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Humanization of Mathematics Pedagogy Amid the Expansion of Intelligent Technology

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Abstract

The expansion of intelligent technologies, especially Artificial Intelligence (AI), has changed mathematics education through adaptive learning systems, learning analytics, and intelligent tutoring systems. While many studies show improvements in efficiency and short-term cognitive outcomes, these technologies do not always ensure meaningful and reflective learning that supports holistic human development. This study aims to review and synthesize recent literature on the humanization of mathematics pedagogy in the era of intelligent technologies, and to develop a conceptual framework that positions technology as a partner, not a replacement, for teachers. A systematic literature review (SLR) was conducted using 10 articles published between 2023 and 2025 from reputable databases. The analysis followed stages of identification, selection, eligibility, and thematic synthesis to integrate empirical findings, humanistic theories, and ethical perspectives. The results show that AI-based mathematics learning is still largely technocentric, focusing on personalization and performance. However, recent studies emphasize the importance of human-AI collaboration, ethical use, and the development of social-emotional aspects in learning. Humanizing mathematics pedagogy requires viewing technology as a tool that supports dialogue, empathy, metacognition, and conceptual understanding. This study offers a conceptual framework for humanizing mathematics pedagogy in the digital era, along with theoretical, practical, and policy implications for AI integration in education. Overall, the findings highlight the need to design technology-based learning that remains grounded in human values, ensuring that digital transformation aligns with the core goals of education.

Keyword: Humanization of Pedagogy, Mathematics Learning, Artificial Intelligence.

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INTRODUCTION

The rapid development of intelligent technologies over the past two decades has fundamentally reshaped the global educational landscape. According to a report by UNESCO, more than 70% of countries have incorporated digital technologies into their national education policies, while the adoption of artificial intelligence (AI) in education has accelerated significantly in the post-COVID-19 era (Kim, 2025). At the global level, the educational technology (EdTech) market is projected to surpass USD 400 billion by the end of this decade, reflecting the widespread expansion of adaptive learning systems, automated assessment tools, and AI-driven platforms (Hossen, 2025). This transformation has not only influenced how students learn but has also redefined how teachers teach, assess, and engage with learners.

Within the context of mathematics education, the expansion of intelligent technologies presents a notable paradox. On the one hand, adaptive learning systems and learning analytics facilitate personalized instruction tailored to individual student needs. On the other hand, international assessments, including the Programme for International Student Assessment (PISA) conducted by the OECD, indicate that increased access to technology does not necessarily lead to improvements in mathematical literacy. Many countries continue to experience stagnation or even declines in students' numeracy performance (Arpacı et al., 2021). This suggests that technological integration has yet to adequately address the humanistic dimensions of mathematics learning, such as pedagogical empathy, interpersonal interaction, and the development of deep conceptual understanding.

Moreover, the World Economic Forum's *Future of Jobs* report highlights critical thinking, complex problem-solving, and creativity as essential competencies for the 21st century workforce (Sardar, 2024). Mathematics education, as a foundation for logical reasoning and analytical thinking, is expected to play a strategic role in fostering these competencies. However, the growing dominance of intelligent technologies in educational settings often prioritizes efficiency, automation, and rapid feedback, potentially undermining the core values of humanistic pedagogy. Therefore, the humanization of mathematics pedagogy becomes increasingly important to ensure that technology serves as a means of empowerment rather than a replacement for meaningful human interaction.

The primary issue that emerges is the reduction of the teacher's role to that of a technical facilitator, while algorithms increasingly assume control over diagnostic processes and instructional recommendations. Other challenges include the digital divide, algorithmic bias, overreliance on automated systems, and the potential weakening of students' reflective capacities. In practice, many AI-based mathematics learning platforms tend to emphasize score

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attainment and procedural problem-solving rather than fostering conceptual understanding and pedagogical dialogue.

Several previous studies have explored the integration of AI in mathematics education, the effectiveness of adaptive learning, and the impact of digitalization on learning outcomes. Mustafa, (2024) found that AI-driven adaptive learning is essential for modern mathematics education, enabling personalized, engaging, and effective learning experiences that lead to improved student performance while requiring continuous development. Integrating AI into the curriculum, as suggested by Maanu et al., (2025), can enhance learning outcomes in mathematics education. Borah & Borah, (2024) also demonstrated the effectiveness of AI in adaptive learning through intelligent tutoring systems, which improve student engagement and understanding. Furthermore, digitalization has a positive impact on learning outcomes by providing personalized experiences and real-time feedback, addressing traditional challenges in mathematics education while taking ethical and contextual limitations into account.

