instruction (Kulik & Fletcher, 2016).

The advantages are more pronounced in the example of the learners whose original levels of proficiency are less, which implies that AI can be regarded as one of the compensatory measures in heterogeneous learning. It goes together with the outcomes of performance and several researches that state the positive impact of AI on the motivation and activity of students. It has also been proven that conversational agents and adaptive platforms may improve the readiness of the learners to work with the target language, reduce anxiety-related to mistakes, and assist in preserving the engagement with instant feedback and gamification (Fryer and Carpenter, 2006).

This type of motivational benefits is particularly relevant to the practice of differentiated classrooms where the variables of confidence and influence affective of the learners are critical in the participation and endurance. Even though these are encouraging results, there are other limitations and contradictions that have been recorded in the literature. The research on long-term learning is inconclusive and most of the research is on short-term interventions or experimental settings, which are not as complex as the classroom.

Furthermore, it has problems with the bias on the algorithm, the openness of the AI decision-making, and the risk of enhancing the already existing inequalities in case access to AI tools is not equal (Williamson and Eynon, 2020). Other publications also caution against an excessive reliance on automated feedback because it is more likely to decrease the levels of interaction and critical use of language unless it is offset with teacher-based learning (Beetham and Sharpe, 2019).

The general conclusion in the literature is that teachers are central to mediate the educational impact of AI. The research papers all emphasize that the achievement of language learning by the means of AI will strongly depend on the degree of pedagogical knowledge, digital skills, and the ability of the teachers to integrate technology into

curriculum and assessment practices in a substantial way (OECD, 2021; Redecker, 2017). Lack of professional development systematically would imply that AI tools could be under-utilized and/or misused or introduced with the purpose of efficiency, instead of the quality of learning.

Overall, it is assumed that Artificial Intelligence can follow a large potential of making foreign language lessons differentiated, in particular, in terms of personalisation and interaction among the learners. However, this potential can only be achieved through implementation and institutional support by using long-term investment and critical and context-sensitive implementation in teacher education and institutional support.

8. The Moral Implications and issues of Artificial Intelligence in Language teaching.

The use of Artificial Intelligence in the teaching of foreign language provokes a set of ethical, social, and pedagogical issues that should be evaluated with the deepest attention to allow the implementation of fair and responsible educational practices. Although AI technologies present encouraging possibilities in the field of differentiated learning, their uncontrolled or unthoughtful application can jeopardize the core educational principles of equity, inclusion, and protection of the learners.

Among the hottest ethical questions, there is the problem of data privacy and protection of personal data. The AI educational systems are fundamentally dependent on the gathering, processing and analysis of the learner data, such as the performance records, communication patterns, and behavioural indicators. This dependency causes significant concerns about the ownership of data, data transparency, consent, and data security especially when the learners are minors (Williamson and Eynon, 2020).

Educational institutions and policy authorities need to make sure the AI technologies adhere to the data protection laws and other ethical regulations, as well as assist educators to learn about the consequences of data-based decision-making. In Europe, the EU AI Act (2024) currently establishes a stringent regulatory framework of the so-called high-risk AI systems in education to avoid discrimination and guarantee human control (EU AI Act, 2024).

The other important issue is associated with the digital divide and the lack of equal opportunities to access AI-enhanced learning conditions. The usefulness of AI in differentiated learning assumes the availability of sufficient digital infrastructure, strong internet connection, and proper devices. In the case of unequal distribution of these resources, the implementation of AI is associated with the likelihood of increasing the existing educational disparities instead of decreasing them (OECD, 2021).
This is especially pertinent when it comes to education systems that receive public funding and socioeconomically disadvantaged setting, where the lack of access to technology could mean that learners will not enjoy equal benefits of technological progress. Intimately connected to this issue is the threat of algorithmic bias and a standardised learning model used in AI systems.

AI technologies are trained to use certain sets of data, which might not be representative of the entire linguistic, cultural, and learning diversity, which may be disadvantageous to some types of learners (Zawacki-Richter et al., 2019). The differentiation provided

by artificial intelligence can be based on the reproduction of deficit-based assumptions or limited ideas of language competence without critical review.

Lastly, the concept of AI in education casts significant doubts on pedagogical accountability. Although AI systems may assist in decision-making in the instructional context, they are not able to substitute ethical decision-making, the contextual awareness, and relationship in teaching. The teachers will still be in charge of the interpretation of AI-generated insights, mediation of feedback, and the realization of technology as being pedagogically focused instead of being managerially or efficiency-focused (Biesta, 2015).

Having human agency in making decisions in education is the key to ensuring the ideals of inclusion, equity, and learner-centred education. Finally, the ethical and pedagogical issues of AI implementation characterize the context within which it will be able to actively contribute to the process of differentiated foreign language learning. To have responsibility in implementation, strong regulatory regimes, digital literacy that is critical and long-term investment in the education of the instructor is needed so that AI becomes a supportive tool in a human-centred education paradigm.

9. Implications and Conclusions.

This paper has discussed how Artificial Intelligence can facilitate differentiated instruction in foreign language teaching, in the framework of the European language policy and the institutional issues the Greek educational system is facing. Regardless of the fact that the rates of foreign language education are high, large gaps in the learning outcomes, the quality of instruction, and dependence on the provision of education privately still exist.

Such disparities highlight the significance of pedagogical strategies that can be adopted to support the heterogeneity of learners and create equity in learning. Differentiation instruction was introduced as one of the most important pedagogical answers to diversity in foreign language classes, which provides the flexibility of meeting different levels of proficiency, learning profile, and educational needs.
In this context, it seems that one potentially useful assistive technology is Artificial Intelligence as it allows personalisation, providing opportunities to build adaptive feedback, extended practice, and making instructional decisions based on the available data. Nonetheless, the review of the literature has explicitly shown that AI cannot substitute pedagogical experience, relationship pedagogy, or the institutional responsibility.

Instead of replacing teachers, AI can be perceived as a facilitating tool which can help teachers better cope with the existence of heterogeneity and provide inclusive learning experiences. It relies on critical pedagogical mediation, ethical governance and alignment with the curricular objectives to form its biases. Otherwise, AI is likely to make the existing disparities more solid and focus on efficiency rather than quality of education.

Resting on this analysis, it is possible to come up with several recommendations. Policy-wise, consistent national frameworks are required to control the pedagogical application of AI, data security and infrastructural disparities between schools. Policies

in this case must focus on a fair accessibility to digital resources, and decrease reliance on individual educational delivery.

Regarding teacher training and professional growth, an organised training method is necessary to allow educators to be critical in selecting, combining and assessing AI-based tools. Digital pedagogy, ethical literacy, and data-informed teaching practices should be part of teacher education programmes, where teachers are not marginalized to technological changes in the learning process.

On the school level, AI implementation must be done in a slow and deliberate manner, prioritizing differentiated instructions in the form of low-stakes adaptive tasks, formative feedback, and learner control. Schools are advised to develop the collaborative cultures that help in the promotion of reflective practice, collective expertise, and balancing technological innovation with inclusive pedagogical values.
Lastly, future studies ought to go past the short-term intervention studies and study the long-term impacts of AI-informed differentiated instruction on language development, educational equity, and teacher practice. Empirical studies within the various educational environments most notably in the public schools and those with resource constraints have been important in informing evidence based policy reform and in maintaining the accountability of Artificial Intelligence to the provision of inclusive and equitable foreign language education.

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A Regional Volunteer Registry for Digital Governance in Secondary Education: Bridging Career Guidance, Artificial Intelligence, and the Innovation Ecosystem

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - The rapid advancement of Artificial Intelligence (AI) and digital transformation is reshaping labor markets, professional identities, and the skills required for future employability. Secondary education is therefore challenged to provide students with meaningful, up-to-date, and experiential School Career Guidance (SCG) that goes beyond traditional occupational information. This paper presents the design, institutional framework, and initial outcomes of the Volunteer Registry of Digital Governance Executives for School Career Guidance, a regional initiative implemented in Central Macedonia, Greece.

The Registry functions as a structured bridge between secondary schools and professionals actively engaged in digital governance, AI applications, and innovation-driven sectors. Its primary objective is to enrich SCG through authentic professional encounters, enabling students to develop informed perceptions of emerging digital professions, AI-related career pathways, and transversal skills required in the contemporary labor market.

The paper is structured in two parts. The first and main part provides a detailed analysis of the Registry, including its development context, selection criteria for volunteers, governance and ethical framework, modes of implementation, and alignment with national educational policy. Evidence from career education programs implemented during the 2024–2025 academic year is discussed to highlight the educational added value of the initiative. The second part focuses on the Alexander Innovation Zone (AIZ) as a representative innovation organization participating in the Registry, highlighting its mission, actions, social role, and contribution to AI-aware career guidance, innovation, entrepreneurship, and the development of both technical and soft skills essential for the professions of the future.

Keywords— Artificial Intelligence in Education, School Career Guidance, Innovation Ecosystems, Digital Governance, Soft Skills

1. Introduction

Artificial Intelligence and digital transformation are redefining professional roles, required skills, and career trajectories across all economic sectors. Educational systems, and particularly secondary education, are challenged to respond to these changes by equipping students not only with technical knowledge but also with informed career awareness and adaptive competencies. School Career Guidance (SCG) plays a critical role in supporting students' self-awareness, educational decision-making, and transition to further studies or the labor market.

In Greece, SCG has progressively evolved from traditional informational approaches toward experiential and competency-based models. However, a persistent gap remains between school curricula and the rapidly changing realities of the digital labor market, especially in domains related to AI, data, cybersecurity, and digital governance. To address this gap, the Regional Directorate of Education of Central Macedonia, in collaboration with the Regional Authority of Central Macedonia, initiated the creation of a structured "*Volunteer Registry of Digital Governance Executives for School Career Guidance*" (Karavasili, 2025).

This paper documents the rationale, structure, and implementation of the Registry as an innovative policy instrument for AI-aware career education. It further examines how collaboration with innovation ecosystem actors, such as the Alexander Innovation Zone S.A., can amplify the educational impact of such initiatives.

2. Selection of Volunteers and Conceptual Framework of the Registry

Participation in the Volunteer Registry of Digital Governance Executives is based on clearly defined qualitative criteria rather than open, unstructured volunteering. Executives and professionals are selected following an open call addressed to public bodies, private enterprises, and innovation organizations, with emphasis on relevance to digital governance, Artificial Intelligence (AI), and digital transformation. Selection criteria include documented professional experience, alignment with emerging digital professions, ability to communicate with adolescent learners, and commitment to ethical, non-commercial engagement within the school context.

A key principle of the Registry is the intentional inclusion of professionals whose profiles respond to documented gaps in School Career Guidance, particularly in fields that evolve faster than formal curricula. Priority is therefore given to individuals who combine applied professional practice with strong academic grounding and awareness of educational realities. This approach ensures that students are exposed not only to occupational descriptions but also to scientifically informed perspectives on AI, technology, and future skills.

The conceptual framework of the Registry is grounded in three complementary educational and policy perspectives: (a) experiential learning in career education, (b) lifelong guidance and employability, and (c) the ethical and socially responsible integration of AI and digital transformation in education.

Experiential learning theory emphasizes learning through direct experience, reflection, and interaction with real-world contexts. Within School Career Guidance, this

translates into structured encounters with professionals who can articulate authentic career pathways, challenges, and skill requirements. Lifelong guidance policies, promoted at European level, stress the importance of sustained links between education, employment, and society. Finally, the ethical dimension of AI integration requires that students encounter digital technologies not only as tools but as socio-technical systems embedded in values, regulation, and public interest.

The Registry operationalizes these principles by institutionalizing voluntary participation of carefully selected professionals from both the public and private sectors who are actively involved in digital governance and AI-related practices.

The Volunteer Registry is grounded in three complementary educational and policy frameworks: (a) experiential learning in career education, (b) lifelong guidance and employability, and (c) ethical integration of AI and digital transformation in education. Experiential learning theory emphasizes learning through direct experience, reflection, and interaction with real-world contexts. Within SCG, this translates into student engagement with professionals who can articulate authentic career pathways, challenges, and skill requirements. Lifelong guidance policies, promoted at European level, stress the importance of sustained links between education, employment, and society. Finally, the ethical dimension of AI integration requires that students encounter digital technologies not only as tools but as socio-technical systems embedded in values, regulations, and public interest.

The Registry operationalizes these principles by institutionalizing voluntary participation of professionals from public and private sectors who are directly involved in digital governance and AI-related practices.

3. Development History and Institutional Context

The development of the Registry followed a phased and collaborative process. Initial awareness activities took place in October 2024 through a regional information event on “Digital Transformation Professions,” organized by the Regional Authority for Digital Governance. This event catalyzed systematic cooperation between the Directorate of Secondary Education of Eastern Thessaloniki and the regional governance structures.

Between October 2024 and June 2025, forty Career Education Programs were implemented in secondary schools, four of which explicitly focused on digital transformation themes. Drawing on this experience and on the Directorate’s long-standing expertise in managing volunteer registries for SCG, the first official *Volunteer Registry of Digital Governance Executives* was formally launched in November 2025.

The Registry operates under the authority of the Regional Directorate of Education of Central Macedonia and aligns with national legislation governing school collaborations with external stakeholders (Regional Directorate of Primary and Secondary Education of Central Macedonia, 2025a).

4. Objectives of the Registry

The Registry pursues a set of interrelated educational and social objectives:

- Strengthening School Career Guidance through the systematic involvement of experienced professionals.
- Connecting students' educational choices with current and emerging labor market needs.
- Creating sustainable bridges between schools, public administration, private enterprises, and the local community.
- Facilitating students' experiential understanding of AI applications, digital transformation processes, and digital governance roles.
- Enhancing awareness of transversal digital skills demanded by the contemporary labor market.

These objectives position the Registry as both an educational support mechanism and a regional development tool.

5. Composition and Structure of the Registry

The Registry comprises a diverse pool of volunteers, including:

- Professionals and representatives of digital-era occupations.
- Executives from public sector organizations.
- Executives from private enterprises and innovation-driven companies.
- Specialists in digital governance and AI applications.
- Professionals with practical experience in digital transformation projects.

All members participate on a voluntary basis and share a commitment to knowledge dissemination, mentoring, and student inspiration. The diversity of profiles ensures coverage of multiple sectors and career pathways, responding to the heterogeneous needs of secondary schools.

6. Implementation Framework: Operational Modalities, Governance, and Safeguards

The Volunteer Registry is implemented through structured and pedagogically grounded engagement formats that enable meaningful interaction between students and digital governance professionals. Schools may utilize the Registry through multiple modalities, including in-person visits by Registry members to school units, online meetings and webinars, professional trajectory presentations, thematic lectures on Artificial Intelligence and emerging technologies, and experiential workshops introducing students to digital professions and innovation-driven career pathways. These formats allow flexibility while maintaining alignment with school career guidance objectives.

Participation in the Registry is optional for schools and subject to institutional approval by school leadership and teaching staff. Student participation is voluntary and requires documented parental consent. The Registry is renewed annually through an open call for new members to ensure transparency, renewal of expertise, and institutional accountability (Regional Directorate of Primary and Secondary Education of Central Macedonia, 2025b).

The operation of the Registry is governed by a comprehensive legal and ethical framework grounded in national education legislation, data protection regulations (GDPR), and intellectual property law. Strict safeguards regulate the protection of personal data of students and volunteers, prohibit recording or commercial promotion during school activities, ensure age-appropriate and pedagogically sound content, and guarantee zero financial cost for students, families, and schools.

Through this structured governance model, the initiative balances innovation, external professional engagement, and student exposure to AI-related careers with educational integrity, institutional responsibility, and learner safety.

7. Preliminary Outcomes and Added Value

Early implementation evidence from the 2024–2025 academic year indicates high student engagement, increased awareness of digital professions, and positive feedback from educators. The Registry has proven effective in contextualizing AI concepts within real professional environments, thereby enhancing the relevance of career education. Moreover, the initiative fosters regional cohesion by mobilizing local expertise and strengthening trust between education and the labor market.

The Alexander Innovation Zone S.A. (AIZ) is a regional innovation organization based in Thessaloniki, Greece, operating as a key intermediary within the innovation ecosystem of Northern Greece. Beyond its core role in fostering entrepreneurship, innovation, and technology transfer, AIZ explicitly recognizes social contribution and educational engagement as integral components of its mission.

AIZ's strategic objectives include:

- Strengthening innovation-driven entrepreneurship and startup development.
- Supporting technology transfer and collaboration between research institutions and industry.
- Facilitating access to innovation support mechanisms, networks, and funding opportunities.
- Contributing to regional, national, and European innovation and digital transformation policies.
- Actively supporting society and education, particularly in initiatives that promote innovation, digital skills, and future-oriented career pathways.

In this context, AIZ views its participation in educational initiatives, such as the Volunteer Registry, not as ancillary activity, but as a core expression of its responsibility toward the regional community. AI, digital transformation, and emerging technologies are treated not only as drivers of competitiveness, but also as critical educational domains that shape employability, entrepreneurship, and professional integration for future generations.

In this context, AIZ places particular emphasis on the development of soft skills, which are increasingly recognized as essential in the era of Artificial Intelligence. Skills such as critical thinking, creativity, communication, collaboration, adaptability, and ethical judgment complement technical AI competencies and enable individuals to work effectively alongside intelligent systems.

Through its educational and innovation activities, AIZ promotes a balanced skills framework, preparing students and future professionals not only to use AI technologies, but also to contribute meaningfully to innovation, entrepreneurship, and socially responsible decision-making.

The Alexander Innovation Zone S.A. (AIZ) is a regional innovation organization based in Thessaloniki, Greece, with a mission to support entrepreneurship, innovation, and technology transfer. AIZ operates as a catalyst within the regional innovation ecosystem, connecting startups, research institutions, industry, and public authorities.

Its strategic objectives include:

- Promoting innovation-driven entrepreneurship.
- Supporting startups and scale-ups through incubation, acceleration, and networking services.
- Facilitating collaboration between research and industry.
- Contributing to regional and national innovation policy implementation.

AIZ's activities span innovation programs, capacity-building initiatives, ecosystem networking events, and participation in European and national projects.

8. AIZ's Role within the Volunteer Registry and the Author's Contribution

AIZ participates in the Volunteer Registry through the voluntary engagement of its executives, who act as bridges between the innovation ecosystem and secondary education. This engagement reflects the organization's strategic commitment to supporting education in areas directly linked to innovation, Artificial Intelligence, and the professions of the future.

A representative example of this engagement is the participation of the second author as a member of the Registry. Her selection as a volunteer reflects the Registry's emphasis on profiles that combine professional experience, advanced academic qualifications, and direct familiarity with the educational system. In her role as Innovation and Information Technology Expert at AIZ, she is actively involved in innovation support structures, digital transformation initiatives, and collaboration between research, startups, and industry. This professional role enables her to present students with a realistic and up-to-date picture of how AI and digital technologies are applied within innovation ecosystems.

At the same time, her background as a Computer Science educator and her academic training up to doctoral level provide a strong pedagogical and scientific foundation for engagement with students. Her PhD research, entitled *"Intelligent Pedagogical Agents for Virtual Learning Environments"*, directly relates to Artificial Intelligence in Education and allows for meaningful translation of complex AI concepts into age-appropriate educational discourse. This dual identity, professional in an innovation organization and educator-researcher, addresses a critical need in School Career Guidance: the presence of individuals who can simultaneously understand educational contexts, technological depth, and labor market dynamics.

Within the Registry, her contributions include presentations on AI-driven innovation, digital governance roles, emerging professions, and the skills required for sustainable

professional integration. Emphasis is placed on the connections between AI, entrepreneurship, employability, and lifelong learning, helping students understand how educational choices relate to evolving career opportunities.

AIZ participates in the Volunteer Registry through the voluntary engagement of its executives, who act as mediators between the innovation ecosystem and secondary education. As Registry members, AIZ professionals contribute by:

- Presenting innovation-driven career paths and entrepreneurial opportunities.
- Introducing students to real-world applications of AI and digital technologies.
- Highlighting the role of innovation zones and clusters in economic development.
- Supporting informed career choices related to technology, research, and entrepreneurship.

This involvement exemplifies how innovation organizations can contribute to social responsibility goals while enriching educational practice.

9. Discussion and Implications

The Volunteer Registry represents a scalable and policy-aligned model for integrating AI-aware career guidance into secondary education. Its effectiveness is closely linked to the quality of volunteer profiles and to the strategic involvement of organizations such as the Alexander Innovation Zone. The case discussed illustrates how professionals who combine applied innovation roles with educational and research expertise can significantly enhance the relevance and credibility of School Career Guidance.

The explicit connection between AI, innovation, entrepreneurship, and employability enables students to conceptualize future professions not as abstract titles, but as dynamic roles shaped by technological, social, and ethical factors. From an institutional perspective, AIZ's engagement demonstrates how innovative organizations can contribute to education as part of their social mission, reinforcing regional innovation capacity while supporting informed career decision-making.

Limitations of the current implementation include uneven geographic coverage and reliance on volunteer availability. Future directions involve expanding participation, strengthening thematic networks focused on AI and digital professions, and systematically evaluating learning outcomes.

The Volunteer Registry represents a scalable model for integrating AI-aware career guidance into secondary education. Its success relies on institutional coordination, volunteer motivation, and clear ethical safeguards. The involvement of innovative ecosystem actors, such as AIZ, adds strategic value by exposing students to forward-looking professional environments.

Limitations include geographic coverage disparities and dependence on volunteer availability. Future development plans involve expanding the Registry's regional reach and establishing thematic networks of schools and professionals.

10. Conclusion

This paper presented the Volunteer Registry of Digital Governance Executives as an innovative mechanism for enhancing School Career Guidance in the era of Artificial Intelligence. By systematically connecting schools with professionals and innovation organizations, the Registry supports informed, ethical, and future-oriented career education. The collaboration with the Alexander Innovation Zone S.A. illustrates the potential of such partnerships to strengthen both educational quality and regional innovation capacity.

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The training needs of adult educators in the learning process using artificial intelligence

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - The rapid development of artificial intelligence (AI) is redefining both educational environments and the demands placed on adult educators, making their training critical for the effective use of new information and communication technologies in the learning process. Adult education, as a field with specific characteristics—such as diversity of experiences, self-directed learning, and orientation to labor market needs—requires educators who are prepared to integrate AI in a pedagogically valid and ethically responsible way (Knowles , 1984 ; Merriam & Bierema , 2014). However, research shows that most adult educators feel inadequately prepared to use AI tools , often due to insufficient digital pedagogical training and limited knowledge regarding the possibilities and risks of new applications (UNESCO , 2023).

The purpose of this paper is to highlight the need for systematic and targeted training of adult educators for the use of AI in the learning process. Since AI has the potential to support the personalization of learning, the provision of immediate feedback and the formation of adaptive learning paths, its integration facilitates the enhancement of the participation and autonomy of adult learners (Holmes and al ., 2021; Popenici & Kerr , 2017). However, the technological and pedagogical competence of educators is a determining factor for the success of any digital intervention and digital competencies of teachers (Mishra & Koehler , 2006; Redecker , 2017).

The analysis of the literature and the findings of recent studies indicate that professional development programs should include: (a) understanding basic principles of AI , (b) development of digital pedagogy, (c) practical application of AI tools in real educational environments, and (d) training on issues of ethics, transparency, data protection and algorithmic bias (Akgün & Greenhow , 2022; Long & Magerko , 2020). At the same time, the adoption of collaborative learning models among educators, formative assessment of skills and continuous renewal of educational materials are proposed, as AI is evolving at a very rapid pace.

The conclusions of the paper highlight that the training of adult educators can no longer be considered a complementary activity, but a basic prerequisite for the quality and effectiveness of education in conditions of digital transformation. Cultivating AI competencies in adult educators not only enhances their pedagogical competence, but also ensures the creation of inclusive, innovative and reflective learning environments, suitable for the needs of adult learners in the 21st century. Finally, directions are proposed for future research that will examine the benefits, risks and best practices of

integrating AI into adult education, with the aim of developing efficient training models.

Keywords — Training, adult educators, learning process, artificial intelligence

Introduction

The rapid development of artificial intelligence (AI) Intelligence – AI) is profoundly affecting educational practices and transforming the role of the educator at all levels of education. In the field of adult education, the integration of AI tools creates new possibilities for personalizing learning, automating assessment processes and supporting self-directed learning. However, the use of these technologies requires new skills and forms of professional development for adult educators. The purpose of this article is to investigate the training needs of adult educators regarding the use of artificial intelligence in the learning process, through a systematic literature review. The main dimensions of digital competence, AI, are analyzed. literacy , pedagogical approaches and ethical issues related to the application of AI in adult education. The results highlight the need for multidimensional training programs that combine technological, pedagogical and critical skills. The article contributes to the dialogue on redefining the role of adult educators in a
Artificial intelligence is one of the most important technological developments of the modern era, affecting many areas of social and professional life, including education (Luckin and al ., 2016). The use of AI tools in the educational process has been particularly strengthened after the development of generative artificial intelligence, which allows for content creation, automated assessment and personalization of learning experiences (Zawacki-Richter and al ., 2019). In adult education, where learning is based on experience, autonomy and the need for practical application of knowledge, AI creates new possibilities but also significant challenges. The educator is called upon to develop new skills and redefine his role from a transmitter of knowledge to a learning facilitator and critical guide (Selwyn , 2019). Despite the potential of AI , the literature indicates that many educators do not have sufficient training to effectively integrate it into teaching practice (Ng and al ., 2021). Therefore, the need arises to investigate the training needs of adult educators in a changing educational environment.

Artificial intelligence and adult education

The rapid spread of artificial intelligence (AI) is redefining both educational environments and the demands placed on adult educators. In this context, the training of adult educators for the effective use of new information and communication technologies in the learning process is important. Adult education, a field with unique characteristics—such as diversity of experiences, self-directed learning, and orientation to labor market needs—requires educators who are prepared to integrate AI in a pedagogically valid and ethically responsible manner (Knowles , 1984 ; Merriam & Bierema , 2014). At the same time, research shows that most adult educators feel inadequately prepared to use AI tools . The main reasons are insufficient digital pedagogical training and limited knowledge regarding the possibilities and risks of new applications (UNESCO , 2023).

A key element is the need for systematic and targeted training of adult educators for the use of AI in the learning process. Since AI has the potential to support the personalization of learning, the provision of immediate feedback and the formation of adaptive learning paths, its integration facilitates the enhancement of the participation and autonomy of adult learners (Holmes and al ., 2021; Popenici & Kerr , 2017). At the same time, the technological and pedagogical competence of educators is a

determining factor for the success of digital intervention and the digital competencies of adult educators (Mishra & Koehler , 2006; Redecker , 2017).

The results of the literature review and research indicate that professional development programs should include: (a) understanding basic principles of AI , (b) development of digital pedagogy, (c) practical application of AI tools in real educational environments, and (d) training on issues of ethics, transparency, data protection and algorithmic bias (Akgün & Greenhow , 2022; Long & Magerko , 2020). At the same time, the adoption of collaborative learning models among educators, formative assessment of skills and the continuous renewal of educational materials are recommended, as AI is evolving at a very rapid pace.

Knowles ' andragogic theory emphasizes self - directed learning, the use of experiences, and the need for immediate application of knowledge (Knowles and al ., 2015). At the same time, Mezirow 's transformative learning emphasizes the importance of critical reflective processes in adult learning (Mezirow , 2009). AI can enhance these principles through personalization of learning paths, real-time feedback, and support for reflective processes. The use of AI in education includes adaptive learning systems, learning data analysis (learning analytics) and generative AI tools (Holmes) and al ., 2022). Research shows that successful implementation depends on the digital competence and pedagogical readiness of educators (Zawacki-Richter and al ., 2019).Digital competence includes technical, cognitive and socio -ethical skills (Redecker , 2017). AI literacy extends this framework, requiring an understanding of the capabilities, limitations, and ethical dimensions of artificial intelligence (Long & Magerko , 2020).

The training needs of adult educators are oriented towards technological skills such as understanding the basic principles of AI , using appropriate tools and assessing the reliability of results. AI requires a shift from teacher-centered approaches to student-centered learning models. The educator assumes the role of a designer of learning experiences (Holmes and al ., 2022). However, lack of technological confidence is a significant obstacle (Ng and al ., 2021). Educators fear that excessive automation can reduce the human dimension of learning (Holmes and al ., 2022). Adult educators must address issues such as data privacy , algorithmic bias, and academic integrity (Selwyn , 2019).

The contribution of educational techniques to education. Education and Information and Communication Technologies (ICT)

The conditions under which learning takes place for adult learners require, among other things, the use of specific educational techniques with the aim of achieving a predetermined (Courau , 2000). The main educational techniques are presentation , practical exercise, case study , role play , questions and answers, discussion, brainstorming , demonstration and working groups . The main goal of using educational techniques is to promote the active participation of learners and the exchange of experiences (Kokkos, 1999). These educational techniques are important in distance education in the context of face-to-face communication. During the educational process, the choice of educational techniques depends on the learning area , the need for active participation of learners , the requirements of the subject matter and the resources available for their application . The decision to select and combine

appropriate teaching techniques is made by the instructor and sometimes by the instructor and the trainees together (Rogers , 1999).

The conditions under which learning takes place for adult learners require, among other things, the use of specific educational techniques with the aim of achieving a predetermined (Courau , 2000). The main educational techniques are presentation, practical exercise, case study , role play , questions and answers, discussion, brainstorming , demonstration and working groups . These educational techniques are important in distance education in the context of face -to-face communication. During the educational process, the choice of educational techniques depends on the learning area , the need for active participation of the learners , the requirements of the subject matter and the available resources for their implementation . The decision to select and combine the appropriate educational techniques is made by the trainer and sometimes by the trainer and the learners together (Rogers , 1999). The need for continuous training of educators is highlighted in order to meet the demands of distance learning for adult learners . The importance of New Technologies in communication in distance education New Information and Communication Technologies (ICT) with their continuous technological development provide new possibilities for the creation of innovative effective teaching and learning environments , redefining and placing educational processes on new foundations. The application of new forms of learning , lifelong learning , self -education and self-development are some of the elements that make up today's Knowledge Society. The application of ICT in distance education offers many opportunities for the enrichment , revision and dissemination of knowledge. (Kalogiannakis , Vasilakis & Psarros, 2005). A new teaching and learning environment is offered by open and distance education with the introduction and use of ICT , bringing about significant changes in the relationship between the learner and the teacher, but also in education in general (Lionarakis, A. 2004). New Technologies enable better and faster communication during distance programs , as learners resolve questions regarding written assignments and teaching materials, are supported and encouraged by the instructor and other learners . McPherson & Nunes (2004) argue that New Technologies need to be designed and developed in the educational process with the appropriate pedagogical approach so as to maximize the benefits to learners .

Conclusions

AI is a field that has entered very large in many areas of people's lives. However, it has also affected the training needs of adult educators in the learning process. The literature reflects that training must combine technological, pedagogical and organizational elements. At the same time, it is important to take into account ethical dimensions, organizational policies and a culture of innovation. Artificial intelligence is transforming adult learning and creating new demands for educators. The development of AI , the strengthening of digital competence and the integration of critical pedagogy are key priorities for the effective use of adult educator training

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From Algorithm to Human: Pedagogical Autonomy, Critical Literacy, and Bridging Social Inequalities in the Age of Artificial Intelligence

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Abstract - Artificial Intelligence (AI) has become an integral part of social life, including the field of education, where in most cases it is used as a tool for personalisation, efficiency, and innovation, opening thus new pedagogical pathways. However, AI implementation is accompanied by significant legal, ethical, and pedagogical concerns, raised by core features that characterize AI systems, such as the intensive processing of personal data (including sensitive data), and the subsequent uncertainty in terms of the reliability, fairness, and accountability of their outcomes. Those issues become more critical within educational settings, as minors are involved and as education assumes a crucial role in shaping agency, autonomy, critical thinking, and democratic citizenship. In line with these, the present theoretical paper examines the application of AI in education, by applying the perspective of critical literacy, pedagogical autonomy, and social inequality, while taking into account the EU regulatory framework (AI Act), which imposes rules of transparency and respect for human dignity, aiming to prevent manipulation and social exclusion. Finally, the aim of this theoretical paper is to contribute to contemporary debates that highlight that the educational value of AI depends highly on the conditions of its use, and suggest that AI should only be used as a human-centred and ethically-grounded supportive tool that has the power to enhance teachers' role and deliver meaningful human interaction, with the ultimate goal of shaping responsible citizens with well-developed critical thinking skills.

Keywords: Artificial Intelligence, Algorithms, Pedagogical Autonomy; Critical Literacy, Digital Divide.

1. Introduction

Artificial Intelligence (AI) is already changing the way we live, work and learn, work, and education is increasingly affected by this development. The introduction of AI applications in education is viewed by some as an immense opportunity and by others as a source of serious concern. These concerns are particularly notable, due to the involvement of minors, whose cognitive, moral and social development is shaped through the educational process. Therefore, experimentation of AI applications in educational contexts should be carried out with caution and heightened ethical responsibility, because any potential harm could be long-standing or irreversible. This does not denote that education should reject AI tools, but instead that their application should be pedagogically grounded, aligned with educational realities, and also carefully regulated, with the primary aim of improving the educational process while remaining faithful to its fundamental objective, which is to cultivate responsible and conscious citizens that will also have ethical thinking (Pliogou & Tromara, 2025; Fu & Weng, 2024).

The first dimension of the relationship between AI and humans in education concerns the transition from the simple adoption of AI systems in teaching practice to the development of critical and pedagogically grounded reflection. Technologies can no longer be treated as neutral tools, but as pedagogical frameworks that shape meanings, relationships, and ways of learning. With their pedagogical autonomy, teachers transform from simple user into designers of learning experiences, as reflective professionals who use digital tools to give meaning to teaching and cultivate creativity and self-regulation in students (Paniagua & Istance, 2018). A second direction being explored is the reconfiguration of learning as an embodied, experiential, and social experience. Applications of augmented, virtual, and mixed reality, digital games, as well as the practices of digital storytelling and robotics, show that 21st-century learning is not limited to cognitive information processing, but activates the body, emotions, and relationships. Technology acts as a catalyst for the creation of emotionally rich, multisensory experiences that enhance the meaning of knowledge and student engagement (Alfredo et al., 2025). In this context, the concept of learning takes on a dialogical and social character, where knowledge is not transmitted but co-created through the interaction of people, objects, and technologies. AI is emerging as a new "educational mediator" that can enhance personalization, feedback, and inclusion, provided that it is integrated with educational reflection and a human-centred approach. A third parameter that is prominent in the relationship between algorithms and humans is the search for new humanism in the digital age, specifically in issues related to special education, inclusion, and accessibility. Technology can serve as a vehicle for equality and social justice, giving a voice to groups that were previously excluded, provided that it is designed based on the principles of Universal Design for Learning (Saborío-Taylor & Rojas-Ramírez, 2024).

However, due to the relatively new integration of AI systems in education (i.e., generative applications), empirical evidence on the impact of AI applications on students' cognitive, socioemotional development and related skills remains limited, with ambiguous findings (Almasri, 2024; Jauhiainen & Guerra, 2023). In other words, many assumptions, concerns, and expectations remain highly theoretical or hypothetical, something that leaves space for systematic empirical evidence that will

evaluate whether these tools are actually innovative, effective and/or meaningful in terms of teaching/learning than existing practices or technologies.

Furthermore, it should be noted that AI technologies often pose risks of violations of privacy and the right to protect personal data, both for students and teachers. Therefore, it is imperative to adhere to the fundamental principle of the General Data Protection Regulation (GDPR) to minimise the extensive processing of personal data when developing and implementing AI systems in education. Moreover, Generative AI relies on pre-existing content and knowledge that has been already produced by humans, raising, thus, concerns related to copyright infringement and to the liability of AI systems' creators/developers and users (National Bioethics & Technoethics Commission, 2025).

The above considerations raise a deeper question, which is the main focus of this theoretical paper -grounded in policy analysis and critical pedagogy- and more specifically, how education can remain human, fair, and creative at a time when AI and automated knowledge are profoundly reshaping teaching practices and learning. The critical question, therefore, is not whether AI tools should be introduced into education, but how to use them pedagogically grounded, responsibly, and ethically, and more specifically how algorithms should be consistent with human values, promote human well-being and pluralism, respect the privacy of learners, and, finally, be evaluated and supervised.

2. Theoretical framework

2.1 The concept of autonomy

School autonomy is a form of decentralization and consists of delegating decision-making and responsibilities to the school unit. However, it should be emphasized that it is a multifaceted concept that cannot be simplistically approached as a "single model" (Verger et al., 2024; Neeleman, 2019). In any case, school autonomy can be defined as the ability given to schools to make their own decisions on issues related to school operations. In this regard, the World Bank (Demas & Arcia, 2016) defines "school autonomy" as a form of school administration in which the school unit is given decision-making powers on a range of issues. School autonomy can be divided into five types: teaching, pedagogical, organizational, financial, and administrative. Teaching autonomy concerns freedom in teaching, the ability to choose curricula, school textbooks, and teaching methods. Pedagogical autonomy, which is particularly crucial, concerns pedagogical approaches, interpersonal relationships, and involves not only teachers but also students, as autonomy can create the right conditions for fostering participation, agency, and social change (Keddie et al., 2023; Wermke & Salokangas, 2021). The importance of pedagogical autonomy and the desire to enhance both reflect a broader philosophy about school autonomy that seeks to increase freedom in teaching and learning as supported by prior empirical evidence in the Greek context (Bouskos, 2020).

Educational settings are reshaped by the introduction of AI systems, which support part of the cognitive functions of learners and educators, and more specifically renegotiate pedagogical processes such as feedback, personalization, and assessment. For example, appropriately designed digital assistants can provide correct answers to various forms

of assessment, solve complex exercises, offer feedback with comments, instructions, and supplementary materials, instantly, and in a reliable and in a pedagogically sound manner. However, this masks a risk: learners may turn into passive consumers of "ready-made solutions," especially when they do not engage with AI outputs in a critical way that will provide them the opportunity to create, to be aware of AI limitations, such as spreading false information or reproducing bias, and self-reflect. These concerns become more noticeable in the Greek educational system, where the exam-centric culture and the authority of teachers and teaching materials (textbooks) have still a dominant role. Therefore, the challenge is twofold: on the one hand, the shift from memorization to the active construction of knowledge, and on the other, the establishment of an educational culture that prepares and supports learners to become more creative, create autonomously and leave their own mark on the final outcome. These challenges are posed in the centre of ongoing debates about the institutional framework that regulates the pedagogical competence of teachers while university pedagogy is taking its first steps, in Greece. As supported by Dimitriadis et al., 2025, preparing and empowering teachers to use AI with confidence and critically constitutes a major challenge for their professional development. Empirical evidence from Greece, is not extensive, something that highlights the research gap in the pedagogical value of AI applications, their effectiveness, and teachers' preparedness. In the case of foreign language teachers empirical evidence showed that teachers integrate AI tools in their teaching practices, while the express positive aspects of this integration they still need support and training/professional development to increase their preparedness and competencies (Varsamidou, 2024). A cross-national research supports that Greek educators, although they recognise the positive aspects of AI integration in their teaching practices, they still remain sceptical around the impact on critical-thinking skills and similarly express the demand for specialised training (Daskalaki et al., 2024). Finally, in the context of preprimary and primary education evidence shows that children expose curiosity and active engagement when interacting with AI applications, while teachers expressed their concerns in relevance to data privacy, lack of experiential learning, and the demand for professional development (Nikolopoulou et al., 2025).

Regarding the broader context of human autonomy within the digital age, Coleman (2019) warns that we are gradually and unconsciously ceasing to use our own judgment for everyday or even serious issues, and as a result we find it difficult to distinguish our own knowledge from the information provided by algorithms. This raises serious concerns about mental privacy, such as the protection of our thoughts and feelings from surveillance, and our cognitive freedom, i.e., the right to think autonomously, without our opinions, desires, and decisions being manipulated by algorithms designed to direct our behaviour in a subtle manner. These pose even more complex challenges, such as the overt limitation of mass scale manipulation, agency, autonomy, and responsibility, Thus, education assumes an even more critical role in terms of counteraction, which is to cultivate and enhance critical thinking, moral imagination, and ethical reflection, competences that can navigate learners and educators to become critical agents who can find equitable solutions to contemporary challenges (Coleman, 2019).

2.2 Critical Literacy and AI

The concept of literacy includes reading, interpreting, decoding, and producing a text. These are processes that are ideologically and politically determined and reproduce rules, narratives and power relations. Critical literacy involves the concept of

questioning through the search for new paths to social awareness. It is a process through which individuals become aware and conscious of the socio-political context in which they operate, and the uneven hierarchies embedded within it. A critically literate person is able to recognize and question processes of knowledge production, any form of bias and oppression masked behind dominant narratives and practices, and most importantly, to dismantle and resist against them (Freire, 1970/2000). In this sense, critical literacy is intertwined with social justice (Comber, 2014). Based on this paradigm, "critical digital literacy", is the ability to read and decode digital media, as well as the ability to access them, and these abilities are inextricably linked to the ideological, social, and cultural context in which digital media operate. critical digital literacy examines how power can shape knowledge, identities, and social relations within the digital realm and guides educators and students to approach the digital world critically, enables them to act as responsible citizens, develop social awareness, and challenge dominant digital/technological cultures instead of acting as mere recipients (Kontostavlou & Katsiampoura, 2024).

Within this context, the term "critical AI" refers to an approach that examines, analyses, and challenges the assumptions, biases, and power relations embedded in AI systems. It is an interdisciplinary perspective that draws elements from diverse scientific fields, such as philosophy, pedagogy, sociology, political science, and computer science, aiming to understand the social and ethical implications of Generative AI (GenAI) (Uddin et al., 2025). Within educational settings, the critical approach to GenAI treats the respective educational context not as a passive recipient of technology but as an active participant in its formulation. More specifically, it centres on human agency and the dynamic, dialectical/reciprocal relationship developed between educators/learners and technology systems that unfolds during the learning process, and on AI ethics. In line with this, critically AI literacy is described as a set of skills based on critical thinking drawing from the insights of critical pedagogy theory, which enable individuals to analyse and critically evaluate the applications, tools, and outputs of GenAI, something that has become pressing, especially in an era where the demand for multiliteracies is becoming even more a prerequisite for educators, learners, and citizens more broadly (Roe et al., 2025).