These studies generally emphasize improvements in short-term cognitive performance, assessment efficiency, and the optimization of personalized learning pathways. However, most research still focuses on technical and quantitative aspects, while ethical, relational, and humanistic dimensions remain insufficiently addressed. Moreover, interdisciplinary approaches that integrate philosophy of education, critical pedagogy, and intelligent technologies are still relatively limited in the literature. A key limitation of prior research lies in the absence of a conceptual framework that explicitly integrates principles of humanization into the design and implementation of mathematics learning technologies. Many studies have not examined the long-term impact of intelligent technologies on the development of students' character, empathy, and mathematical dispositions. In addition, existing literature tends to be fragmented between educational technology studies and humanistic pedagogy, resulting in the lack of a comprehensive theoretical synthesis. This gap opens opportunities for a systematic literature review that maps, critiques, and synthesizes the concept of pedagogical humanization within the context of the expansion of intelligent technologies.

This study is expected to contribute novel insights through the development of an integrative conceptual framework that positions intelligent technologies within a humanistic pedagogical perspective. The novelty of this research lies in its attempt to synthesize empirical findings, theories of mathematics pedagogy, and ethical considerations of technology to formulate a model of pedagogical humanization that is adaptive to the digital era. The urgency of this study is further reinforced by the rapid adoption of AI in education, which has not yet been fully accompanied by adequate philosophical and pedagogical reflection. Therefore, a

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comprehensive literature review on the humanization of mathematics pedagogy amid the expansion of intelligent technologies is crucial to ensure that digital transformation remains grounded in human values and the essential goals of education.

METHOD

This study employs a qualitative literature review approach aimed at identifying, analyzing, and synthesizing previous research findings related to the concept of humanizing mathematics pedagogy amid the expansion of intelligent technologies. The research design is descriptive-analytical in nature; rather than conducting direct experimentation, the study systematically examines a range of scholarly sources. The data sources consist of 10 scientific journal articles and academic publications from 2023 to 2025 that are relevant to the topics of authentic assessment, project-based learning, and mathematics education. Data analysis was conducted using content analysis and thematic synthesis methods. Content analysis was utilized to interpret the meaning of each study, while thematic synthesis was applied to categorize findings into major themes, including: (1) the role of teachers in the AI era, (2) ethical and relational dimensions in digital mathematics learning, (3) the impact of intelligent technologies on students' mathematical dispositions, and (4) integrative models of technology-based humanizing pedagogy. The synthesis process was carried out inductively by identifying patterns, relationships among concepts, and gaps emerging from prior studies. The final stage of the research involved constructing a narrative synthesis that integrates various findings into a conceptual framework of humanizing mathematics pedagogy in the era of intelligent technology. This framework is designed to bridge the gap between technological efficiency and humanistic values in education. Therefore, this research method not only aims to map the existing literature but also to generate a new conceptual formulation that can serve as a foundation for developing more humanistic and adaptive mathematics learning models in response to technological advancements.

RESULTS AND DISCUSSION

RESULT

The synthesis of ten articles reveals a consistent pattern indicating that intelligent technologies particularly artificial intelligence (AI), learning analytics, and intelligent tutoring systems are capable of improving learning efficiency and short-term cognitive performance outcomes in mathematics. However, most studies highlight that these improvements tend to be procedural and score-based rather than fostering conceptual understanding or strengthening students' mathematical dispositions. Ethical and relational dimensions emerge as central issues

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in recent literature. Several studies emphasize risks such as algorithmic bias, the reduction of teachers' roles, and the dominance of data-driven approaches that shift learning away from dialogical processes in mathematics education. International policy reports also indicate that teachers' readiness to integrate AI reflectively remains limited, resulting in suboptimal realization of humanistic potential.

Studies conducted 2025 begin to show a paradigm shift toward collaborative models between teachers and AI (human and AI collaboration). These findings suggest that learning effectiveness increases when technology is positioned as a pedagogical partner rather than a substitute for teachers. However, no conceptual model has yet explicitly formulated the principles of humanizing mathematics pedagogy within this context. Overall, the synthesis confirms that the 2023–2025 literature remains dominated by technocentric approaches. The primary gap lies in the lack of integration among humanistic pedagogical theory, technology ethics, and AI-based mathematics learning practices within a unified conceptual framework. This study contributes by developing an integrative synthesis that positions human values empathy, dialogue, reflection, and meaning-making as foundational in the use of intelligent technologies. Thus, the findings underscore the urgency of developing a humanized mathematics pedagogy model that is adaptive to the expansion of intelligent technologies while preserving the essence of education as a process of holistic human development.