One of the main concerns in the field focuses on data and algorithmic bias (Mehrabi et al., 2021). Data are not just numbers, but complex media that convey meaning through various "modes" or "forms" (i.e., language, texts, images, sounds). In the same way a text combines words and images to narrate a story, data sets similarly compose and reflect an image of reality (Schneider & Oliveira, 2025). This "image", however, is affected by the way data is selected, collected, synthesized, and interpreted, resulting in non-neutral data. On the contrary, they shape the way meaning is constructed and perceived and can contribute to the production, reproduction, and sustain social inequalities. Algorithms function and are trained with data produced by specific individual and/or social groups that hold power and control in terms of gender, race/ethnicity, and class (Pliogou & Tromara, 2026), and consequently they inherit human stereotypes/biases (racism, sexism, classism), which overall can widen existing disparities or create new inequalities. If the data that provide input to AI systems reflect those biases, then the decisions taken by AI systems, will reinforce unequal power relations, hierarchies, and various forms of discrimination and exclusion. Within this context, critical AI literacy involves recognizing how AI systems influence and are influenced by social, political, and economic structures, and therefore reflect wider

structures of (in)equality (i.e., facial recognition and outputs affecting people of colour), power dynamics (who owns the technology and who controls the knowledge), and access to resources (which students have access to advanced AI tools and which are excluded) (Mac Fadden et al., 2024). This extends to educational settings and processes, where students and educators must cultivate and develop skills in order to mitigate the effect of mis/disinformation, algorithmic bias, and the perpetuation of inequalities and discrimination, both within and beyond educational contexts (Lytrivi et al., 2025). However, a critical perspective has to acknowledge certain limitations and challenges to this assumption, which means that while critical AI literacy can function as a mode of awareness and resistance, education cannot on its own dismantle or even eliminate long established unequal political, social and economic structures and the multiple and overlapping inequalities that they produce (Bulathwela et al., 2024). Strong alignments and efforts between educational policies, technology design, and AI regulatory frameworks can provide a more holistic, equitable, and democratic framework for sharing responsibility and for effective practices

2.3 The Digital Divide and the Spectrum of Inequalities

Inequalities relating to access to technological resources and the internet, digital skills, and the ability to use such technologies to achieve outcomes are commonly referred as the "digital divide". This divide has strong socioeconomic roots and mainly emerges due to the unequal distribution of technological and digital resources and power among citizens. The digital divide is conventionally divided into three basic levels. The first level refers to access or lack thereof to electronic devices and the internet and is marked by material access. The second level concerns the individual's skills in using such technologies (skills access), and also examines the quality of access, i.e. access to a reliable and stable internet connection and modern technological equipment. The quality of digital media and how they are used based on appropriate skills is clearly influenced by socioeconomic factors, as users from privileged socioeconomic backgrounds tend to have access to better quality equipment. The third level concerns the results that can be achieved by combining access with the use of necessary skills and the benefits that individuals can gain from using digital technologies (usage access) (Lythreatis et al., 2022).

The digital divide is a global phenomenon with democratic and social implications, as it defines the right or not -inclusion or exclusion- to active participation, fairness, and social justice to the digital public realm and to the knowledge society (Barockas et al., 2019). The digital divide cannot be explained solely in terms of access, but also in terms of ability (digital skills and technical knowledge), quality of use, and utilization of Internet content. In other words, it refers to those who can benefit from digital technologies and those who remain marginalized or excluded from social and economic progress (Dijck, 2020; Ragnedda, 2017; Trevlaki, 2017).

Ongoing research highlights prejudice, ethics, and privacy as risks associated with the development of AI, something that poses a direct threat to inclusive practices and democratic rights, and fairness. These risks are even greater when it comes to AI systems for people with disabilities, for several reasons (Bennett & Keyes, 2020). Computational models and algorithms are trained on data that may be based on biases and perpetuate them. For example, if those reviewing student applications to universities systematically reject applications of disabled students, or if an insurance

agent systematically denies insurance coverage to people with disabilities, this may result in a model trained with this data continuing the same behaviour. A large amount of data is required to train the systems, which can lead to the underrepresentation of certain groups, especially since data relating to disability belong to the special category of personal data and data subjects may not want to disclose them (Foley & Melese, 2025). It is therefore crucial but also extremely difficult to form AI systems that do not discriminate or exclude specific categories of people, while considering regulatory frameworks and mechanisms of ensuring transparency and accountability (Costanza-Chock, 2020). Finally, the question is whether people with disabilities are involved in the groups responsible for data collection, machine training, protocols, and programming. In order to develop and evolve, AI systems require a wealth of data that is highly specific to each disability and its individual characteristics. Providing the system with continuous information and interacting with large databases expands the system's capabilities and, by this extension, the benefits of using it. Artificial Intelligence has been accused of being opaque. There are even cases where the scientists who programmed an algorithm are unable to know how the "smart" computer has evolved over time. AI systems are often referred to as "black boxes" (Pasquale, 2015) to show that it is hard or even impossible for users to understand how they work inside and the decision-making logic based on algorithms and statistical data correlations. It is very important that computational models should receive input and be trained with accurate and relevant data, and that they are able to evaluate the data that is most important for a specific processing purpose. Human oversight is necessary when defining the model's operating criteria, as well as ex post quality control on how an algorithm was used and what results are produced, something that stresses the imperative demand of comprehensive unbiased design (Raji et al., 2020; Floridi et al., 2018).

3. From Algorithm to Human

For the proper use of Artificial Intelligence and to limit the negative impact previously outlines, the European Union has established two legal texts that, for the first time, impose rules defining the use of this emerging technology. The first is the "Framework Convention on Artificial Intelligence and Human Rights, Democracy and the Rule of Law" (Council of Europe, 2022), which is the first international legally binding treaty to regulate AI as a system consistent with democracy, human rights, and the rule of law, and it is opened for signature since 2024. The second is the Regulation (EU) 2024/1689 of the European Union, widely known as the "AI Act" (EU, 2024). This is the EU's framework law that establishes harmonised rules for the development, placing on the market and use of AI systems within the European Union. These two legal texts take into account in their provisions the fundamental ethical principles of respect for autonomy, equal access, complementarity and transparency.

However, even while these regulatory frameworks are a crucial advancement in the field, their effectiveness within educational settings depends upon the way they are implemented at an institutional level. Respect for human dignity requires the exclusion of applications that manipulate student behaviour from the education system. Practices of monitoring student behaviour inside or outside of school, "social scoring", or leaking either data on their behaviour or opinions they have expressed in class to third parties, through AI systems, violate the core of their personality, no matter how much they may be justified as aiding the "effectiveness" of education. For the same reasons, moreover,

AI applications that determine access to education or the assessment of learning outcomes or the appropriate level of education a person will receive, or the detection of prohibited behaviour by students during exams, are classified as “high risk” systems, as they may have a decisive and unfair impact on the professional future of pupils or students after the end of their education.

According to the principle of autonomy, every available educational tool or method, including AI- based applications, must be evaluated on the basis of whether it contributes to the cultivation of critical thinking or, conversely, whether it may be an illegitimate and dependent substitute, offering “ready-made solutions” to students. The use of AI in education should serve the principles of benefit and non-harm, i.e., maximize benefits and mitigate or eliminate potential risks of harm. For example, advanced students in a high socioeconomic environment may make more creative use of the tools than other students who are content with simpler and more mechanical uses. The ultimate goal of integrating AI systems into education is to mitigate existing inequalities in access to education (economic, social, geographical, or other), promoting educational equality and bridging the performance gap between different groups of learners.

Based on the principle of complementarity, AI systems in education should not replace the student-teacher relationship or interpersonal relationships in the educational community. The direct relationship between people needs to be maintained as the basis of the educational method, for two main reasons: because a) at least for the time being, AI systems have not yet reached the same level of precise understanding of the particularities of specific learning needs (as expressed by each student individually in their school and family environment) as that provided by the intellectual abilities of the teacher, and b) interpersonal contact at school is a critical parameter in the socialisation of students, no matter how much new technologies may contribute to it under certain conditions.

The introduction of new technologies into the educational process requires that those directly responsible for the school, teachers, and parents understand how the relevant applications work, the expected benefits, and the risks they may pose to the quality of education. The principle of transparency requires that teachers supervise the use of applications at all times and be able to request information about the design of the algorithms. Even if specialized technical features are often impossible for non-specialists to understand, at least the basic parameters on which an algorithm is programmed must be understandable to non-specialists (i.e. in terms of the sources of data it evaluates to derive results, or whether the evaluation criteria are objective or biased) (National Bioethics & Technoethics Commission, 2025).

4. Conclusions

AI systems and AI-based educational applications must be aligned with the fundamental principles of protecting human dignity, privacy, transparency, promoting prosperity, inclusion, and pluralism. At the same time, while they offer significant opportunities for teaching and learning, their application cannot be approached only in technical terms or left unsupervised. On the contrary, it must be monitored by appropriate supervisory authorities. In line with this, this paper concludes with several recommendations. First, AI tools must supplement conventional education, assist and

not replace teachers. Traditional education based on dialogue between teachers and learners should not be gradually diminished but enriched by new educational methods. Second, particular emphasis should be placed on the ethical use of technology in education, something that raises serious implications about the basic aims of education, which is to provide equitable access and opportunities to all students regardless of their different backgrounds and individual trains, and create responsible and conscious citizens. In order to address the risk of exacerbating educational inequalities, targeted education policies need to be implemented to ensure equal access for learners, while also providing the necessary technological infrastructure, the provision of specific digital education programs, and an appropriate regulatory framework that guarantees inclusive access to these technologies. In particular, it is recommended that institutional measures be taken to protect linguistic and cultural specificities in order to prevent the deliberate or inadvertent neglect of these elements by those who design, develop, and supply AI systems. Finally, for the pre-service training of future teachers, it is recommended that the curricula of all Higher Education Institutions should be enriched with specific AI courses, including technoethics, in order to provide the future teaching workforce with increased pedagogical knowledge in AI applications, and familiarize students with the ethical, social, and legal implications of AI systems.

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"LearnAIng about Green Energy": A Teaching Scenario Enriched with Artificial Intelligence Tools

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Abstract - Rapid technological advancement has led to the development of artificial intelligence tools that promote a human-centered approach and can be applied in education, introducing innovative methods in teaching and learning. Within this framework, the present paper proposes a lesson plan enriched with artificial intelligence tools, implemented in the context of the Skills Workshops. It targets sixth-grade students and aims to raise their awareness of the use of clean and affordable energy through renewable sources (Goal 7 of the 17 United Nations Sustainable Development Goals).

More specifically, with the support of artificial intelligence, students are expected to: (a) become familiar with renewable energy sources and the clean energy they provide, (b) record their advantages and disadvantages, (c) identify the means that deliver clean energy, (d) distinguish their main components, (e) raise awareness and motivate the community to adopt green energy, and (f) become familiar with artificial intelligence tools. The teaching proposal promotes students' active citizenship and is implemented in an interdisciplinary manner across Language, Science, Mathematics, and Informatics. The project-based learning method is employed, and the duration of the scenario is five weeks. Students work collaboratively in groups, locate and manage information on the topic through search engines, and conduct an interview with the "teacher" via Poe (an AI chat tool) in order to learn more about clean energy. They record renewable energy sources, the forms of energy they provide, the delivery means, as well as their advantages and disadvantages using mindmapai.app/canvas. They design a questionnaire with ChatGPT about household use of green energy, format and distribute it, collect and present the results, create a poster with CapCut, and produce a video with Invideo to raise community awareness about green energy. The teacher creates quizzes with Jotform for knowledge consolidation and assessment, while rubrics for group self-assessment and individual student evaluation are designed with ChatGPT and adapted to meet the needs of the class. Through the use of artificial intelligence, students develop information search and management skills, critically acquire new knowledge, and cultivate metacognitive skills. Digital and information literacy, as well as individual and social responsibility, are strengthened. AI tools help students identify the consequences of using green energy and sensitize the community, thus shaping responsible and active citizens.

Keywords: artificial intelligence tools, critical thinking, digital skills

Introduction

The use of fossil fuels concerns modern society because it exacerbates climate change, degrades quality of life by causing air pollution, and raises concerns about the fact that the Earth's natural resources are not inexhaustible (Holechek et al., 2022). The adverse effects of climate change (natural disasters, loss of human life, economic crises), the health problems faced by millions of people due to increasing air pollution, the depletion of fossil fuel reserves, and the conflicts or even wars they generate among states make the use of green energy imperative (Li et al., 2023).

Green energy is the form of energy produced from sources that are naturally replenished and do not pollute the environment (Kalyani et al., 2015). For this reason, green energy is also called clean energy. Natural sources that provide green energy include sunlight, wind, rain, tides, and geothermal heat. These energy resources are renewable and are called renewable energy sources. The sun provides solar energy, wind provides wind energy, rain, tides, and water movement in general provide hydrodynamic energy, and geothermal heat provides geothermal energy. Plants constitute biomass, whose combustion can provide heat, electricity, and biofuels. Biomass can provide green energy only when combustion takes place under conditions that do not pollute the environment.

The use of green energy constitutes only one parameter in solving environmental problems. The spread of green, clean energy in households, together with the eradication of poverty, elimination of hunger, ensuring good health, quality education, clean and safe water, gender equality, decent work, sustainable cities, responsible production and consumption, reduction of inequalities, promotion of sustainable industry, climate action, preservation of biodiversity and marine resources, achievement of peaceful and inclusive societies, and global cooperation, contributes to sustainable development. These parameters constitute the 17 Sustainable Development Goals formulated by the United Nations General Assembly in New York in September 2015. Countries worldwide seek to achieve these goals in order to address critical environmental problems and achieve development that will not compromise the future of coming generations.

The contribution of education is crucial. Through Skills Workshops, Active Citizen initiatives, and modern fields of knowledge, schools can help shape tomorrow's responsible citizens who, having developed critical thinking and metacognitive skills, can work toward achieving sustainable development. Artificial intelligence can also contribute in this direction.

Artificial intelligence refers to the field of computer science that aims to design intelligent computational systems—that is, systems that resemble human behavior (learning, problem solving, object recognition, etc.) (Xu et al., 2021). In education, artificial intelligence promotes personalized learning, collaboration, interaction, and enhances students' interest in the lesson (Han et al., 2020). Thus, learning can be adapted to each student's pace (Hines, 1996). The creation of digital teaching assistants (chatbots) operates in this direction. Additionally, it constitutes a valuable aid for teachers in designing instruction, assessing students, and reflecting on the achievement of teaching goals (Ma et al., 2014).

Activities implemented within Skills Workshops and primary school teaching can be enriched with artificial intelligence tools. These offer personalized learning, create interactive content, train students in searching for and managing information, constructing knowledge, and conducting self-assessment and peer assessment, while strengthening digital and information literacy. A number of tools promote the human-centered character of artificial intelligence and can be used in teaching. Indicatively, ChatGPT uses large language models to understand and generate human-like text, answering questions, writing essays, code, poems, and translating languages (Vakarou et al., 2025). With it, teachers can create lesson plans, various types of texts, and self-assessment and peer-assessment rubrics for individuals and groups. Quizizz AI, Jotform, and Kahoot enable teachers to create quizzes for consolidation and assessment of knowledge. Pixlr, CapCut, and Canva AI allow images and videos to be generated from text. There are also AI avatar generators with which students can converse in order to practice oral language and locate information that helps enrich their knowledge. Furthermore, with AI tools for generating posters and images, students can transform a text into visuals and create posters to raise community awareness about issues concerning society. Music can also be produced with the help of artificial intelligence. Suno AI and AIVA are some of the tools capable of creating musical accompaniment or even composing a complete song with music, lyrics, and vocals.

Within this framework, the present teaching scenario is implemented in order to sensitize students regarding the 7th of the 17 Sustainable Development Goals, which concerns the use of clean and affordable energy. Specifically, the objectives of the teaching scenario, addressed to sixth-grade students, are:

- to become familiar with renewable sources and the clean energy they provide,
- to record their advantages and disadvantages,
- to identify the means that provide clean energy,
- to distinguish their components,
- to raise awareness and mobilize the community toward the use of green energy,
- to become familiar with artificial intelligence tools.

Through the activities, the following are pursued:

- cultivation of collaborative learning,
- development of critical and creative thinking and cooperation,
- strengthening of communication and research skills,
- promotion of information and digital literacy,
- awareness of individual and social responsibility,
- connection of the individual with the community,
- acquisition of environmental awareness,
- understanding of the concept of sustainable development,
- promotion of active citizenship skills.

The design of the activities places the student at the center. The scenario constitutes a student-centered process, as it motivates learners to participate, investigate, take initiatives, design and implement actions for problem solving. It enhances collaborative learning by giving students opportunities to interact, communicate, and cooperate to achieve their goal. It promotes active, experiential, inquiry-based learning using the project method. The teaching proposal is implemented in Skills Workshops within the

framework of initiatives that strengthen students' active citizenship. The topics are approached interdisciplinary in Language, Physics, Mathematics, and Informatics.

The teaching scenario is applied to sixth-grade students who have already been taught what energy is, what its forms are, and how it is converted from one form to another. They have participated in environmental programs and have been introduced to the concept of sustainable development. They have developed sufficient vocabulary to support their views, use appropriate registers in oral communication, and can expand the digital skills they acquired in previous grades. Students are divided into groups and work collaboratively on the worksheets provided. The intervention is completed over five weeks.

Teaching Scenario

The teaching proposal was implemented in the 6th grade of the 18th Primary School of Kavala. The students were divided into four groups of five members each. Below are the phases of implementation of the teaching scenario by week.

According to the plan, during the first week, in the Physics class, the students referred back to their 5th-grade Physics textbook to recall what energy is, what forms it can take, and to identify its transformations from one form to another. They were then given a worksheet in which they were asked to gather information from the provided links (https://greeco.gr/business/ti-inai-i-kathari-energheia-kai-pws-skhetizetai-me-tin-prasini-energheia/, https://el.wikipedia.org/wiki/%CE%95%CE%BD%CE%AD%CFfile:///C:/Users/agasl/Downloads/10-0178-02_V2_Fysika_ST-Dimotikou_Vivlio-Mathiti(1).pdf) and answer the question: which forms of energy are inexpensive and clean? They were also given the link https://poe.com/, which leads to an online artificial intelligence platform that allows users to interact with many different language models, so that they could "converse" with Mr. Teacher and ask him which forms of energy are clean and from which renewable sources they originate. The students filled in the table provided with the inexpensive and clean forms of energy they identified and their renewable sources. The four groups then presented what they had written, and the table was completed collaboratively by the whole class.

Μορφή Ενέργειας	Χαρακτηρισμός (Φθηνή/Καθαρή)	Πηγή
Ηλιακή ενέργεια	Φθηνή & καθαρή	Ηλιακή ακτινοβολία
Αιολική ενέργεια	Φθηνή & καθαρή	Άνεμος
Υδροηλεκτρική ενέργεια	Φθηνή & καθαρή	Ροή νερού σε ποτάμια/φράγματα
Γεωθερμική ενέργεια	Καθαρή & σχετικά φθηνή	Θερμότητα από το εσωτερικό της Γης
Βιομάζα	Ανανεώσιμη αλλά όχι πάντα καθαρή	Οργανικά απόβλητα, φυτική ύλη
Ηλιακή θερμική ενέργεια	Φθηνή & καθαρή	Θερμότητα ήλιου για θέρμανση νερού
Παλιρροϊκή ενέργεια	Καθαρή (ακριβότερη σήμερα)	Παλίρροιες και θαλάσσια ρεύματα

Figure 1. Table of Clean Forms of Energy

During the same week, in the Skills Workshops class, the students completed a worksheet according to which each group selected one form of green/clean energy and listed its advantages and disadvantages. A representative from each group presented their notes to the whole class. Their responses were compared with the table created by the teacher using mindmapai.app/canvas, which illustrated the advantages and disadvantages of clean forms of energy.

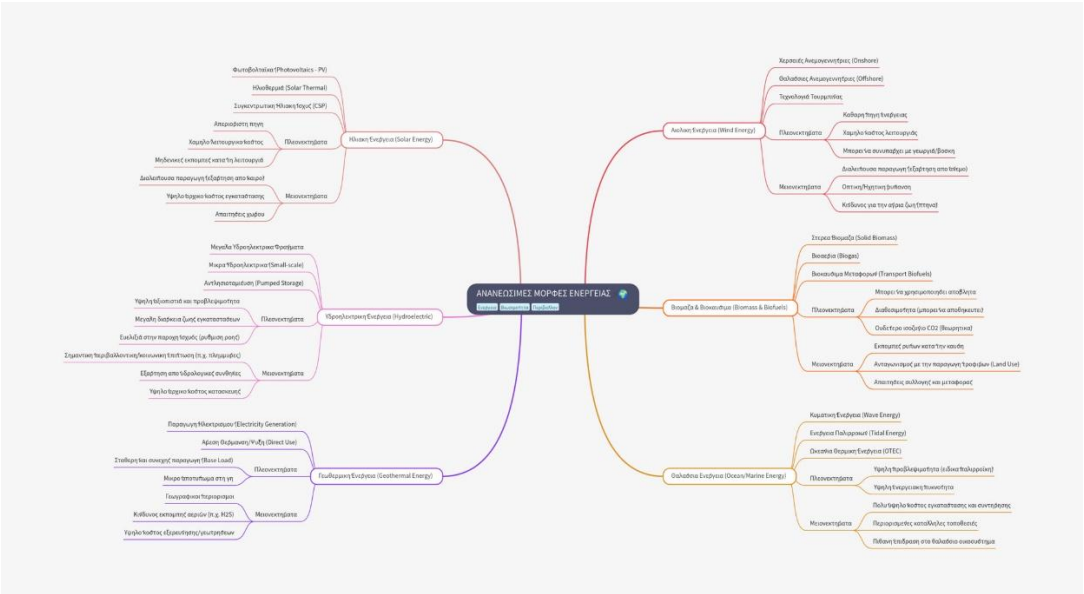


Figure 2. Table of Advantages and Disadvantages of Clean Forms of Energy

In the second week, during the Skills Workshops class, the students were asked to convert the clean/green energy form they had chosen the previous week into a form of energy they need to meet their daily needs. They were then instructed to name the means by which this conversion takes place and to draw its parts. The first group, which had selected wind energy and recorded its advantages and disadvantages, decided to convert

it into electrical energy. The device they designed for this conversion was the wind turbine. They recorded its parts after searching for information online using search engines.

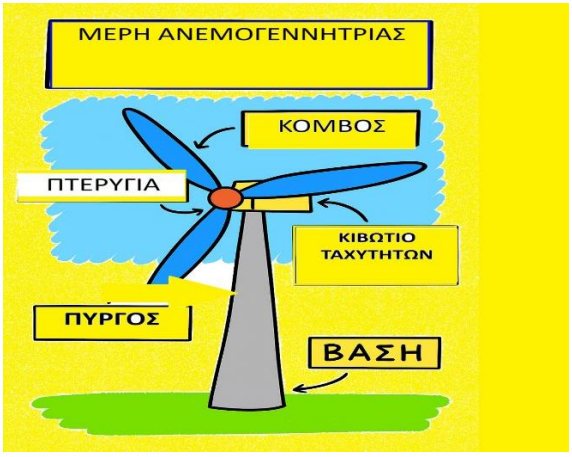


Figure 3. Parts of a Wind Turbine as recorded by the Students

The second group selected solar energy and aimed to convert it into electrical energy. They searched online and found that this conversion is achieved through photovoltaic systems, and they recorded their components. The third group chose hydrodynamic energy (the energy of moving water) and emphasized that it can be converted into electrical energy. Through online searches, they found that this is done using a hydroelectric power station and recorded its parts. The fourth group selected solar energy and decided to convert it into thermal energy. They followed the same process as the previous groups, discovering that the conversion is achieved through a solar collector, and they recorded its components.

In the third week, during the Skills Workshops class, the students created posters using CapCut in order to highlight the advantages of the green energy source they had selected and to raise community awareness about it. The first group created a poster on the advantages of wind energy, the second on solar energy, the third on hydrodynamic energy, and the fourth also on solar energy. The posters created by the students were uploaded to the school's website.



Figure 4. Student Posters on Wind and Solar Energy

In the fourth week, during the Language lesson, the students, with the help of ChatGPT, created a questionnaire investigating household use of green/clean energy. The questionnaire was reviewed and corrected by the whole class. It included ten questions on whether households were familiar with green energy, which forms they used, which factors would facilitate its use, and how well informed they were about its benefits. It also asked whether they would invest in green energy in the future, what factors discouraged them from using it, whether they believed that using green energy could have a positive impact on their household's environmental footprint, to what extent they would support government initiatives promoting green energy, and whether they would like more information and educational programs about it. The questionnaire was then printed in copies and distributed by the students to their parents at dismissal time.

In the fifth week, during the Mathematics lesson, the students entered the households' responses into a Google document created by the teacher https://docs.google.com/document/d/1yE3f70qUEdxPrjcRG5duL2sRHW-YS3O5OkCJweVTYMk/edit?usp=sharing. Then, following the worksheet instructions on how to use Excel to create charts https://docs.google.com/document/d/10AEIfbNJyqAf9njiX5Yrg_WBxsZSxcIne5vDjLVM7hY/edit?usp=sharing, they presented the results in graphs. The results were discussed in plenary. The students commented on the responses of 70 households. They emphasized that a large percentage of the surveyed households (60%) were aware of green energy, 38.6% used green energy at home, and most of these used solar energy.

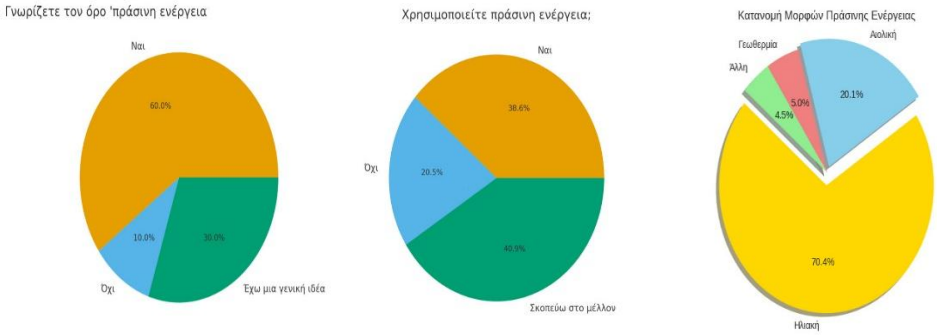


Figure 5. Charts of Survey Results on Green Energy

Additionally, the students noted that energy independence was the factor that led many households to use clean energy, while 34% stated that they were only slightly informed about green, clean energy. Notably, 44.4% of households were unsure whether green energy constitutes an investment for the future.

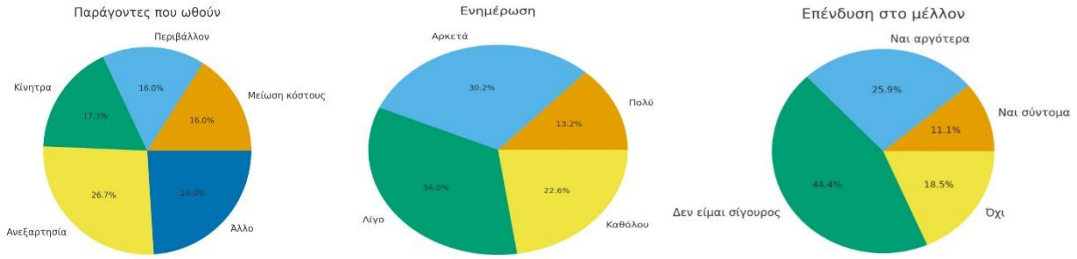


Figure 6. Charts of Survey Results on Green Energy

Furthermore, the students found that 25.3% of households reported that lack of information was the main factor preventing them from using green energy. They also pointed out that households believed insufficient incentives were provided to encourage a shift toward clean energy use. Moreover, many were uncertain whether the use of green/clean energy could have a positive impact on their household environmental footprint. At the same time, they observed that households would offer only limited support to government initiatives promoting green energy.

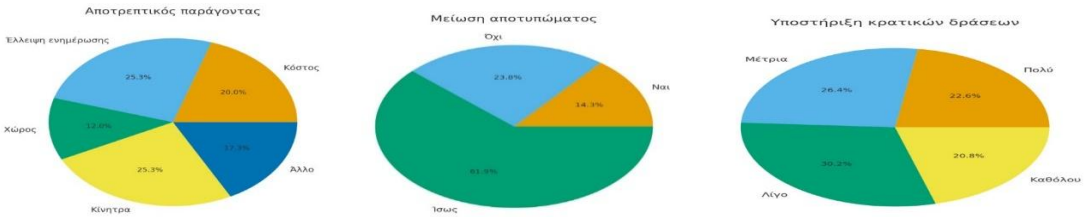


Figure 7. Charts of Survey Results on Green Energy

The students emphasized that 44.2% of households stated they might like to receive more information or educational programs about green energy.

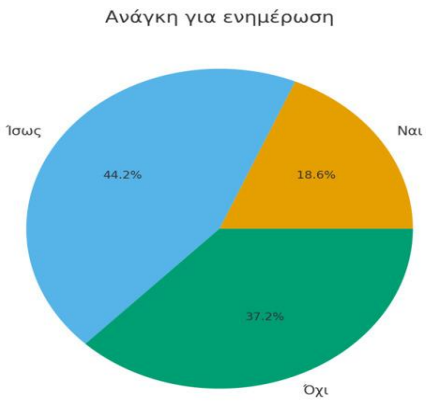


Figure 8. Charts of Survey Results on Green Energy

From the survey, the students concluded that the community needs to be further sensitized to the use of green, clean energy. For this reason, during the ICT lesson (in the same week), they created, with the help of InVideo (an artificial intelligence tool), a video presenting the advantages of green energy. The video is available at the following link: https://screenrec.com/share/6t1IDvTCNZ and was sent from the school's email account to all students.

During the same week, in the Skills Workshops class, the students completed an online quiz created by the teacher using Jotform, by clicking on the link https://form.jotform.com/253455777058368. In this way, the newly acquired knowledge was consolidated and, through the automatic generation of test results, the teacher was able to provide immediate feedback. Afterwards, individual and group self-assessment rubrics were distributed to the students, which had been created by the teacher with the help of ChatGPT. The rubrics are available at the following links: https://docs.google.com/document/d/11awnSU39LMl7XvOAir55cX6hzPSEWF94bblZGc5URQ/edit?usp=sharing https://docs.google.com/document/d/1yhlf5qH8SxFTvuvGRqotf1HPh_WKR49ALqZHtqacpTk/edit?usp=sharing This was followed by a plenary class discussion during which each group reflected on and evaluated its work, highlighting what went well and what they would change. The discussion concluded with a summary of the topic by the teacher. The students' project was presented at a special event attended by parents and students from all grades.

Conclusions

The use of green, clean energy is crucial for the future of the planet. Its inclusion among the 17 Sustainable Development Goals demonstrates the necessity of raising community awareness about the use of green energy and renewable sources. The role of education in informing students about achieving sustainable development—one that does not deprive future generations of natural resources and a clean environment—is pivotal. Students' understanding of the parameters of sustainable development and the ways to achieve it creates the conditions necessary to address the economic, social, and environmental problems affecting modern society.

Through educational programs, students acquire knowledge and develop skills that enable them to become responsible future citizens who care about and act for the prosperity and well-being of their community through sustainable development.

Artificial intelligence plays a decisive role in supporting this effort. A range of AI tools (such as ChatGPT, Poe, CapCut, InVideo, Canva AI, ChatFAI, etc.) have been developed and integrated into teaching practice, enriching it. These tools can personalize learning, maximize interaction, strengthen collaboration, increase students' interest and engagement, provide continuous and immediate feedback, and facilitate communication and understanding. In addition, they help teachers design teaching scenarios, organize materials more effectively, identify students' weaknesses, provide prompt feedback, and conduct assessment. Artificial intelligence in education supports the development of critical and creative thinking, metacognition, and digital, information literacy. It contributes to the formation of active, responsible, and aware citizens who act for social well-being while pursuing sustainable development.

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«Learning to Eat Properly: Using Artificial Intelligence Tools in an Instructional Scenario»

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract - The rapid advancement of information technology and new technologies, along with the introduction of Artificial Intelligence (AI) in education, is bringing significant changes to the learning process, creating opportunities and posing new challenges for classroom teachers. In this context, educators are called upon to utilize AI tools in practice, adding a human-centered dimension while addressing ethical and deontological issues. The present paper refers to the implementation of the teaching scenario entitled *"Learning to Eat Properly,"* in the Physical Education course for middle school students, aiming to help them understand the value and proper way of healthy nutrition through the use of artificial intelligence tools. Teaching is enriched with collaborative group activities supported by AI applications, which make the learning process more engaging and enhance students' digital literacy and creativity. Specifically, the following tools are used by both the teacher and the students: **Veed.io** at the beginning of the lesson (video) to introduce students to healthy eating; **CapCut** for designing the image of the nutritionist by the teacher; **ChatFAI** for creating and interacting with the "Super Nutritionist," from whom student groups obtain information about a healthy dietary model. After critically processing the information, the groups compose their own healthy eating plan, highlighting its value. Finally, **ChatGPT** is used to create a rubric for individual and group student assessment. Through this scenario, it is demonstrated that AI can contribute to improving the quality of teaching without overlooking the central role of the teacher.

Keywords: Artificial Intelligence, healthy nutrition, teaching

Introduction

The impact of nutrition on an individual's physical, cognitive, psychological, and social development is decisive at all stages of biological growth. Especially during adolescence, which coincides with school life, a balanced and healthy diet contributes to reducing the occurrence of health problems (iron-deficiency anemia, tooth decay) and one of the greatest global problems, obesity (Frühbeck et al., 2013). At the same time, this critical age lays the foundations for longevity and the prevention of chronic diseases (cardiovascular diseases, diabetes mellitus, osteoporosis), while dietary habits and behaviors are established and adopted by adolescents and tend to follow them into adulthood. According to findings from scientific studies and data from the World Health Organization (WHO), most children at this age do not follow a healthy and active lifestyle, resulting in high global rates of adolescent obesity. Greece records the highest percentage (32%) in Europe among children and adolescents with excess body weight or obesity (WHO, 2022c) and ranks second highest among fifteen-year-old boys with obesity (Rakić et al., 2024). The effects of obesity in children and adolescents are adverse both in the short and long term, negatively affecting their physical development and functioning, mental health, socialization, and school performance (Haqq et al., 2021). Recognizing the risks arising from obesity, it is necessary to modify and change students' dietary habits through school education, aiming at prevention and management, as well as promoting lifelong health and quality of life. The school environment and teachers can contribute decisively to students' proper nutritional education through the implementation of appropriate interventions and the development of Health Education programs, Skills Workshops, and Active Citizenship initiatives. In this direction, the contribution of artificial intelligence (AI) as a supportive tool for teachers in transforming the learning process and creating an engaging learning environment is of key importance.

Artificial intelligence is the study of mechanisms that govern intelligent behavior through the creation and evaluation of systems that imitate these mechanisms (Luger & Stubblefield, 1998). In education, artificial intelligence is an important assistant for teachers, as it enables them to design lesson plans, personalize learning, immediately assess students, and receive quick and continuous feedback on their teaching progress (Luckin et al., 2016). Its contribution to students is also significant, as it can adapt to their individual learning pace, create appropriate environments for collaborative learning that enhance interaction, help them develop metacognition, and provide tools for self-assessment (individual and group) along with immediate, targeted feedback (Holmes et al., 2019).

The penetration of artificial intelligence into education is now a reality and is expected to substantially influence the learning process. Its adoption in everyday school practice has understandably sparked a wide range of discussions about the opportunities and challenges it presents, while also raising serious concerns related to issues such as security, data protection and privacy, copyright, and manipulation (UNESCO, 2024). Many educators welcomed its arrival and adopted a positive stance, viewing it as a pedagogical ally, while others approached it with fear or as a threat (Tlili, 2023). Despite the initial concerns of the educational community regarding AI tools—and especially ChatGPT—about the potential undermining of learning assessment through student plagiarism (Anders, 2023) and the risks associated with their use, their contribution to transforming the learning process is decisive, provided they are used

responsibly, safely, and creatively. This requires teachers to be familiar with the technology and its capabilities, to stay informed and receive ongoing training, and for students to be supported in using AI tools effectively, ethically, and transparently (Russell Group, 2023).

There are many and varied artificial intelligence tools that can contribute to the educational process and assist both students and teachers. Indicatively, these include ChatGPT and Grammarly, which enable lesson development, text writing, and immediate feedback. Quizlet, ClassMarker, ProProfs, QuestBase, and QuizRevolution can be used by teachers to create tests. CapCut and Canva AI generate images from text, allowing students to visualize their written descriptions. Veed.io is a tool for creating videos from text. Additionally, there are avatar-creation tools that allow users to interact with them, such as ChatFAI.
In this context, the present teaching scenario was developed for third-grade Gymnasium (lower secondary school) students in the Physical Education course, with a duration of two teaching hours. Its purpose is for students to understand the value and proper way of healthy nutrition through collaborative group activities using artificial intelligence tools.

After completing the teaching scenario, students are expected to achieve the following:

At the level of Knowledge

- To know the food pyramid of the Mediterranean diet
- To understand the value of proper nutrition
- To evaluate their own dietary habits

At the level of Skills

- To take initiatives and create educational activities related to healthy nutrition
- To become familiar with AI tools and use them responsibly and safely
- To increase their sense of responsibility through role-taking
- To strengthen skills of teamwork and collaboration

At the level of Attitudes

- To utilize nutrition-related sources through critical thinking
- To adopt healthy eating habits for health and quality of life

The teaching scenario aligns with the objectives of the New Curricula, specifically the cognitive objective and the thematic unit concerning knowledge of nutrition issues that contribute to the promotion of health and performance. It can be implemented either in the computer lab or in the classroom, where an interactive whiteboard, tablets, and an internet connection are required.

The instructional approach of the scenario is student-centered. The student plays the leading role, working mainly collaboratively in groups and becoming co-responsible for their learning. They take initiatives, collaborate, and interact both with their classmates and with the teacher. The teacher's role is guiding, supportive, and encouraging, gradually transferring learning initiatives to the students and increasing their intrinsic motivation. The teacher supervises the learning process and intervenes when requested.

Description of the Teaching Process / 1st Teaching Hour

Taking as a starting point the fact that the school canteen is closed because the new lease tender process has not yet been completed, the teacher attempts to stimulate students' interest and explore their prior knowledge regarding nutrition, daily meals, meeting their nutritional needs, and healthy eating through questions. Indicative questions include: *Now that the canteen is closed, do we eat a mid-morning snack? Do we have water with us? What does the package our mother prepared include? Was it homemade or did we choose a ready-made sandwich?*

A brainstorming session follows, during which the teacher does not comment. Students' responses are recorded on the board. Next, groups of three to four students are formed randomly per computer, depending on class size, or each group is given a tablet. Each group selects its name (related to nutrition) and assigns roles (coordinator, recorder, equal members).

A video on healthy nutrition is then shown on the interactive board. It was created by the teacher with the help of artificial intelligence using the tool **Veed.io** (33 seconds long). The next activity for each group is to complete an interactive concept map on the basic components of food and examples of each category, using the National Aggregator of Educational Content "Fotodentro."

The first teaching hour concludes with a worksheet that groups are asked to complete using information from both the image and the text of the Fotodentro resource *"We Are What We Eat."* It should be noted that the worksheet image was created by the teacher using artificial intelligence and the **CapCut** tool.



Figure 1. Healthy Eating Poster

Students reflect on their choices and eating habits, draw conclusions, present them to the whole class, and a discussion follows. The worksheet is also uploaded to the E-class platform.

2nd Teaching Hour

At the beginning of the second hour, connections are made with the concepts and topics covered in the previous lesson. Each group is then asked to think of questions and interact with the *Super Nutritionist*, interviewing her about issues related to nutrition

and exercise. The nutritionist is an AI-generated character created by the teacher using the tool **ChatFAI**.

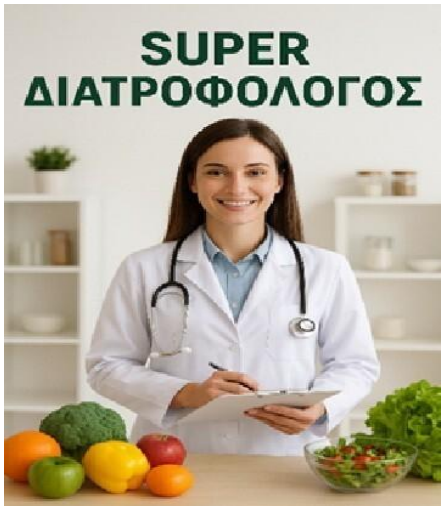


Figure 2. Nutritionist picture

Next follows the evaluation of each group's dietary habits through their connection to the "Fotodentro" platform. The aim of this activity is both for students to assess their own eating habits and to adopt a healthy dietary model in order to maintain or improve their health. At the same time, they learn about the "ideal" composition of breakfast.

This is followed by each group's self-assessment through the completion of a rubric consisting of five criteria related to participation, collaboration, and communication. It is noted that such an assessment rubric could also be created with the help of artificial intelligence.

Homework is then assigned: each group is asked to create a poster about nutrition with the help of AI, using one of the tools (Canva or CapCut). The coordinator of each group uploads the poster to the teacher's online classroom. A summary of the activities takes place, focusing on the use of AI tools, and the teaching scenario is completed.

Conclusions

Healthy nutrition for children and adolescents is a topic at the center of interest in modern times, as sedentary lifestyles, increased academic obligations, young people's engagement with electronic games, poor dietary choices, and lack of information lead to obesity. It is necessary for schools to inform students about healthy dietary choices and their impact on health so that they can build the foundations of a strong and healthy body. Through educational programs and experiential activities, adolescents can become aware of the benefits of a healthy, balanced diet and adopt eating habits that contribute to their well-being and quality of health.

Artificial intelligence can contribute in this direction because the tools it provides to teachers enable personalized learning, development of cognitive skills (analysis, synthesis, comparison of information), immediate and rapid feedback, individual and group self-assessment and peer assessment, as well as the cultivation of metacognition and digital literacy. The use of artificial intelligence enhances collaboration,

responsibility-taking, communication, engagement, and active participation in the learning process, increasing students' self-esteem and self-confidence. It makes lessons more enjoyable and increases motivation for participation. In this way, it contributes to the formation of responsible, informed future citizens who act for individual and social well-being and quality of life.

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Teachers' Insights into Mixed Reality in Education: Challenges, Opportunities, and Limitations

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Abstract- Mixed Reality (MR) technologies are increasingly promoted as catalysts for digital transformation in education, yet their integration into formal schooling remains uneven and contested. This study investigates teachers' perceptions of MR adoption in Greece through a mixed-methods design that combines quantitative survey data (N = 115) with qualitative thematic analysis. Findings indicate that educators hold predominantly positive views of MR's pedagogical potential, particularly in fostering exploratory learning, critical thinking, and sensory-enriched experiences across STEM and humanities subjects. At the same time, teachers voiced substantial concerns related to infrastructural gaps, limited professional training, and equity risks that could exacerbate the digital divide. The qualitative analysis further highlights educators' emphasis on the need for scenario authoring tools that safeguard pedagogical autonomy and position teachers as active co-creators rather than passive users of immersive technologies. By framing results through TAM, UTAUT2, and TPACK, this study demonstrates how teachers' perceptions align with established models of technology acceptance while also revealing critical tensions between innovation, ethics, and systemic readiness. Importantly, the study identifies a forward-looking opportunity: the convergence of MR with learning analytics and cognitive computing, which can enable responsive, data-informed teaching but also raises new ethical challenges around privacy and transparency. These insights contribute to international debates on how immersive technologies can be embedded sustainably into teacher-centered, equitable, and ethically grounded educational ecosystems.

Keywords— Mixed Reality, Teachers' Perceptions, Digital Transformation, Technology Integration, Educational Technology

Introduction

The education field has continuously sought to integrate new technological tools, but the pace of adoption often lags behind the rapid evolution of digital innovations. Mixed Reality (MR)—an umbrella term covering Virtual Reality (VR), Augmented Reality (AR), and their hybrids—has emerged as one of the most promising educational technologies of the last decade. Its applications span a wide range of contexts, from language learning (Manna, 2023) and STEAM education (Pellas et al., 2020) to Natural Sciences (Faria & Miranda, 2024). Positive outcomes have also been reported in special education, where MR tools support learners with disabilities or learning difficulties through personalized instruction (Köse & Güner-Yildiz, 2021; Imashev et al., 2024). Beyond disciplinary boundaries, recent studies emphasize MR's capacity to enrich cognitive engagement, foster creativity, and stimulate embodied learning processes that go beyond traditional didactic approaches (Garzón et al., 2019; Haleem et al., 2022).