DISCUSSION

The humanization of mathematics pedagogy amid the expansion of intelligent technologies must be linked to contemporary theoretical developments that position the human–technology relationship as a central of educational transformation. The theory of AI-Augmented Learning developed by Rose Luckin emphasizes that artificial intelligence should function as an "amplifier of human intelligence," rather than replacing the role of teachers. Educators serve as moral exemplars, guiding students through complex ethical landscapes that AI cannot navigate (Terantino et al., 2025). Teachers also provide emotional support and foster interpersonal relationships, which are essential for effective learning (Felix, 2020). In the context of mathematics pedagogy, this theory highlights the importance of maintaining students' metacognitive and reflective dimensions when using intelligent tutoring systems. Thus, humanization does not imply rejecting technology but ensuring that AI enhances dialogical processes rather than merely automating procedural exercises.

Furthermore, the Critical AI in Education theory proposed by Neil Selwyn highlights the performative and market-oriented tendencies of educational technologies. Educational

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technology is increasingly driven by datafication and algorithmization, prioritizing measurable outcomes over educational quality. This may lead to a loss of pedagogical value, as technologies are designed to optimize efficiency rather than enrich learning experiences (Selwyn et al., 2025). In mathematics education, this trend may result in excessive standardization that overlooks students' diverse learning styles and backgrounds. From this perspective, the humanization of pedagogy requires critical awareness of the power structures embedded within intelligent technological systems.

The Human and AI Collaborative Teaching theory introduces the concept of co-agency between teachers and AI systems. According to this theory, learning effectiveness improves when teachers remain the primary pedagogical decision-makers, while AI serves as a provider of analytics and adaptive recommendations. Teachers need to strengthen their decision-making authority in the design and use of AI tools while addressing challenges and integrating technology with educational values (Ren, 2025). In mathematics education, this collaborative approach enables teachers to interpret students' errors contextually, ensuring that instructional interventions consider emotional and social dimensions.

Meanwhile, the Ethical AI Governance in Education theory proposed by Ben Williamson emphasizes the need for value-based regulation in the development of educational technologies (Komarudin, 2025). Williamson argues that AI governance must include algorithmic transparency, data accountability, and teacher participation in the design process. In mathematics pedagogy, such regulation is essential to prevent adaptive learning systems from confining students within static "ability profiles." The Learning Analytics for Human Development theory developed by Ryan Baker highlights the potential of learning analytics to support both cognitive and affective development. Learning analytics can enhance cognitive development by providing insights into learning patterns and outcomes, enabling personalized education tailored to individual needs (Sarita & Rajeev, 2025). Additionally, it supports socio-emotional growth by fostering emotional awareness and collaborative learning environments (Pacheco et al., 2025). In mathematics, analytics should not focus solely on problem-solving speed but also on conceptual error patterns and students' thinking strategies.

The AI Competency Framework for Teachers developed by UNESCO expands the discourse on humanization through capacity building. This framework emphasizes the development of competencies aligned with universal human values such as dignity, inclusion, equity, and sustainability, transforming teachers into ethical mediators and students into reflective global citizens (Sebire, 2025). It highlights that AI literacy for teachers encompasses ethical, pedagogical, and technical dimensions in an integrated manner. In mathematics education, this competency

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enables teachers to facilitate reflective discussions about how algorithms work, ensuring that students do not become passive users of technology. The Personalized Learning with Safeguards approach promoted by OECD stresses that AI-driven personalization must be accompanied by mechanisms that protect student autonomy. This approach seeks to balance the benefits of tailored learning experiences with ethical considerations and student well-being (Mohsen, 2025). In mathematics education, personalization should allow space for exploration, productive struggle, and collaborative discussion. Humanization in this context involves maintaining a balance between system adaptability and students' intellectual freedom. AI can analyze individual learning styles and provide real-time feedback, thereby personalizing curricula to meet diverse student needs (Hamida et al., 2025).

The Socio-Emotional AI in Education theory developed by Wayne Holmes underscores the importance of integrating socio-emotional dimensions into educational AI systems. AI should be designed to support empathy and emotional engagement, not merely academic performance. It can enhance emotional interaction and facilitate understanding of socio-affective relationships, contributing to more meaningful learning experiences (Mayrene et al., 2024). This integration is crucial for holistic student development, particularly in addressing mathematics anxiety, which often becomes a major barrier to learning (Akintayo et al., 2024). In addition, the Constructivist Digital Pedagogy theory updated by Dirk Ifenthaler emphasizes that digital technologies should support active knowledge construction by learners. This approach aligns with constructivist principles advocating learner-centered environments where students actively build understanding through experience and reflection. The integration of digital technologies such as learning management systems (LMS), AI, and gamification enhances interactive, personalized, and collaborative learning experiences (Zin et al., 2024). In mathematics, this means that AI should facilitate open-ended problem exploration and reflective discussion rather than merely structured exercises. Humanization is realized when students become active subjects constructing meaning rather than passive objects of algorithms.