Although the actual use of MR in schools is relatively recent, an increasing body of literature provides insights into how to achieve an effective transition (Mystakidis et al., 2022), while also highlighting persistent barriers such as lack of institutional support, curriculum rigidity, and insufficient training (Kaimara et al., 2021). Teachers' attitudes remain a decisive factor: positive perceptions and willingness to experiment often translate into successful integration (Marín-Marín et al., 2023), while skepticism or lack of preparedness can hinder adoption (Khukalenko et al., 2022). Importantly, research also points to subject-specific opportunities: for example, MR has been shown to foster exploratory learning in Mathematics and Sciences, while in Language and History it can enhance cultural heritage education (Zhabykbayeva et al., 2021).

At the same time, MR is increasingly discussed not only as a pedagogical innovation but also as part of a broader data-driven educational ecosystem. MR environments generate rich streams of interaction data—such as gaze, gestures, and task performance—that can inform cognitive modelling and adaptive instructional systems (Abdurrahman et al., 2021). When paired with Artificial Intelligence and learning analytics, such data can be leveraged to design personalized and equitable learning trajectories (Valtonen et al., 2025). This convergence aligns with broader trends in predictive modelling and personalized digital learning, which aim to forecast student performance, identify at-risk learners, and support teachers in decision-making (Van Schoors et al., 2025).

Nevertheless, integrating MR into education raises several equity and ethical considerations. Scholars have noted that immersive technologies may inadvertently reproduce the "digital divide," privileging well-resourced schools while leaving underfunded ones behind (Garzón et al., 2019). Concerns about privacy, transparency, and data ownership also remain critical, particularly when immersive systems collect biometric or behavioural data from minors (Cruz et al., 2025). These challenges underscore the need for comprehensive frameworks that combine teacher training, ethical safeguards, and inclusive design principles to ensure that MR adoption is sustainable, equitable, and pedagogically meaningful.

To situate the present study within established theoretical perspectives, three key frameworks are relevant. The Technology Acceptance Model (TAM) emphasizes perceived usefulness and ease of use as predictors of technology adoption (Davis,

1989). The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) expands this framework by incorporating performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and habit (Venkatesh et al., 2012). Finally, the Technological Pedagogical Content Knowledge (TPACK) framework stresses the interplay between teachers' technological, pedagogical, and content knowledge as a determinant of meaningful integration (Mishra & Koehler, 2006). Together, these frameworks provide a solid foundation for interpreting teachers' attitudes, intentions, and readiness to adopt MR into the educational system. Accordingly, this study addresses the following Research Questions (RQs):

• RQ1: To what extent do teachers perceive MR technologies as useful for enhancing pedagogical practices across different subjects?
• RQ2: To what degree do UTAUT2-related factors (effort expectancy, social influence, facilitating conditions) explain teachers' readiness to adopt MR?
• RQ3: How do teachers' perceptions of MR align with the TPACK framework, particularly in balancing technology, pedagogy, and content knowledge?

Methodology

Research Design: This study employed a mixed-methods design, combining quantitative analysis of structured survey items with qualitative insights derived from open-ended responses. This dual approach allowed for both breadth and depth in examining teachers' views, capturing measurable patterns as well as nuanced perspectives.

Participants: The final sample consisted of 115 in-service teachers across multiple educational levels in Greece, representing a variety of subject areas including STEM, humanities, and foreign language education. Participants were recruited via professional networks and institutional mailing lists. In terms of demographics, participants had an average age of 45 years old, with the age range spanning from 26 to 77 years old. They also reported an average of 15 years of teaching experience across various educational levels (from Elementary School to University level). Notably, women accounted for about 70% of the sample—a figure consistent with natural frequencies and national trends, as more than 60% of teachers in Greece are female (Hellenic Statistical Authority, 2024).

Geographic location was not a limiting factor, as the web-based nature of the survey allowed for broad accessibility. It was also determined that regional differences within Greece do not significantly affect educators' perceptions, making nationwide participation both feasible and appropriate for the study's goals.

Survey Design, Reliability and Validity: The survey instrument was developed based on established themes in the literature regarding teachers' perceptions of immersive technologies. The questionnaire comprised nine closed-ended items organized into three thematic scales (pedagogical opportunities, challenges and barriers, and ethical concerns), and four open-ended questions designed to capture deeper qualitative insights.

Internal consistency was assessed through reliability analysis, with Cronbach's alpha coefficients for the three scales ranging between 0.78 and 0.85, indicating satisfactory

levels of reliability. The instrument's content validity was ensured through iterative design and refinement by the research team, grounded in prior studies of AR/VR/MR adoption in educational contexts (e.g., Ibáñez & Delgado-Kloos, 2018; Khukalenko et al., 2022).

Data Analysis: Quantitative data were analyzed using descriptive and inferential statistics to identify trends and relationships across variables. Qualitative responses were coded thematically following Braun & Clarke's (2006) framework, enabling the identification of recurrent patterns related to pedagogical opportunities, systemic barriers, and ethical dilemmas.

Ethical Considerations: The study was conducted in compliance with institutional and European data protection standards. Prior to data collection, approval for administering the questionnaire was obtained from the authors' university. Participants were informed, at the beginning of the survey, about the scope of the study and the voluntary nature of their involvement. The questionnaire explicitly stated that personal data would be protected in accordance with the General Data Protection Regulation (GDPR). Responses were collected anonymously, and no identifying information was requested or stored, ensuring that the research team could not link any set of responses to an individual participant. Informed consent was implied through the voluntary completion of the questionnaire.

Results

Quantitative Analysis

1. Teachers' Familiarity and Training Needs: In response to the first question—training related to Mixed Reality (MR), including Virtual Reality (VR) and Augmented Reality (AR), technologies — the vast majority of respondents (76.5%) reported no prior seminar or training experience in MR. Only 23 respondents indicated having received even minimal exposure to such technologies. When asked about their actual use of MR, nearly 40% stated they had never used MR tools. The second most common response (25.2%) reflected usage limited to entertainment purposes, while 18.3% had used these technologies within educational programs, and just 13% reported use for cultural heritage applications.

Participants were also asked how frequently they stay informed about developments in educational technology. Equal proportions (32.1%) indicated being updated "often" or "moderately," while 20% selected "not so often." Only 13% of respondents reported being updated "very often".

Finally, in regard to their motivation for participating in a seminar on MR, the majority (61.8%) stated they would do so for professional or teaching-related needs, whereas 23.5% expressed personal interest as their primary motivation (see Figure 1).

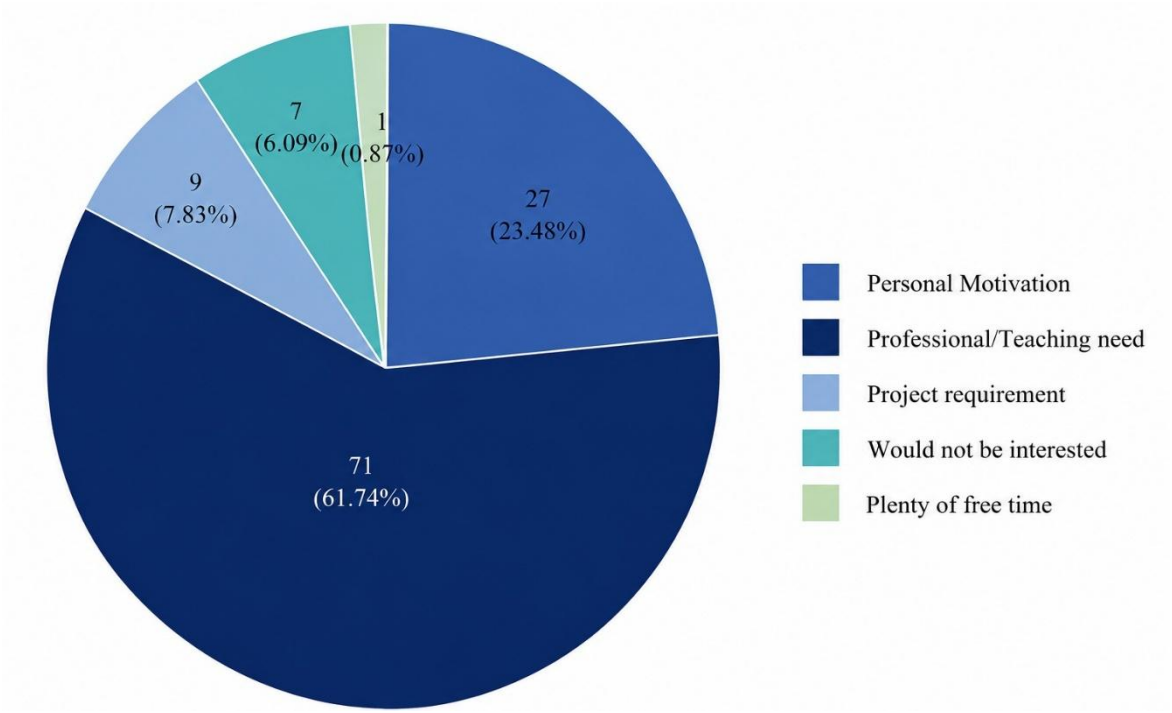


Figure 1: Survey results on question: "Which of the following would motivate you most to participate in a seminar on MR technologies?"

2. Teachers' Perceptions on Educational Applications of MR: The analysis of participants' responses regarding the pedagogical applications of MR technologies revealed largely positive expectations and consistent patterns of acceptance, both in terms of cognitive skill development and applicability across specific school subjects and teaching methodologies. Concerning the perceived enhancement of cognitive abilities through MR, critical thinking was widely endorsed, with 34.8% responding "often" and 22.6% "very often". Similar results were recorded for analytical thinking (39.1% "often", 20% "very often"), while computational thinking also received strong support, with 33.9% choosing "often" and 25.2% "very often".

Exploratory learning stood out as the most strongly endorsed, with 49.6% selecting "very often" and 35.7% "often". In the case of Problem-based Learning (PBL), 30.4% of participants responded "often" and 27% "very often", although 7.8% expressed skepticism by selecting "never".

Social skills development was met with more cautious views, with 37.4% choosing "sometimes" and a cumulative 33.1% responding negatively or rarely. In contrast, sensory-enriched learning experience was strongly endorsed, with 62.6% expressing a "strongly positive" perception. In summary, the results are shown in Table 1.

Question	Mean	Standard Deviation
2a. Do you believe that Critical Thinking can be a genuine potential offered by MR technologies?	3.62	0.98
2b. Do you believe that Analytical Thinking can be a genuine potential offered by MR technologies?	3.68	0.97

2c. Do you believe that Computational Thinking can be a genuine potential offered by MR technologies?	3.73	1.03
2d. Do you believe that Exploratory Learning can be a genuine potential offered by MR technologies?	4.30	0.81
2e. Do you believe that Problem-based Learning (PBL) can be a genuine potential offered by MR technologies?	3.79	1.01
2f. Do you believe that Social Skills Development can be a genuine potential offered by MR technologies?	3.03	1.19
2g. Do you believe that Sensory-Enriched Learning Experience can be a genuine potential offered by MR technologies?	4.42	0.91

Table 1: Results of the question "Which of the following do you believe are the genuine potentials offered by MR technologies in education?"

The applicability of MR across educational disciplines was also explored. The highest levels of perceived usefulness were recorded in History and Archaeology, with 59.1% responding "very much" and 27% "a lot". Equally strong approval was noted for Biology and Health Sciences (58.3% "very much") and for Geography and Geology (63.5% "very much"). In Information Technology and Technological Sciences, 66.1% responded "very much" and 22.6% "a lot". For the Sciences (Mathematics, Physics, Chemistry), 83.4% of participants overall believed MR could be used "a lot" or "very much".

Positive responses were also observed in Language and Literature (57.4%) and Foreign Language Learning (73.9%). The most hesitant views were found in Physical Education, with 48.7% responding "moderately" and 19.1% indicating low or no perceived usefulness. In summary, the results are shown in Table 2.

In terms of instructional methods perceived as compatible with MR, the Project-Based Learning approach received the highest level of support, with 54.8% expressing a positive stance. The same percentage was recorded for experimentation and exploration. Brainstorming was also well received (40%), while methods such as Think-Pair-Share, Roundtable, and Guided Reciprocal Discussion were met with more neutral attitudes or lower familiarity. Focus Listing appeared to be the least known and accepted method, with 22.6% declaring unfamiliarity and only 20.9% showing a positive view.

Question	Mean	Standard Deviation
3a. In your opinion, to what extent can MR technologies be used in Language and Literature?	3.71	0.93
3b. In your opinion, to what extent can MR technologies be used in History and Archaeology?	4.39	0.81

3c. In your opinion, to what extent can MR technologies be used in Foreign Language Learning?	4.00	0.85
3d. In your opinion, to what extent can MR technologies be used in Information Technology & Technological Sciences?	4.53	0.71
3e. In your opinion, to what extent can MR technologies be used in Science (Mathematics, Physics, Chemistry)?	4.25	0.76
3f. In your opinion, to what extent can MR technologies be used in Biology and Health Sciences?	4.47	0.73
3g. In your opinion, to what extent can MR technologies be used in Geography and Geology?	4.52	0.70
3h. In your opinion, to what extent can MR technologies be used in Physical Education (Gymnastics)?	3.20	1.02

Table 2: Results of the question "To what extent can MR technologies be used across different educational disciplines?"

Finally, when participants were asked to assess the long-term potential of MR technologies to improve the education system, the findings were highly encouraging. A significant 45.2% believed MR could contribute "a lot" to systemic improvement, and another 29.6% responded "very much" (see Figure 2).

Overall, 74.8% expressed a positive stance, while only 1.7% stated that they expected no contribution at all. These findings highlight a strong tendency to perceive MR technologies as instruments of innovation, experiential learning, and long-term transformation of educational practice.

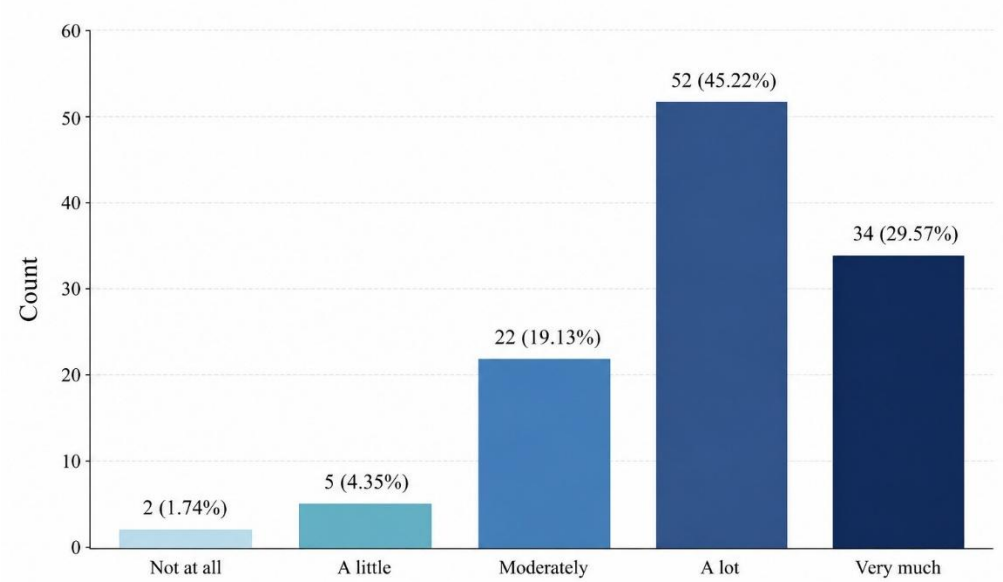


Figure 2: Survey results on question: *"To what extent do you think that the education system can be improved in the long term by the integration and systematic use of MR technologies?"*

3. Issues of Access, Equity, and Creativity: In the question "To what extent do you agree with the opinion that MR can reinforce inequalities in access to certain educational opportunities?", nearly two-thirds of participants believe that the use of MR technologies may reinforce existing inequalities (see Fig. 3). Specifically, 42.6% responded "A lot" and 20% "Very much," amounting to a combined total of 62.6%. In contrast, only 6.1% answered "Not at all." This finding indicates that educators hold serious reservations about the equitable implementation of these technologies, particularly in environments with limited resources or unequal access to digital tools.

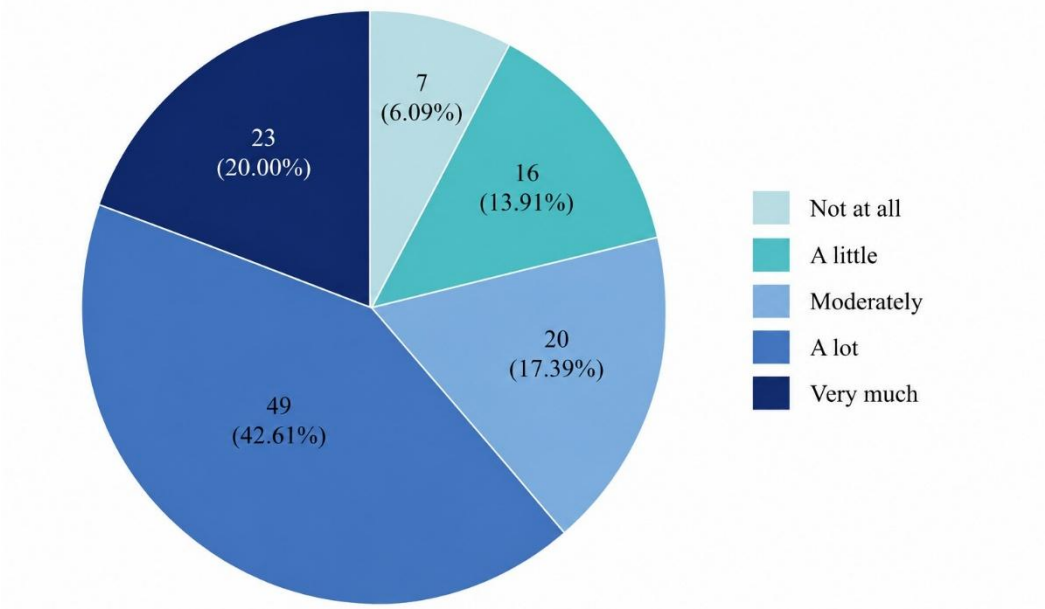


Figure 3: Survey results on question: *"To what extent do you agree with the opinion that virtual/augmented reality can reinforce inequalities in access to certain educational opportunities?"*

In the question "How important do you consider the ability of MR applications to provide teachers with the ability to create their own scenarios?", the creative potential of MR technologies is clearly appreciated by the sample. Specifically, 40% of respondents answered "A lot" and 28.7% "Very much," together accounting for 68.7% of responses in the highest positive categories (see Figure 4).

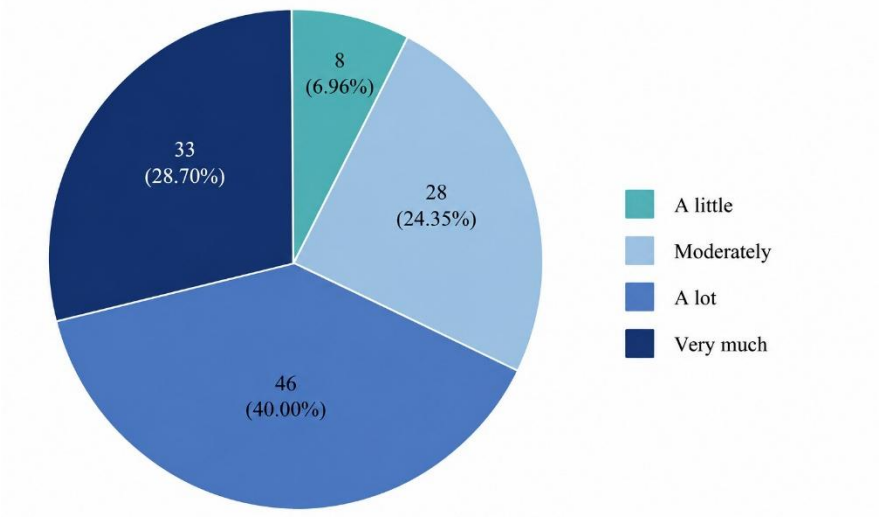


Figure 4: Survey Results on question: *"How important do you consider the ability of MR applications to provide teachers with the ability to create their own scenarios?"*

This suggests that educators value the opportunity to design personalized or customized instructional scenarios as a means of enhancing educational effectiveness. Conversely, only 7% downplayed the importance of this feature, indicating broad acceptance of teachers' active and creative involvement in using MR tools.

4. Associations between experience, demographics and attitudes: To investigate relationships between instructors' experience, age, and education and specific attitude variables, Spearman's rank correlations and Kruskal-Wallis tests were used. Kruskal-Wallis tests were employed for comparisons between categorical groups (education level, teaching level), while Spearman correlations were employed for continuous/ordinal pairs (years of experience, age).

Years of teaching experience were shown to be negatively correlated with the perception of MR's appropriateness for helping students with particular learning challenges (Spearman's ρ = -0.228, n = 114, p = 0.015). This indicates that more experienced teachers tend to rate the suitability of MR for this group slightly lower than less experienced colleagues. A similar negative trend was observed between years of experience and belief in MR's capacity to improve the education system in the long term, but this effect did not reach statistical significance (Spearman's $\rho = -0.173$, n = 114, p = 0.066).

Furthermore, years of experience did not significantly correlate with the belief that MR may perpetuate inequality (Spearman's $\rho = -0.117$, n = 114, p = 0.214). Similarly, there was no difference in education level responses to the inequality item (Kruskal–Wallis H(2) = 0.55, p = 0.758; medians all = 4), indicating that there is widespread agreement across all qualification levels that inequalities are a pertinent concern. Lastly, there was no significant difference in the frequency of professional updating on educational technology by teaching level (Kruskal–Wallis H(2) = 3.93, p = 0.140) or chronological age (Spearman's $\rho = -0.039$, n = 114, p = 0.677). However, higher education teachers reported a slightly higher average frequency of updates, but the sample size was small and no reliable conclusions could be drawn.

These analyses indicate that experience is the strongest demographic correlate among those tested, primarily linked to slightly more cautious appraisals of MR's suitability for learners with specific difficulties and with moderate skepticism regarding the long-term plan to adopt MR in the educational process.

Qualitative Analysis

Thematic analysis was employed to examine participants' open-ended responses, following the six-step procedure proposed by Braun and Clarke (2006). This method enabled an inductive, data-driven approach to theme development, facilitating the exploration of both semantic and latent dimensions of meaning. The aim of this analysis was to explore the perceptions and experiences of educators regarding the implementation of MR in education. This method was chosen for its flexibility and its capacity to identify and interpret meaningful patterns within qualitative data. The process was conducted in three iterative and interrelated phases:

Phase	Description of the process
1. Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas. Responses that included the phrase "No answer" were excluded.
2. Generating initial codes:	Coding was conducted inductively, with semantic units emerging directly from the content of the responses, without the imposition of pre-existing categories. Each code captured a meaningful aspect of the data, often based on keywords or recurring ideas
3. Searching for themes:	Identify main patterns, in the answers of the questionnaires.
4. Reviewing themes:	During the fourth phase, similar codes were grouped together into broader thematic categories
5. Defining and naming themes:	Three actual themes are finally identified
6. Producing the report:	The final report is presented by showing the findings together with the corresponding examples.

Table 3: The six-step procedure applied in the qualitative analysis

Initial Coding

In the first phase, all textual responses were read and re-read in order to achieve familiarity with the data and to begin the generation of initial codes. Coding was conducted inductively, with semantic units emerging directly from the content of the responses, without the imposition of pre-existing categories. Each code captured a meaningful aspect of the data, often based on keywords or recurring ideas (e.g., "lack of infrastructure," "pedagogical innovation," "ethical concerns").

Responses that included the phrase "No answer" were excluded from the analysis, as they did not offer interpretative content relevant to the research aims. However, this represented a noteworthy percentage, exceeding 20% in each question.

The following main patterns/codes were identified:

- Instructional use through immersion,
- Insufficient teacher training/education,
- Infrastructure and cost constraints,
- Hesitations to ethical use,
- Need for training and support,
- Potential benefits to learning through experiential learning

Final Report

This process was driven by both semantic similarity and functional relevance, and involved constant comparison across data entries to ensure coherence and distinction. Through this process, the following three main themes were identified, and are presented in the final analysis below:

Theme 1: Pedagogical Benefits and Opportunities

This theme captures the perceived added value of MR in educational practice. Respondents recognise the value of virtual and augmented reality in active and experiential learning. Several respondents emphasized the motivational and experiential dimensions it introduces to the learning process. MR is described as a tool that promotes engagement, interactivity, and better conceptual understanding, especially in complex or abstract subjects. In some cases, MR was seen as offering differentiated instruction and fostering digital literacy. Moreover, some teachers (in the literary field) reported that Cultural Heritage knowledge can be improved through Innovative Technologies, such as Mixed Reality. Indicatively: "With applications of virtual environments, tours of historical sites, experiments and laboratory activities.", "Presentation of information, exploration by the learner."

As a result, we can conclude that Technology is seen as a tool to enrich teaching, especially in fields where other tools are difficult to approach (e.g. science, history).

Theme 2: Barriers to Implementation

Despite the perceived benefits, numerous responses highlighted practical obstacles. These included the lack of sufficient technological infrastructure in schools, limited digital training for educators, and institutional or systemic constraints. "Lack of training, teacher resistance to new technologies, high installation and maintenance costs.", “Necessary training.”, “It is not easy to change a successful plan that has been in place for so many years.”.

Many participants expressed skepticism regarding the scalability and sustainability of AR use, particularly in public education contexts. Concerns were also raised about the digital divide and the unequal access to devices and internet connectivity among students. “It is not so easy for all schools and universities to get all these modern tools. It's mainly for financial reasons”, was the answer of an educator.

Theme 3: Ethical and Pedagogical Concerns

This theme reflects deeper apprehensions regarding the role of technology in reshaping the teacher-student relationship. “Augmented reality is merely a tool to enhance and improve education, not the goal. The guidance of the teacher and the intellectual effort of the pupils cannot be avoided, nor can it be replaced.”

Some educators raised questions about the ethical implications of extensive MR use, such as privacy issues, screen dependency, and the fear of dehumanizing the learning process. “We need to liberalise the use of mobile devices in education for educational

purposes, but with digital security". Additionally, concerns were noted regarding whether MR might eventually substitute essential aspects of face-to-face teaching or even the teacher's role itself.

Discussion

The findings of this study offer a multidimensional view of teachers' relationship with Mixed Reality (MR) technologies in education. Both the quantitative and qualitative data reveal a mixture of enthusiasm and skepticism regarding the integration of MR into teaching practice. A key issue that emerged is the lack of systematic training: the vast majority of participants reported no prior exposure to MR technologies, while only a small minority had limited hands-on experience. Nevertheless, many respondents expressed awareness of developments in educational technology and a willingness to engage further, signaling latent readiness if adequate institutional support is provided. This aligns with previous findings that professional development and targeted training are prerequisites for sustainable technology adoption (Basilotta-Gómez-Pablos et al., 2022). From a theoretical perspective, this result resonates with the UTAUT2 framework, where facilitating conditions and effort expectancy play critical roles in shaping intention to use. In this context, teachers' motivation to attend MR seminars reflects their perceived usefulness of the technology (performance expectancy), but also underscores the necessity of structured support mechanisms.

At the same time, teachers in this study did not regard MR as a purely technological novelty but as a potentially useful pedagogical tool with clear classroom applications. This finding is consistent with prior reviews highlighting the importance of linking immersive technologies to concrete teaching practices (Ibáñez & Delgado-Kloos, 2018; Haleem et al., 2022). In line with the TPACK model, teachers' responses suggest that effective MR integration depends on the interplay between technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). Without professional preparation that addresses these three domains in combination, MR may remain underutilized. Similar arguments have been advanced by Celik et al. (2024), who emphasize the importance of designing learner-centered environments that allow teachers to innovate meaningfully.

With regard to pedagogical outcomes, participants perceived MR as particularly beneficial for enhancing exploratory and experiential learning. The skills most frequently identified as supported by MR included exploratory learning, critical thinking, and computational reasoning, which suggests that teachers see MR not as a superficial tool but as an enabler of active and embodied learning. These findings echo Marín-Marín et al. (2023), who stressed that positive teacher attitudes are a prerequisite for good practices with AR. They also connect to Van Schoors et al. (2025), who showed that the success of personalized digital learning depends strongly on teachers' readiness to translate theoretical promises into practical implementation. From a disciplinary standpoint, there was greater acceptance of MR in STEM subjects, while Language and History teachers highlighted its potential for cultural heritage education, consistent with the work of Zhabykbayeva et al. (2021).

Equity concerns also emerged as a central theme. Many respondents expressed skepticism that MR could widen existing inequalities, particularly in under-resourced schools. This reflects broader debates about the digital divide and the risk of reinforcing

social inequities through uneven access to advanced technologies (Garzón et al., 2019). At the same time, respondents valued MR's creative potential and its ability to transform the teacher's role from consumer to creator of immersive scenarios. Approximately 70% of participants emphasized scenario design as an essential capability, echoing the socio-cognitive perspective of Masclet et al. (2021). The strong creative dimension attributed to MR suggests that teachers view themselves as agents of design rather than passive adopters, which again ties back to the TAM model, where perceived usefulness and perceived ease of use shape attitudes and adoption intentions.

The results of this study reveal that teachers generally perceive Mixed Reality as a tool with strong pedagogical opportunities, particularly in fostering exploratory learning, critical thinking, and embodied knowledge construction. At the same time, they identify concrete barriers such as limited training opportunities, insufficient infrastructure, and lack of institutional support, which restrict broader adoption. Ethical concerns were also emphasized, including equity of access, privacy, and the risk of reinforcing the digital divide in under-resourced settings. Looking toward the future, teachers envision MR not as a replacement for traditional pedagogy, but as a complementary technology that can be sustainably integrated if supported by teacher-centered design, professional development, and policy frameworks that safeguard inclusivity and transparency.

Conclusion

This study underscores the pivotal role of teachers' perceptions in shaping the pathways through which Mixed Reality (MR) technologies can be meaningfully integrated into education. The findings clearly indicate that while teachers recognize MR as a powerful pedagogical tool with the capacity to foster exploratory learning, critical thinking, and cognitive engagement, systemic barriers such as insufficient training, lack of infrastructure, and equity concerns continue to constrain adoption. These results highlight not only the importance of professional development but also the necessity of embedding MR within structured institutional frameworks that support experimentation, resource provision, and pedagogical guidance. In order to make immersive technologies sustainable, scalable, and pedagogically meaningful in actual classroom settings, it is imperative that instructors' practical concerns are addressed, as highlighted by Fransson et al. (2020). This is consistent with broader evidence that teachers' positive attitudes and readiness are fundamental for translating potential into practice (Marín-Marín et al., 2023).

For the educational community, the implications are twofold. First, MR should be approached not as an isolated innovation but as part of a broader pedagogical ecosystem, aligned with existing teaching methods and curricular goals. Teachers' emphasis on scenario creation, exploratory learning, and critical thinking demonstrates that MR can complement established practices while opening new avenues for embodied and experiential learning. Second, the study affirms the need for teacher-centered design: educators must be supported as active co-creators of immersive learning environments, rather than passive users of pre-designed tools. This emphasis on co-creation aligns with recent research on personalized digital learning, which highlights the importance of integrating teachers' expertise into the design of adaptive systems (Van Schoors et al., 2025).

Future research should continue to examine how MR technologies can be integrated into teacher-centered and ethically grounded educational environments. Longitudinal studies and classroom-based implementations may provide deeper insights into the sustainability and pedagogical impact of immersive technologies in education.

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Interdisciplinary Integration of Agronomy and Artificial Intelligence in Special Vocational Education: A Project-Based Learning Approach

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Artificial Intelligence and Innovation in Education: Ethical and Technological Dimensions - AI-Education 2025
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Abstract Artificial Intelligence (AI) technologies are increasingly shaping contemporary educational practices, offering new opportunities for inclusive and experiential learning. Despite these developments, their application in special vocational education—particularly in agricultural domains—remains limited. This study presents an interdisciplinary educational intervention integrating agronomy and artificial intelligence through a Project-Based Learning (PBL) approach in a special vocational education setting.

The intervention was implemented in a Special Vocational Education and Training Laboratory School in Greece and focused on diagnosing nutrient deficiencies in lettuce plants. Students engaged in hands-on and visual learning activities to understand the symptoms of nitrogen (N), phosphorus (P), and potassium (K) deficiencies. Subsequently, they collected and labeled images and used Teachable Machine along with the "lettuce-npk-dataset" from Kaggle to train an image classification model.

The project followed four PBL stages: introduction, data collection and annotation, model training, and evaluation. Data collection relied on classroom observation and reflective notes.

Findings indicate increased student engagement, improved understanding of plant nutrition concepts, and the development of basic AI literacy. The study highlights the potential of accessible AI tools to support inclusive, interdisciplinary, and digitally enriched learning environments in special vocational education.

Keywords— Artificial Intelligence, Special Education, Agricultural Education, Project-Based Learning, Image Classification

1. Introduction

The rapid advancement of Artificial Intelligence (AI) has significantly influenced contemporary educational discourse, particularly in the field of educational technology. AI-based systems are increasingly integrated into learning environments to support personalization, inquiry-based learning, and the development of higher-order cognitive and digital skills (Luckin et al., 2016; Holmes et al., 2019; OECD, 2021).

Despite this progress, the integration of AI in vocational education and training (VET)—and especially in special vocational education—remains limited. Students with special educational needs require pedagogical approaches that emphasize accessibility, experiential learning, and meaningful engagement with real-world tasks (Florian & Black-Hawkins, 2011; Cedefop, 2020). Consequently, there is a need for empirical studies examining how AI can be integrated in ways that support inclusion.

Special vocational education combines inclusive education principles with the development of practical skills. Learners often present diverse cognitive and social profiles, making it essential to design flexible, multimodal, and context-based learning experiences. Within this framework, technology should function as a mediating tool that enhances engagement and understanding.

Agronomy and horticulture are particularly suited to experiential and project-based approaches, as they rely on observation and interpretation of visual cues. However, diagnosing plant nutrient deficiencies can be challenging for students with special educational needs when instruction relies heavily on abstract explanations (Marschner, 2012).

Recent advances in computer vision offer new opportunities for supporting such learning processes. AI-based image classification tools can help learners recognize patterns and connect visual symptoms to underlying biological processes, while also fostering basic AI literacy when used in an accessible and pedagogically structured way (Holmes et al., 2019).

Project-Based Learning (PBL) provides an effective framework for integrating technology, interdisciplinary knowledge, and real-world problem solving. It promotes collaboration, engagement, and the application of knowledge in authentic contexts, while supporting inclusive practices through flexibility and learner participation (Thomas, 2000; Krajcik & Blumenfeld, 2006).

Despite growing interest in AI in education, there is limited research on hands-on implementations in special vocational agronomy contexts. Addressing this gap, the present study introduces an interdisciplinary educational project that integrates agronomy and AI through PBL. Students engaged in training an image recognition model to diagnose nutrient deficiencies in lettuce plants, linking domain knowledge with foundational AI concepts.

The study aims to explore the pedagogical integration of AI tools in a horticulture course, examine the educational value of combining agronomy, AI, and PBL, and reflect on the potential and limitations of such approaches in special vocational education. Ultimately, it argues that AI can function as a supportive and empowering tool when embedded within inclusive and experiential learning environments.

2. Theoretical and Pedagogical Framework

The educational intervention presented in this study is grounded in a combination of complementary theoretical and pedagogical approaches, namely STEM education, Project-Based Learning (PBL), inclusive pedagogy and the pedagogically oriented integration of Artificial Intelligence (AI). Together, these frameworks provide a coherent foundation for designing learning experiences that are interdisciplinary, experiential and accessible to students with special educational needs in vocational education contexts.

2.1. STEM Education in Vocational and Special Education Contexts

STEM education emphasizes the integration of science, technology, engineering and mathematics in ways that promote problem solving, inquiry and real-world application of knowledge. Rather than treating these disciplines as isolated subjects, STEM-oriented instruction encourages learners to engage with complex problems that require interdisciplinary thinking and the application of multiple forms of knowledge (Bybee, 2013). In vocational education, STEM approaches are particularly relevant, as they align closely with the practical and applied nature of professional training (Means et al., 2016).

In special vocational education, STEM education offers additional pedagogical value by supporting contextualized learning and reducing cognitive abstraction. Authentic problems drawn from real occupational environments—such as diagnosing plant nutrient deficiencies—allow students to connect theoretical concepts to observable phenomena. Research suggests that such contextualization is especially beneficial for learners with special educational needs, as it enhances comprehension, motivation and transfer of learning (Cedefop, 2020). Within this framework, technology serves not merely as a delivery mechanism but as a mediating tool that supports exploration and understanding.

2.2. Project-Based Learning as a Core Instructional Methodology

Project-Based Learning (PBL) constitutes the central instructional methodology of the present intervention. PBL is characterized by student engagement in extended learning processes organized around authentic, meaningful problems, culminating in the creation of concrete outcomes or artifacts (Thomas, 2000). Through collaboration, inquiry and reflection, learners construct knowledge actively rather than passively receiving information.

Extensive research highlights the effectiveness of PBL in promoting deeper conceptual understanding, learner autonomy and the development of transversal skills such as communication and collaboration (Krajcik & Blumenfeld, 2006; Bell, 2010). In STEM-related domains, PBL supports the integration of theory and practice, enabling students to apply scientific concepts to real-world situations. This alignment is particularly important in agronomy education, where observational skills and practical reasoning are essential.

In special education settings, PBL offers significant advantages. The flexible structure of PBL allows for differentiation in roles, pacing and modes of participation, making it

suitable for heterogeneous classrooms (Florian & Black-Hawkins, 2011). Moreover, the emphasis on teamwork and shared goals fosters social interaction and inclusion, key elements of effective special education pedagogy. By engaging students in a collective project with tangible relevance, PBL contributes to increased motivation and sustained engagement (Dede, 2014).

2.3. Inclusive Pedagogy and Learner-Centered Design

Inclusive pedagogy provides a critical lens through which the educational intervention was designed and implemented. Rather than adapting instruction solely for individual deficits, inclusive pedagogy focuses on creating learning environments that enable participation and success for all learners from the outset (Florian & Black-Hawkins, 2011). This approach emphasizes flexibility, accessibility and respect for learner diversity.

In the context of special vocational education, inclusive pedagogy requires instructional strategies that combine visual, experiential and collaborative elements. Learning activities must be designed to support multiple ways of engagement and expression, allowing students to contribute according to their strengths. Research indicates that inclusive practices are most effective when they are embedded within meaningful learning tasks and authentic contexts (UNESCO, 2021).

The present intervention adopted these principles by emphasizing hands-on activities, visual materials and collaborative problem solving. Students were not positioned as passive recipients of technology but as active participants in a learning process that valued exploration and reflection. This learner-centered orientation aligns with broader constructivist perspectives, which view knowledge as actively constructed through interaction with the environment and others (Papert, 1993).

2.4. Artificial Intelligence as a Pedagogical Tool

A key theoretical consideration of this study concerns the role of Artificial Intelligence in education. While AI is often discussed in terms of automation, personalization, or large-scale data analytics, recent literature emphasizes the importance of framing AI as a pedagogical tool that supports learning processes rather than replacing human instruction (Luckin et al., 2016; Holmes et al., 2019).

From this perspective, AI-based tools should be introduced in ways that are transparent, accessible and aligned with educational objectives. For learners, especially those with special educational needs, understanding basic AI concepts—such as data classification, pattern recognition and model limitations—can contribute to the development of digital and critical AI literacy (OECD, 2021). However, such understanding must be scaffolded through intuitive interfaces and meaningful tasks.

In the present project, AI was not treated as a complex technical system but as an exploratory medium through which students could interact with data and observe how machine learning models respond to visual inputs. The use of an accessible platform such as Teachable Machine enabled students to focus on conceptual understanding rather than programming skills. This approach is consistent with UNESCO's

recommendations for ethical and inclusive AI integration in education, which stress accessibility, transparency and pedagogical coherence (UNESCO, 2019).

2.5. Integrating Agronomy, AI and PBL within a Unified Framework

The integration of agronomy content, AI tools and PBL methodology represents a deliberate attempt to create a coherent interdisciplinary learning environment. Agronomy provided the scientific and vocational context, PBL structured the learning process and AI functioned as a mediating tool that enhanced observation and analysis. Together, these elements supported a learning experience that was both cognitively meaningful and pedagogically inclusive.

Diagnosing nutrient deficiencies in plants requires the interpretation of visual symptoms and the linking of these symptoms to underlying biological processes (Marschner, 2012). By incorporating AI-based image classification into this process, students were able to compare their own observations with the outputs of a machine learning model, fostering reflection and discussion. This comparison encouraged critical thinking about both agronomic knowledge and the capabilities and limitations of AI systems.

Overall, the theoretical and pedagogical framework of the intervention underscores the importance of alignment between technology, pedagogy and content. Rather than introducing AI as an isolated innovation, the project embedded it within a structured, inclusive and vocationally relevant learning process. This alignment forms the basis for the methodological design described in the following section.

3. Methodology and Description of the Educational Intervention

3.1. Research Design and Methodological Approach

The present study adopts a qualitative, practice-oriented research design, appropriate for exploring educational interventions implemented in authentic classroom settings, particularly within special vocational education. Rather than aiming for generalizable results, the study seeks to provide an in-depth examination of a pedagogically grounded implementation of artificial intelligence in a real educational context. Qualitative methodologies are widely regarded as suitable for capturing the complexity of learning processes, student engagement and instructional dynamics in inclusive education environments (Dede, 2014).

The intervention was designed as a small-scale educational project embedded within the regular curriculum of a horticulture laboratory course. Emphasis was placed on ecological validity, ensuring that learning activities were closely aligned with students' vocational training and everyday educational experience. Data were collected through systematic classroom observation, informal discussions with students and reflective notes maintained by the educator throughout the implementation. This approach aligns with research practices commonly adopted in studies focusing on pedagogical innovation and educational technology integration (Holmes et al., 2019).

3.2. Educational Context and Participants

The educational intervention was implemented in a Special Vocational Education and Training Laboratory School (EEEEK) in Greece. These schools serve students with diverse special educational needs and aim to provide both general education and vocational training tailored to students' abilities and interests. The participants were students enrolled in a horticulture laboratory course, which forms part of the agronomy-related vocational curriculum.

The student group was heterogeneous, reflecting a range of cognitive, social and learning profiles. Such diversity necessitated the adoption of inclusive instructional strategies emphasizing visual support, experiential learning and collaborative activities. The learning objectives were adapted to focus on functional understanding and practical competence rather than abstract theoretical mastery. Ethical considerations were addressed through adherence to school guidelines, ensuring that student participation respected principles of inclusion, dignity and educational benefit.

3.3. Learning Objectives

The educational intervention was guided by a set of clearly defined learning objectives spanning three complementary domains: agronomic knowledge, digital and AI literacy and transversal skills.

At the level of agronomic knowledge, the primary objective was to enable students to recognize and describe visual symptoms associated with deficiencies of key macronutrients—nitrogen (N), phosphorus (P) and potassium (K)—in lettuce plants. This objective aligns with foundational content in plant nutrition and crop management (Marschner, 2012).

In terms of digital and AI literacy, the project aimed to introduce students to basic concepts of artificial intelligence, including image classification, data labeling and model accuracy. Importantly, these concepts were presented in an intuitive and experiential manner, avoiding technical complexity and focusing instead on conceptual understanding (Luckin et al., 2016; OECD, 2021).