Finally, the Augmented Intelligence for Equity theory developed by the World Economic Forum highlights the importance of ensuring that AI expands access and educational equity. This approach advocates using AI to bridge educational gaps by providing personalized learning experiences, optimizing resource allocation, and supporting diverse learning needs (Sharma, 2025). In mathematics pedagogy, this requires leveraging technology to reduce numeracy disparities rather than exacerbate them. Strong policies and frameworks prioritizing human rights, cultural contexts, and ethical considerations are essential for advancing educational equity (Virani & Gulzar, 2024).

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This study has significant theoretical implications for developing a conceptual framework for the humanization of mathematics pedagogy in the era of intelligent technologies. The literature synthesis indicates that dominant technocentric approaches must be balanced with humanistic pedagogical paradigms emphasizing relationships, empathy, and reflection. By integrating AI-augmented learning and critical perspectives, this study expands mathematics education discourse from performative effectiveness toward meaning-making and character development. Methodologically, this study highlights the importance of interdisciplinary approaches in AI-based mathematics education research. The integration of learning analytics and human–AI collaboration suggests that future research should combine quantitative data analysis with qualitative exploration of students' learning experiences. This implies the need for research designs that assess not only improvements in mathematical performance but also the development of mathematical dispositions, confidence, and reflective abilities.

Practically, the implications of this study target the transformation of mathematics teachers' roles. Based on UNESCO's AI competency framework, teachers must be equipped with not only technical but also ethical and pedagogical literacy. Humanizing pedagogy requires teachers to act as meaning mediators capable of interpreting algorithmic recommendations contextually. Therefore, professional development programs should include reflective training on algorithmic bias, data privacy, and dialogical AI integration strategies.

Policy implications are equally significant. In line with Ben Williamson's perspective, regulations governing AI use in mathematics education should emphasize transparency, accountability, and equity. Governments and educational institutions must establish guidelines ensuring that adaptive technologies do not restrict students' academic mobility through rigid ability categorization. The implications for mathematics curriculum design are also substantial. AI-based personalization approaches promoted by OECD should be balanced with opportunities for collaborative discussion and open exploration. Future curricula should integrate project-based learning, contextual problem-solving, and metacognitive reflection while leveraging technology without diminishing social interaction. This ensures that mathematics learning evolves beyond procedural orientation toward fostering critical reasoning and intellectual empathy.

From a psychological perspective, this study underscores the importance of addressing socio-emotional dimensions in digital mathematics learning. The concept of socio-emotional AI highlights the potential of technology to support motivation and reduce mathematics anxiety. Consequently, learning platforms should incorporate supportive feedback mechanisms, emotional adaptability, and features that build students' confidence in tackling mathematical challenges. More broadly, this study contributes to a paradigm reorientation of mathematics

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education in the era of the Industrial Revolution 4.0 and Society 5.0. Reports from the World Economic Forum emphasize the importance of critical thinking and complex problem-solving skills. Humanizing mathematics pedagogy ensures that technology integration enhances rather than diminishes students' reflective and creative capacities. By positioning AI as an ethical and reflective pedagogical partner, mathematics education can contribute to the development of adaptive, critical, and socially responsible individuals in the age of intelligent technologies.

CONCLUSION

Based on the synthesis of the literature and theoretical discussion, this study affirms that the expansion of intelligent technologies in mathematics education presents both significant opportunities and fundamental challenges to the essence of pedagogy. Technologies such as intelligent tutoring systems, learning analytics, and adaptive platforms have been shown to enhance efficiency, personalization, and short-term cognitive performance outcomes. However, recent literature indicates that these improvements do not consistently contribute to deep conceptual understanding, positive mathematical dispositions, or students' character development. This suggests a tendency toward technocentrism that may potentially reduce the relational and reflective dimensions of learning. The integration of theories from various scholars demonstrates that the humanization of mathematics pedagogy does not contradict the use of AI; rather, it calls for a repositioning of technology as an ethical, transparent pedagogical partner oriented toward holistic human development. Humanization is understood as an effort to preserve empathy, dialogue, learner autonomy, and the construction of conceptual meaning amid the dominance of data-driven and algorithm-based systems. This study also emphasizes that the role of the teacher remains central within technology-based learning ecosystems. Teachers need to possess comprehensive AI literacy in order to interpret, critically evaluate, and contextually integrate algorithmic recommendations. Thus, the humanization of mathematics pedagogy is not merely a normative concept, but a strategic framework to ensure that digital transformation remains grounded in human values.

Future research should develop and empirically test models of humanized mathematics pedagogy based on human and AI collaboration in authentic classroom contexts. Experimental studies or design-based research may be conducted to evaluate how dialogic AI integration influences students' conceptual understanding, mathematical dispositions, and socio-emotional development over the long term. Furthermore, future studies need to explore ethical and policy dimensions more deeply, including issues of algorithmic bias, data privacy, and equity of access in digital mathematics learning. Cross-national comparative studies may also provide insights into

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best practices for humanistically oriented governance of AI in education.

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