Finally, the intervention sought to promote transversal skills such as collaboration, communication, observation and reflective thinking. These skills are central to both vocational competence and inclusive education practices (Bell, 2010; Cedefop, 2020).

3.4. Structure of the Intervention: Project-Based Learning Stages

The educational project was structured according to four stages of Project-Based Learning, ensuring coherence between pedagogical objectives, learning activities and assessment practices.

3.4.1. Stage 1: Problem Introduction and Conceptual Preparation

The first stage focused on introducing students to the central problem of the project: identifying nutrient deficiencies in lettuce plants. Instruction began with experiential and visual activities, including direct observation of plants in the school garden or laboratory and examination of photographs illustrating healthy and deficient leaves.

The educator facilitated guided discussions to help students articulate observed differences in color, shape and growth patterns.

Basic concepts of plant nutrition were introduced using simplified language and visual aids, emphasizing the role of nitrogen, phosphorus and potassium in plant growth. This preparatory phase aimed to establish a shared conceptual foundation while accommodating diverse learning needs, consistent with inclusive pedagogy principles (Florian & Black-Hawkins, 2011).

3.4.2. Stage 2: Data Collection and Image Labeling

In the second stage, students engaged in the collection and organization of visual data. Photographs of lettuce leaves were taken using mobile devices or tablets within the school environment. These images were complemented by the use of the publicly available "lettuce-npk-dataset" from the Kaggle platform, which provided additional examples of nutrient deficiencies.

Students worked collaboratively to sort and label images according to predefined categories (healthy, nitrogen deficiency, phosphorus deficiency, potassium deficiency). This activity served a dual pedagogical purpose: reinforcing agronomic knowledge through repeated visual comparison and introducing the concept of data preparation for machine learning models. The labeling process also highlighted the importance of data quality and consistency, key ideas in AI literacy (Holmes et al., 2019).

3.4.3. Stage 3: Model Training Using Teachable Machine

The third stage involved training an image classification model using the Teachable Machine platform. This environment was selected for its user-friendly interface, immediate visual feedback and suitability for learners with limited technical backgrounds. Students uploaded labeled images and observed how the system learned to differentiate between categories based on visual patterns.

The educator facilitated discussions around the learning process of the model, encouraging students to reflect on why certain images were classified correctly or incorrectly. Rather than emphasizing performance metrics, the focus remained on conceptual understanding—how machines "learn" from examples and why errors occur. This approach aligns with recommendations for introducing AI in education through transparent and accessible practices (UNESCO, 2019).

3.4.4. Stage 4: Model Testing, Evaluation and Reflection

In the final stage, students tested the trained model using new images of lettuce leaves. They compared the model's predictions with their own observations and discussed discrepancies. This reflective process fostered critical thinking and reinforced the idea that AI systems are tools with limitations rather than infallible authorities.

Students were encouraged to articulate what they had learned about both plant nutrition and artificial intelligence. Group discussions emphasized collaboration and shared understanding, reinforcing the social dimension of learning inherent in PBL environments (Krajcik & Blumenfeld, 2006).

3.5. Role of the Educator and Pedagogical Scaffolding

Throughout the intervention, the educator assumed the role of facilitator and guide rather than sole knowledge provider. Instructional scaffolding was provided through guiding questions, visual supports and structured collaboration. This approach aligns with constructivist and learner-centered pedagogies, which emphasize the active role of learners in knowledge construction (Papert, 1993).

By carefully sequencing activities and providing continuous support, the educator ensured that AI tools enhanced rather than hindered learning. This pedagogical mediation was particularly critical in the special education context, where students benefit from clear structure and consistent guidance.

4. Results and Educational Value

4.1. Overview of Data Collection and Evaluation Approach

The evaluation of the educational intervention was primarily qualitative in nature, reflecting both the scope of the study and the characteristics of the educational context. Given that the project was implemented in a special vocational education setting with a limited number of participants, the emphasis was placed on understanding learning processes, student engagement and pedagogical value rather than on quantitative measurement or statistical generalization. This approach is consistent with research methodologies commonly adopted in studies of inclusive education and classroom-based technological interventions (Dede, 2014; Holmes et al., 2019).

Data were collected through systematic classroom observation, informal group discussions and reflective notes maintained by the educator throughout the intervention. Particular attention was given to student participation, collaboration, verbal expressions of understanding and behavioral indicators of motivation and engagement. These data sources enabled a holistic assessment of both cognitive and affective learning outcomes.

4.2. Student Engagement and Motivation

One of the most prominent outcomes of the intervention was a noticeable increase in student engagement and motivation across all stages of the project. From the initial introduction of the problem to the final evaluation of the AI model, students demonstrated sustained interest in the activities and a willingness to participate actively. This finding aligns with existing research indicating that Project-Based Learning can enhance motivation by situating learning within authentic and meaningful contexts (Bell, 2010; Thomas, 2000).

The use of real plant material and visual data from the school environment contributed significantly to this engagement. Students expressed curiosity when observing differences between healthy and deficient lettuce leaves and showed enthusiasm when comparing their own observations with the predictions generated by the AI model. The interactive nature of the Teachable Machine platform further reinforced this

engagement, as students could immediately see the impact of their actions on the model's behavior.

Importantly, the accessibility of the AI tool played a critical role in sustaining motivation. Because the platform did not require programming skills or complex technical knowledge, students were able to focus on exploration and experimentation rather than procedural difficulties. This accessibility is particularly important in special education contexts, where overly complex interfaces can act as barriers to participation (UNESCO, 2019).

4.3. Development of Agronomic Knowledge

In terms of subject-specific learning outcomes, students demonstrated improved understanding of basic concepts related to plant nutrition and nutrient deficiencies. Through repeated observation and discussion, they became more capable of identifying visual symptoms associated with nitrogen, phosphorus and potassium deficiencies in lettuce plants. Students were able to describe differences in leaf color, size and overall plant appearance using appropriate terminology introduced during the project.

The combination of hands-on observation and AI-supported classification reinforced learning by providing multiple representations of the same concepts. Comparing their own judgments with the model's predictions encouraged students to reflect on their understanding and to reconsider initial assumptions when discrepancies arose. This process supports deeper conceptual learning by promoting metacognitive awareness and critical reflection (Krajcik & Blumenfeld, 2006).

These findings are consistent with agronomy education research emphasizing the importance of experiential learning in developing observational and diagnostic skills (Marschner, 2012). For students with special educational needs, the visual and contextualized nature of the activities was particularly beneficial, as it reduced reliance on abstract explanations and textual descriptions.

4.4. Development of Digital and AI Literacy

Beyond agronomic knowledge, the intervention contributed to the development of introductory digital and AI literacy. Students gained practical experience with fundamental AI concepts, including data collection, labeling, pattern recognition and model evaluation. While the project did not aim to provide technical mastery, students developed a basic understanding of how machine learning systems rely on data and why errors may occur.

Through guided discussions, students were encouraged to reflect on the limitations of the AI model, recognizing that incorrect predictions often resulted from insufficient or ambiguous data. This awareness is a key component of critical AI literacy, which involves understanding not only the capabilities but also the constraints and potential biases of AI systems (OECD, 2021; Holmes et al., 2019).

The transparent and exploratory use of AI tools helped demystify artificial intelligence and positioned it as a human-designed system rather than an autonomous or authoritative entity. Such framing is particularly important in special education, as it

supports learner confidence and agency while preventing the uncritical acceptance of technological outputs.

4.5. Collaboration and Social Interaction

The collaborative structure of the Project-Based Learning approach fostered positive social interactions among students. Working in small groups during data collection, image labeling and model training encouraged communication, shared decision-making and mutual support. Students frequently discussed observations, negotiated classifications and jointly interpreted the model's outputs.

These collaborative behaviors are consistent with research highlighting the social benefits of PBL, particularly in inclusive education settings (Florian & Black-Hawkins, 2011; Bell, 2010). For students with special educational needs, opportunities for structured collaboration can enhance social skills, self-esteem and a sense of belonging within the learning community.

The shared goal of completing the project and evaluating the AI model contributed to a collective sense of achievement. Students expressed pride in the final outcomes and demonstrated increased confidence in their ability to engage with both scientific and technological content.

4.6. Pedagogical Value and Inclusive Impact

From a pedagogical perspective, the intervention demonstrated the value of integrating AI tools within a coherent instructional framework grounded in inclusive pedagogy and experiential learning. The alignment between agronomic content, PBL methodology and accessible AI technology created a learning environment that supported diverse learners without isolating or stigmatizing individuals.

The educator's role as facilitator was critical in maintaining this alignment. Through continuous scaffolding, guided reflection and adaptive support, the educator ensured that technology served pedagogical goals rather than dominating the learning process. This finding reinforces existing literature emphasizing the importance of teacher mediation in technology-enhanced learning environments (Luckin et al., 2016; UNESCO, 2019).

Overall, the results indicate that the educational value of AI in special vocational education lies not in technical sophistication but in thoughtful pedagogical integration. When embedded within meaningful projects and inclusive learning designs, AI tools can support engagement, understanding and learner empowerment.

5. Discussion, Limitations and Future Directions

5.1. Discussion of Findings in Relation to the Literature

The findings of the present study reinforce existing research highlighting the pedagogical potential of Artificial Intelligence when integrated into education through carefully designed instructional frameworks. Consistent with prior studies, the results indicate that AI tools can enhance learner engagement, conceptual understanding and

motivation when they are embedded within experiential and student-centered learning approaches (Luckin et al., 2016; Holmes et al., 2019). In this intervention, AI did not function as an autonomous instructional agent but as a mediating tool that supported observation, reflection and dialogue.

The increased student engagement observed throughout the project aligns with literature emphasizing the motivational benefits of Project-Based Learning, particularly in STEM-related and vocational contexts (Bell, 2010; Krajcik & Blumenfeld, 2006). The authenticity of the learning task—diagnosing nutrient deficiencies in real plants—appears to have played a critical role in sustaining student interest and facilitating meaningful learning. This finding supports arguments that vocationally relevant problems enhance the perceived value of learning activities and promote deeper engagement (Cedefop, 2020).

From an inclusive education perspective, the results resonate strongly with the principles of inclusive pedagogy outlined by Florian and Black-Hawkins (2011). The intervention demonstrated that when learning activities are designed to accommodate diversity from the outset, rather than retrofitted for individual needs, students with special educational needs can participate meaningfully in complex, interdisciplinary learning processes. The combination of visual materials, hands-on activities and collaborative work enabled students to engage with both agronomic content and introductory AI concepts in accessible ways.

The development of basic AI literacy observed in the study aligns with emerging international priorities emphasizing the importance of preparing learners to understand and critically engage with AI technologies (OECD, 2021; UNESCO, 2019). By focusing on transparency, data quality and model limitations, the intervention supported a foundational understanding of AI that extends beyond technical skills to include critical awareness. This approach is particularly relevant in special education contexts, where empowering learners to interact confidently with digital technologies is essential for social inclusion and lifelong learning.

5.2. Pedagogical Implications

The findings suggest several important pedagogical implications for educators and curriculum designers. First, the study underscores the importance of aligning AI tools with clear learning objectives and pedagogical frameworks. Rather than introducing AI as a standalone topic, embedding it within existing curricular content—such as agronomy—can enhance relevance and coherence.

Second, the results highlight the value of accessible AI platforms in special education. Tools that provide immediate feedback and intuitive interaction enable learners to focus on conceptual understanding rather than technical complexity. This reinforces calls in the literature for the development and adoption of educational technologies that prioritize usability and inclusivity (UNESCO, 2019).

Third, the educator's role emerges as a central factor in the success of AI-enhanced learning. Effective scaffolding, guided reflection and adaptive support were essential in ensuring that technology served pedagogical purposes. This finding aligns with research emphasizing that technology alone does not transform learning; rather, it is the

pedagogical choices made by educators that determine educational impact (Luckin et al., 2016).

5.3. Limitations of the Study

Despite its contributions, the present study is subject to several limitations that should be acknowledged. First, the intervention was conducted in a single special vocational education setting with a relatively small number of participants. As a result, the findings cannot be generalized to all special education or vocational contexts. Instead, they should be interpreted as illustrative of pedagogical possibilities rather than definitive evidence of effectiveness.

Second, the study relied primarily on qualitative data, including classroom observations and reflective discussions. While this approach provided rich insights into learning processes and educational value, it did not include standardized assessments or quantitative measures of learning outcomes. Future studies could complement qualitative findings with mixed-methods approaches to provide a more comprehensive evaluation.

Third, the duration of the intervention was limited to a single project cycle. Longer-term implementations could provide additional insights into the sustainability of student engagement and the development of more advanced AI-related competencies over time.

5.4. Future Directions

Building on the findings of this study, several directions for future research and practice can be identified. Expanding similar interventions to other vocational domains such as animal science, food technology, or environmental management—could further explore the interdisciplinary potential of AI in vocational education. Additionally, adapting the project for different age groups and educational settings would contribute to a broader understanding of its applicability.

Future research could also investigate the impact of structured teacher professional development on the effective integration of AI in special education. Equipping educators with pedagogical and ethical frameworks for AI use is essential for ensuring inclusive and responsible implementation (UNESCO, 2021).

Finally, longitudinal studies examining the long-term effects of AI-enhanced PBL on student learning, motivation and vocational readiness would provide valuable insights into the enduring educational value of such approaches.

6. Conclusions

This paper presented an interdisciplinary educational project integrating agronomy and artificial intelligence within a special vocational education context through Project-Based Learning (PBL). The study explored how accessible AI tools can be embedded in inclusive, vocationally relevant learning environments to support both subject knowledge and basic digital competencies.

Findings indicate that when AI is used as a pedagogical tool rather than a technical objective, it enhances student engagement, motivation, and conceptual understanding. By addressing an authentic task—diagnosing nutrient deficiencies in lettuce plants—students connected scientific knowledge with real-world practice, reducing abstraction and supporting experiential learning.

PBL played a central role by providing a flexible framework that promoted collaboration, inquiry, and inclusive participation. Additionally, the use of accessible AI tools supported the development of introductory AI literacy, including understanding data, pattern recognition, and model limitations.

The study highlights the importance of aligning content, pedagogy, and technology, emphasizing that the educational value of AI depends on thoughtful instructional design. Despite its limited scope, the research demonstrates that AI can effectively support inclusive and interdisciplinary learning in special vocational education.

Overall, the findings suggest that integrating AI through PBL can enrich vocational education and foster both practical skills and digital competence in inclusive learning environments.

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Artificial Intelligence as a Creative Learning Partner in STEAM Education

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Abstract - In contemporary education, the development of 21st century skills requires innovative learning approaches that combine creativity, problem solving, collaboration, and digital competence. The STEAM framework (Science, Technology, Engineering, Arts, and Mathematics) provides a strong pedagogical foundation for interdisciplinary learning, while Artificial Intelligence (AI) is increasingly emerging as a dynamic learning partner that enhances student engagement, personalization, and creative expression. This paper theoretically examines the role of Artificial Intelligence as a creative collaborator in learning, focusing on how AI tools can support student autonomy, personalized learning pathways, and the development of higher-order cognitive and creative skills.

The analysis includes examples of AI applications in educational robotics and STEAM activities, illustrating how students can use technological tools to design, construct, and program innovative projects. Through these activities, learners are encouraged to engage in authentic problem-solving processes, experiment with ideas, and iteratively improve their designs with the support of intelligent systems. In addition, the paper explores teachers' perceptions of collaboration with AI, emphasizing the pedagogical value of AI-supported learning environments, the potential to enhance creativity, and the ethical and pedagogical challenges that arise from the integration of AI technologies in the classroom.

Based on a review of relevant literature and good practices, the paper highlights the advantages of AI as a learning partner, including support for critical thinking, promotion of collaborative learning, facilitation of self-regulated learning, and development of innovation and entrepreneurial skills. At the same time, key challenges are identified, such as the need for systematic teacher training in AI tools, the management of technical and infrastructural limitations, and increased sensitivity to ethical issues related to data privacy, transparency, and algorithmic bias.

Finally, conclusions and recommendations are presented for the optimal integration of Artificial Intelligence in STEAM programs. The study emphasizes that AI should be viewed as a learning partner rather than a replacement for the teacher, with the aim of fostering creativity, innovation, and essential 21st century skills among students. Overall, the paper argues that Artificial Intelligence can function as a powerful tool for strengthening pedagogical practice and expanding the possibilities for teaching and learning in the digital era.
Keywords— Artificial intelligence, creative learning, STEAM, robotics, 21st century skills

Introduction

The rapid development of digital technologies has significantly transformed educational systems worldwide, creating new opportunities and challenges for teaching and learning. In particular, Artificial Intelligence (AI) has emerged as one of the most influential technological developments of the 21st century, with increasing applications in areas such as adaptive learning systems, intelligent tutoring, learning analytics, and educational robotics (Russell & Norvig, 2021; Kasneci et al., 2023). As schools and higher education institutions seek to prepare learners for complex, technology-rich societies, there is a growing emphasis on the development of 21st century skills, including critical thinking, creativity, collaboration, communication, and digital literacy.

Within this context, the STEAM educational framework has gained increasing attention as an interdisciplinary approach that integrates Science, Technology, Engineering, Arts, and Mathematics. STEAM education promotes experiential, project-based, and inquiry-driven learning, encouraging students to connect knowledge across disciplines and apply it to real-world problems (Yakman, 2008; Quigley & Herro, 2016). The inclusion of the Arts dimension further emphasizes creativity, design thinking, and aesthetic expression, supporting holistic learning experiences that go beyond traditional subject boundaries (Henriksen, 2014).

Artificial Intelligence has the potential to further enhance STEAM education by acting not only as a technological tool, but also as an active learning partner that supports creativity, personalization, and student-centered learning (Luckin et al., 2016; Holmes et al., 2022). AI-powered systems can provide real-time feedback, adaptive learning pathways, and intelligent support for problem solving and design processes (Zawacki-Richter et al., 2019). In educational robotics and STEAM projects, AI can be embedded in programming environments, simulation tools, and intelligent agents that assist students in experimenting with ideas, testing hypotheses, and refining their solutions.

The purpose of this paper is to theoretically explore the role of Artificial Intelligence as a creative collaborator in STEAM education. The study aims to examine how AI tools can support creative learning processes, enhance student autonomy, and contribute to the development of key 21st century skills. In addition, the paper discusses pedagogical, technical, and ethical considerations related to the integration of AI in educational settings, with a particular focus on the role of the teacher and the need for responsible and pedagogically informed use of AI technologies.

Artificial Intelligence and Creative Learning

Creativity is increasingly recognized as a core competence for the 21st century, closely linked to innovation, problem solving, and adaptability (OECD, 2019; World Economic Forum, 2023). In educational contexts, creative learning involves the ability to generate original ideas, explore multiple solutions, and engage in iterative design and reflection processes (Craft, 2005). AI technologies can support creative learning by providing tools that extend students' cognitive and creative capacities, enabling them to explore complex problem spaces and receive intelligent feedback.

AI-powered creative tools, such as generative systems, intelligent design assistants, and adaptive learning platforms, can act as cognitive partners that stimulate idea generation and support experimentation (Resnick, 2017; Kasneci et al., 2023). For example, students can use AI-based programming environments to test different algorithms, simulate outcomes, and visualize the impact of design choices in real time. This process encourages exploratory learning and helps students develop a deeper understanding of both technical and conceptual aspects of their projects.

From a constructivist and constructionist perspective, learning is most effective when students actively construct knowledge through meaningful activities and artifact creation (Piaget, 1972; Papert, 1980). Educational robotics and STEAM projects align strongly with these principles, as learners design, build, and program tangible or digital artifacts (Eguchi, 2014). In this context, AI can enhance constructionist learning by providing intelligent scaffolding, personalized hints, and adaptive challenges that respond to students' individual needs and progress (Luckin et al., 2016; Holmes et al., 2022).

Moreover, AI can support metacognitive processes by helping students reflect on their learning strategies and outcomes (Azevedo & Aleven, 2013). Through learning analytics and intelligent feedback systems, students can gain insights into their performance, identify areas for improvement, and set personalized learning goals (Siemens & Baker, 2012). This contributes to the development of self-regulated learning skills, which are essential for lifelong learning in rapidly changing technological environments.

AI Applications in STEAM and Educational Robotics

Educational robotics represents a key area where AI and STEAM education intersect in meaningful ways (Eguchi, 2014; Benitti, 2012). Robotics activities typically involve the integration of hardware, software, and design thinking, providing rich opportunities for interdisciplinary learning (Mikropoulos & Bellou, 2013). When AI components are incorporated into robotics projects, students can explore advanced concepts such as machine learning, computer vision, and autonomous decision making, even at introductory levels *(Touretzky et al., 2019)*.

For example, students may design and program robots that can recognize objects, follow lines, or respond to environmental stimuli using AI-based algorithms. Through these activities, learners engage in authentic engineering and computational thinking processes, including problem decomposition, algorithmic design, testing, and debugging (Wing, 2006; Bers, 2018). AI tools can support these processes by offering intelligent code suggestions, automated error detection, and simulation environments that allow students to test their designs before implementing them on physical robots (Kasneci et al., 2023).

In STEAM projects, AI can also be used to support creative design and artistic expression (Henriksen et al., 2020). Students may use AI-driven image, sound, or text generation tools as part of interdisciplinary projects that combine technology with the arts (Khalifa & Islam, 2023). For instance, learners might design interactive installations, digital storytelling projects, or smart art exhibits that respond to user input

through AI algorithms. These activities highlight the potential of AI to support not only technical learning, but also creative and aesthetic dimensions of STEAM education.

Importantly, the use of AI in STEAM and robotics projects encourages collaborative learning (Johnson & Johnson, 2009). Students typically work in teams to design, build, and refine their projects, negotiating ideas, sharing responsibilities, and learning from each other. AI tools can facilitate collaboration by providing shared digital workspaces, real-time feedback, and adaptive support that helps teams coordinate their efforts and overcome challenges (Holmes et al., 2022).

Examples of AI Tools in STEAM Education

A growing number of AI-powered tools are increasingly being integrated into STEAM educational contexts to support creativity, experimentation, and interdisciplinary learning. These tools allow students to engage with Artificial Intelligence in both conceptual and practical ways, bridging theoretical understanding with hands-on application.

For instance, conversational AI systems such as ChatGPT can be used to support idea generation, brainstorming, coding assistance, and reflective dialogue during project-based learning activities (OpenAI, 2023). Similarly, Google's Teachable Machine enables students to train simple machine learning models without advanced programming knowledge, making AI concepts accessible even at introductory levels (Google, 2024).

In programming education, Scratch with AI extensions allows learners to explore computational thinking and interactive storytelling while incorporating basic AI functionalities such as speech recognition or decision-based behaviors (MIT Media Lab, 2023). In robotics education, LEGO® Education SPIKE™ Prime integrates sensors and programmable components that can be extended with AI-based logic to support autonomous decision-making in student-designed robots (LEGO Education, 2023).

For immersive and interdisciplinary STEAM projects, CoSpaces Edu provides a platform where students can create virtual environments and integrate AI-driven behaviors, enabling simulation-based learning and digital storytelling (CoSpaces Edu, 2023). In addition, generative AI tools such as DALL·E can be used in STEAM contexts to support visual ideation, design thinking, and creative prototyping by generating images from textual prompts (OpenAI, 2022).

Overall, these tools illustrate how AI can function not only as a technological subject of study, but also as an active learning partner that supports exploration, creativity, and problem-solving across STEAM disciplines.

Ethical and Technical Challenges

The integration of Artificial Intelligence (AI) in educational environments introduces a wide range of ethical and technical challenges that require careful consideration in order to ensure responsible, inclusive, and pedagogically meaningful implementation (Holmes et al., 2022; UNESCO, 2021). While AI technologies offer substantial

opportunities for enhancing personalization, creativity, and efficiency in teaching and learning, they also raise complex concerns related to data privacy, transparency, algorithmic bias, accountability, access, and the evolving role of human judgment in educational decision-making (Luckin et al., 2016; Zawacki-Richter et al., 2019). These challenges are particularly significant in STEAM and educational robotics contexts, where students are not only users of AI systems but also emerging designers and creators of intelligent technologies (Eguchi, 2014).

One of the most critical ethical challenges concerns data privacy and the protection of students' personal and learning-related information. AI-driven educational systems typically rely on the collection and processing of large volumes of data, including academic performance, interaction logs, behavioral patterns, and sometimes sensitive personal information (Holmes et al., 2022). This data-intensive nature of AI raises risks related to unauthorized access, data breaches, and misuse of student information (UNESCO, 2021). In the European educational context, compliance with the General Data Protection Regulation (GDPR) is essential, requiring institutions to implement strict data governance policies, ensure informed consent, and provide transparency regarding how student data are collected, stored, and used (European Parliament & Council of the European Union, 2016). Failure to adequately address data protection issues may undermine trust among students, parents, and educators and can have serious legal and ethical consequences (Williamson & Eynon, 2020).

Closely related to privacy is the issue of transparency and explainability of AI systems. Many contemporary AI models, particularly those based on machine learning and deep learning techniques, operate as complex systems whose internal processes are difficult to interpret (Adadi & Berrada, 2018). This "black box" nature of AI poses significant challenges in educational settings, especially when AI tools are used for assessment, grading, feedback, or recommendations related to student learning pathways (Holmes et al., 2022). When teachers and learners cannot clearly understand how decisions or feedback are generated, it becomes difficult to evaluate the fairness, accuracy, and pedagogical appropriateness of these systems (UNESCO, 2021). From both an ethical and educational perspective, there is a growing need for explainable AI solutions that allow users to gain insight into system logic and decision-making criteria, thereby supporting trust, accountability, and meaningful pedagogical use (Adadi & Berrada, 2018).

Algorithmic bias represents another major ethical concern in the deployment of AI in education. AI systems are trained on historical and contemporary datasets that may reflect existing social, cultural, and educational inequalities (O'Neil, 2016). As a result, these systems may unintentionally reproduce or even amplify biases related to gender, ethnicity, language, socioeconomic background, or disability (UNESCO, 2021). In educational contexts, biased algorithms may influence recommendations, predictions of student performance, or adaptive learning pathways in ways that disadvantage certain groups of learners (Williamson & Eynon, 2020). This can contribute to unequal learning opportunities and reinforce existing structural inequalities. Addressing algorithmic bias requires continuous evaluation of AI tools, careful selection of training data, and collaboration between educators, researchers, and technology developers to promote fairness, diversity, and inclusivity in system design and implementation (Holmes et al., 2022).

In addition to ethical considerations, the integration of AI in education presents substantial technical challenges. One of the most significant technical barriers relates to infrastructure and access. AI-powered educational tools often require stable internet connections, modern devices, and sufficient computational resources (OECD, 2021). In many educational settings, particularly in under-resourced schools or rural areas, such infrastructure may be limited or inconsistent (UNESCO, 2021). This can lead to unequal access to AI-enhanced learning opportunities and may exacerbate the digital divide (OECD, 2021). Ensuring equitable access to technology is therefore a crucial policy and institutional priority, as unequal access can undermine the inclusive potential of AI in education.

Another technical challenge involves interoperability and integration with existing educational platforms and systems. Schools and universities typically rely on multiple digital tools, including learning management systems, student information systems, and assessment platforms (Zawacki-Richter et al., 2019). Integrating AI applications with these existing systems can be complex and costly, requiring technical expertise, ongoing maintenance, and institutional support (Holmes et al., 2022). Lack of interoperability may result in fragmented learning environments, increased administrative workload, and reduced usability for teachers and students. Sustainable implementation of AI therefore requires strategic planning, technical support structures, and alignment between institutional digital strategies and pedagogical goals (UNESCO, 2021).

Teacher preparedness and digital competence represent a critical challenge at the intersection of ethical and technical dimensions. Even when AI tools are available, educators may lack sufficient training and confidence to use them effectively and responsibly (European Commission, 2022). Without adequate professional development, teachers may struggle to understand how AI systems function, how to interpret AI-generated outputs, and how to align AI use with pedagogical principles (Holmes et al., 2022). This can lead to superficial use of technology, over-reliance on automated systems, or misuse of AI tools in ways that do not support meaningful learning. Systematic and ongoing professional development is therefore essential, focusing not only on technical skills but also on ethical awareness, critical evaluation of AI systems, and pedagogical strategies for integrating AI into inquiry-based and student-centered learning environments (European Commission, 2022).

Furthermore, there is a risk of over-reliance on AI systems, which may affect students' agency, autonomy, and development of higher-order thinking skills (Selwyn, 2019). While AI can provide valuable scaffolding and feedback, excessive dependence on automated guidance may reduce opportunities for learners to engage in independent problem solving, critical reflection, and creative exploration (Luckin et al., 2016). In STEAM and robotics education, where experimentation, iteration, and failure are important components of the learning process, it is particularly important to ensure that AI supports rather than replaces cognitive effort (Eguchi, 2014). Pedagogical design should therefore emphasize AI as a supportive tool that enhances learning while preserving the central role of human judgment, creativity, and reflective thinking (Holmes et al., 2022).

Finally, broader societal and ethical implications must also be considered, including questions related to automation, the future of work, and the role of human expertise in

an increasingly AI-driven world (World Economic Forum, 2023). The presence of AI in education may shape students' perceptions of intelligence, authority, and knowledge (Selwyn, 2019). If AI systems are perceived as inherently objective or superior to human judgment, students may develop uncritical attitudes toward technology. Educational practice must therefore promote critical digital literacy, helping learners understand both the capabilities and limitations of AI, as well as the human values, assumptions, and power structures embedded in technological systems (UNESCO, 2021).

In conclusion, while Artificial Intelligence holds significant promise for enhancing STEAM education and creative learning, its integration is accompanied by complex ethical and technical challenges (Holmes et al., 2022). Addressing issues of privacy, transparency, bias, access, teacher preparedness, and learner agency is essential for ensuring that AI contributes positively to educational practice (UNESCO, 2021). A responsible, human-centered, and pedagogically grounded approach is necessary in order to harness the benefits of AI while minimizing potential risks, reinforcing the view of AI as a supportive learning partner rather than an autonomous or value-neutral technological solution (Luckin et al., 2016).

Implications for Curriculum Design and Educational Policy

The increasing integration of Artificial Intelligence as a creative learning partner in STEAM education has significant implications for curriculum design and educational policy (Holmes et al., 2022; UNESCO, 2021). As AI technologies become more deeply embedded in teaching and learning processes, traditional curricula that are organized around discrete subjects and standardized learning pathways may no longer be sufficient to support the development of complex, interdisciplinary, and future-oriented competencies (OECD, 2019). Instead, curriculum frameworks need to be re-envisioned to accommodate AI-enhanced, inquiry-based, and project-based learning models that emphasize creativity, problem solving, collaboration, and technological fluency (Quigley & Herro, 2016; Henriksen, 2014).

From a curriculum design perspective, the incorporation of AI in STEAM education requires a shift toward more flexible, interdisciplinary structures (Yakman, 2008). AI-supported learning environments naturally cut across disciplinary boundaries, as students engage simultaneously with concepts from computer science, engineering, mathematics, science, and the arts (Henriksen, 2014). Curriculum designers should therefore promote integrated learning units and thematic projects that allow students to apply knowledge from multiple domains in authentic problem contexts (Quigley & Herro, 2016). Such approaches align with the core principles of STEAM education and support deeper conceptual understanding, as learners are encouraged to make meaningful connections between theory and practice (Yakman, 2008; Henriksen, 2014).

In addition, the presence of AI in learning environments calls for a stronger emphasis on computational thinking, data literacy, and AI literacy as core curriculum components (Wing, 2006; Touretzky et al., 2019). Students should not only learn how to use AI tools, but also develop a foundational understanding of how AI systems work, including basic concepts related to algorithms, data, machine learning, and model limitations (Long & Magerko, 2020). This knowledge is essential for enabling students to critically

evaluate AI outputs, make informed decisions, and participate responsibly in AI-mediated learning activities (UNESCO, 2021). Embedding AI literacy within the curriculum supports the development of informed and critical users and creators of technology, rather than passive consumers of automated systems (Touretzky et al., 2019).

AI integration also has important implications for assessment practices within STEAM curricula. Traditional assessment methods, which often prioritize standardized testing and summative evaluation, may not adequately capture the complex learning outcomes associated with AI-enhanced, project-based learning (OECD, 2019). Creative problem solving, collaboration, design thinking, and iterative development processes are difficult to measure through conventional tests alone (Henriksen et al., 2020). Curriculum frameworks should therefore promote more formative, process-oriented, and performance-based assessment strategies, supported by AI tools that provide real-time feedback and learning analytics (Siemens & Baker, 2012; Holmes et al., 2022). Such approaches can help teachers monitor student progress, support self-regulated learning, and provide personalized guidance, while also recognizing diverse forms of achievement and creativity (Azevedo & Aleven, 2013).

At the level of educational policy, the integration of AI as a creative learning partner requires coherent and forward-looking policy frameworks that support innovation while ensuring ethical and equitable implementation (UNESCO, 2021; European Commission, 2022). Policymakers play a critical role in setting strategic priorities, allocating resources, and establishing guidelines for the responsible use of AI in education (OECD, 2021). Clear national and institutional policies are needed to address issues such as data protection, ethical standards, procurement of AI technologies, and quality assurance (European Parliament & Council of the European Union, 2016; UNESCO, 2021). Without such frameworks, AI adoption may occur in fragmented and inconsistent ways, potentially leading to unequal learning opportunities and variable educational quality (Williamson & Eynon, 2020).

Equity and inclusion should be central considerations in AI-related educational policy (UNESCO, 2021). As AI-enhanced learning environments often require advanced infrastructure and digital resources, there is a risk that students in under-resourced schools or regions may be excluded from the benefits of AI-supported education (OECD, 2021). Educational policy should therefore prioritize investment in digital infrastructure, access to devices, and connectivity, in order to ensure that all learners have the opportunity to participate in AI-enhanced STEAM learning (European Commission, 2022). Targeted funding and support programs may be necessary to reduce disparities and promote inclusive access to emerging technologies (UNESCO, 2021).

Teacher education and professional development represent another critical area for curriculum and policy alignment (European Commission, 2022). The effective integration of AI in STEAM education depends heavily on teachers' ability to design meaningful learning activities, interpret AI-generated feedback, and support students in ethical and critical use of technology (Holmes et al., 2022). Educational policy should therefore support the systematic inclusion of AI and digital pedagogy in both pre-service teacher education and in-service professional development programs (European Commission, 2022). Such initiatives should go beyond technical training to include

pedagogical strategies, ethical considerations, and opportunities for teachers to collaboratively explore and reflect on innovative practices (UNESCO, 2021).

Furthermore, curriculum and policy frameworks should encourage collaboration between educational institutions, industry partners, and research organizations (OECD, 2021). Partnerships with technology companies, universities, and research centers can provide access to expertise, resources, and authentic learning contexts that enrich STEAM education (Holmes et al., 2022). However, such collaborations must be carefully managed to ensure that educational goals, rather than commercial interests, remain the primary focus (Williamson & Eynon, 2020). Clear guidelines and ethical standards are necessary to govern partnerships and protect the integrity of educational practices (UNESCO, 2021).

Finally, long-term strategic planning is essential for ensuring the sustainability of AI integration in education (OECD, 2021). Given the rapid pace of technological change, curricula and policies must be designed with flexibility in mind, allowing for continuous updating and adaptation (World Economic Forum, 2023). Policymakers and educational leaders should adopt a long-term perspective that considers not only immediate implementation, but also future developments in AI and their potential impact on education and the workforce (OECD, 2019). By aligning curriculum design and educational policy with a human-centered, ethical, and innovation-oriented vision, educational systems can better prepare learners to thrive in complex, AI-rich societies (UNESCO, 2021).

In summary, the integration of Artificial Intelligence as a creative learning partner in STEAM education requires substantial rethinking of both curriculum design and educational policy (Holmes et al., 2022). Flexible interdisciplinary curricula, enhanced AI and data literacy, innovative assessment practices, equitable access, comprehensive teacher professional development, and coherent policy frameworks are all essential components of a successful and sustainable approach (UNESCO, 2021; European Commission, 2022). Such alignment ensures that AI is not simply added as a technological layer, but is meaningfully embedded within pedagogical structures that support creativity, critical thinking, and lifelong learning (Henriksen, 2014; OECD, 2019).

Future Directions and Research Agenda

As Artificial Intelligence continues to evolve and become increasingly integrated into educational contexts, there is a growing need for systematic research that explores its long-term impact on teaching, learning, and educational systems (Holmes et al., 2022; UNESCO, 2021). While existing studies provide valuable insights into the potential benefits and challenges of AI in education, much of the current research remains exploratory or short-term in nature (Zawacki-Richter et al., 2019). Future research should therefore adopt more comprehensive and longitudinal approaches in order to better understand how AI functions as a creative learning partner in STEAM education over time (Luckin et al., 2016).

One important direction for future research involves investigating the impact of AI-enhanced STEAM learning environments on different dimensions of student learning, including cognitive, metacognitive, social, and emotional outcomes (Azevedo &

Aleven, 2013; Holmes et al., 2022). Beyond academic achievement, researchers should examine how AI-supported learning influences students' creativity, motivation, self-efficacy, and attitudes toward technology and learning (Craft, 2005; OECD, 2019). Longitudinal studies would be particularly valuable in assessing whether early exposure to AI-enhanced STEAM education contributes to sustained interest in STEM-related fields, innovation-oriented mindsets, and long-term development of 21st century skills (World Economic Forum, 2023; Touretzky et al., 2019).

Another key area for future research concerns the role of teachers in AI-supported learning environments. While much attention has been given to the technical capabilities of AI systems, less is known about how teachers adapt their pedagogical practices in response to AI integration (European Commission, 2022). Future studies should explore how educators design learning activities that effectively incorporate AI, how they interpret and use AI-generated data, and how their professional identities and roles evolve in AI-enhanced classrooms (Holmes et al., 2022). Research in this area can inform the development of targeted professional development programs and support evidence-based guidelines for pedagogically sound AI integration (UNESCO, 2021).

Future research should also examine issues of equity, inclusion, and access in greater depth. While AI has the potential to personalize learning and support diverse learners, there is also a risk that existing educational inequalities may be reinforced or exacerbated (Williamson & Eynon, 2020; UNESCO, 2021). Researchers should investigate how AI tools affect different student populations, including learners from diverse socioeconomic, cultural, and linguistic backgrounds, as well as students with special educational needs (OECD, 2021). Such research can help identify potential unintended consequences and inform the design of more inclusive and equitable AI-enhanced learning environments (Holmes et al., 2022).

In addition, there is a need for more research on the design and evaluation of explainable and ethical AI systems for education. Future studies should explore how transparency, explainability, and user control can be effectively incorporated into educational AI tools, and how these features influence teacher and student trust, engagement, and ethical awareness (Adadi & Berrada, 2018; UNESCO, 2021). Understanding how users perceive and interact with explainable AI can contribute to the development of systems that are not only technically effective but also pedagogically meaningful and ethically responsible (Holmes et al., 2022).

Another promising research direction involves the integration of AI with emerging educational technologies, such as virtual and augmented reality, learning analytics, and Internet of Things (IoT) devices (OECD, 2021). The convergence of these technologies may create new forms of immersive and data-rich learning environments that further transform STEAM education (Luckin et al., 2016). Future research should investigate how these combined technologies can support experiential learning, simulation-based problem solving, and authentic real-world applications, as well as the potential cognitive and pedagogical implications of such environments (Quigley & Herro, 2016; Siemens & Baker, 2012).

Methodologically, future research should adopt mixed-methods approaches that combine quantitative data with qualitative insights from students, teachers, and other stakeholders (Creswell & Plano Clark, 2018). While learning analytics and

performance metrics can provide valuable information about patterns and outcomes, qualitative methods such as interviews, classroom observations, and reflective journals are essential for understanding how participants experience AI-enhanced learning and how meaning is constructed in these contexts (Siemens & Baker, 2012). Such approaches can provide a more holistic understanding of the complex interactions between technology, pedagogy, and human learning (Holmes et al., 2022).

Finally, future research should contribute to the development of theoretical frameworks that conceptualize AI not merely as a tool, but as a learning partner within sociotechnical educational systems (Luckin et al., 2016; Holmes et al., 2022). This involves examining how human and artificial agents interact, how responsibility and agency are distributed, and how learning is co-constructed in AI-mediated environments (Selwyn, 2019). By advancing theoretical perspectives alongside empirical research, the field can move toward more robust and nuanced understandings of the role of Artificial Intelligence in education (UNESCO, 2021).

Conclusion

This paper has explored the evolving role of Artificial Intelligence as a creative learning partner within the context of STEAM education and educational robotics (Holmes et al., 2022; Luckin et al., 2016). Through a theoretical analysis of current practices, pedagogical perspectives, and emerging challenges, the study highlights the transformative potential of AI to support creativity, personalization, collaboration, and the development of essential 21st century skills (Kasneci et al., 2023; OECD, 2019). Rather than positioning AI as a replacement for human teaching or learning, this work emphasizes its role as a supportive and collaborative presence that can enrich educational experiences and expand the possibilities for innovative pedagogy (Holmes et al., 2022; UNESCO, 2021).

The analysis demonstrates that AI-enhanced STEAM environments can foster deeper student engagement by enabling learners to design, experiment, and reflect in dynamic and interactive ways (Quigley & Herro, 2016; Henriksen, 2014). In robotics and interdisciplinary projects, AI tools can provide timely feedback, adaptive support, and opportunities for iterative improvement, encouraging students to view learning as an active and creative process (Eguchi, 2014; Zawacki-Richter et al., 2019). These learning experiences not only strengthen technical and computational competencies, but also nurture broader skills such as critical thinking, problem solving, communication, and self-regulation, which are increasingly vital in complex and technology-rich societies (Wing, 2006; World Economic Forum, 2023).

At the same time, this paper underscores that the successful integration of AI in education depends fundamentally on human-centered pedagogical design (UNESCO, 2021; Holmes et al., 2022). Teachers remain central actors in shaping meaningful learning experiences, guiding students' use of AI tools, and supporting reflective and ethical engagement with technology (European Commission, 2022). The role of the educator evolves toward that of a learning designer, facilitator, and mentor, who helps students navigate both the opportunities and the limitations of AI (Luckin et al., 2016). In this sense, the relationship between human educators and intelligent technologies is best understood as a partnership, in which professional judgment, empathy, and pedagogical expertise continue to play an irreplaceable role (Selwyn, 2019).

The discussion of ethical, technical, and policy-related challenges further highlights the importance of responsible and reflective implementation (UNESCO, 2021; Williamson & Eynon, 2020). Issues related to data privacy, transparency, algorithmic bias, equity, and access must be carefully addressed in order to ensure that AI contributes to more inclusive and just educational systems (European Parliament & Council of the European Union, 2016; Adadi & Berrada, 2018). Without such attention, there is a risk that technological innovation may inadvertently reinforce existing inequalities or undermine trust in educational institutions (UNESCO, 2021).

Ultimately, this study argues that the true value of Artificial Intelligence in STEAM education lies not in automation alone, but in its capacity to support human creativity, curiosity, and collaborative learning (Henriksen, 2014; Luckin et al., 2016). When thoughtfully integrated, AI can serve as a catalyst for reimagining teaching and learning, empowering both students and educators to explore new ideas, take intellectual risks, and engage more deeply with complex real-world problems (Holmes et al., 2022; OECD, 2019). By embracing a human-centered and ethically grounded vision, educational communities can harness the potential of AI to foster more creative, reflective, and future-ready learners (UNESCO, 2021; World Economic Forum, 2023).

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