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Artificial Intelligence for Physics Education in STEM Classrooms: A Narrative Review within a Pedagogy Technology Policy Framework

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ABSTRACT

Purpose of the study: This study seeks to consolidate existing global research on the incorporation of Artificial Intelligence (AI) into school-level STEM education, with a particular emphasis on physics teaching and learning in primary and secondary settings, to delineate principal trends, recognize emerging opportunities, and underscore ongoing challenges in pedagogy and learning.

Methodology: A narrative literature review was performed utilizing Google Scholar and Scopus to identify significant studies published from 2015 to 2025. The selection emphasized peer-reviewed journal articles and conference proceedings that concentrate on the pedagogical, technological, and policy aspects of AI in STEM education.

Main Findings: The analysis indicates that artificial intelligence is transforming STEM education via intelligent tutoring systems, adaptive learning platforms, automated assessments, and virtual laboratories. These technologies improve personalization, engagement, and inquiry-based learning, yet they also present ethical dilemmas concerning bias, privacy, and equity. A novel conceptual framework that integrates pedagogy, technology, and policies is proposed to direct future research and practice.

Novelty/Originality of this study: This study presents a novel three-dimensional framework that interconnects pedagogy, technology, and policy as mutually reinforcing components in AI-enhanced STEM education. The model presents a novel analytical framework for assessing existing initiatives and outlines a strategy for creating inclusive and sustainable AI-enhanced learning environments.

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1. INTRODUCTION

The swift advancement of Artificial Intelligence (AI) is revolutionizing various sectors of society, with education, especially in the fields of Science, Technology, Engineering, and Mathematics (STEM), leading this change. In this review, the focus is placed on the integration of AI into primary and secondary school STEM education, and more specifically on physics education, to provide insights relevant to school curricula and classroom practice. In the last ten years, AI has transitioned from a backend computational instrument to an engaged collaborator in educational processes [1], [2]. Intelligent tutoring systems, machine learning algorithms, natural language processing, and adaptive analytics facilitate unparalleled personalization of instruction, fostering learning environments that dynamically respond to the unique needs and capabilities of individual students [3], [4]. These technologies facilitate data-driven decision-making, providing educators with comprehensive insights into student performance and enabling real-time interventions that were previously unattainable [5].

The necessity to incorporate AI into STEM education stems from technological and societal demands. As global economies grow more reliant on automation, data science, and computational thinking, students must possess both disciplinary knowledge and the capacity to critically engage with AI-driven tools and systems [6]. STEM disciplines are especially conducive to AI integration due to their inherent focus on problem-solving, modeling, and inquiry-based learning—capabilities that inherently correspond with the advantages of AI technologies [7]. STEM methodologies have been effectively employed in early childhood settings to introduce intricate physical concepts such as magnetism [8] and in primary education through the incorporation of emerging technologies and robotics [9].

Recent studies have examined educators' perceptions regarding the integration of educational robotics into STEM learning [10], and a supplementary theoretical framework has been proposed to delineate the attributes of an effective STEM educator by amalgamating literacy, knowledge, collaboration, and self-efficacy [11]. Recent implementations underscore the innovative application of robotics in early childhood STEM education, including festive Beebot activities tailored for preschoolers [12] and the direct utilization of artificial intelligence to enhance comprehension of magnetism in preschool environments [13]. Comprehensive examinations of AI integration in science education underscore the pedagogical advantages and possible obstacles associated with these advancements [14]. Recent research has yielded practical AI-driven tools and comprehensive lesson plans to enhance physics education, providing implementable strategies for educators across various educational tiers [15]. Moreover, studies examining students' comprehension of Einsteinian physics underscore the capacity of AI-enhanced teaching methods to connect abstract scientific theories with classroom implementation [16].

Simultaneously, examining primary school students' stereotypical views of scientists offers essential insights for developing AI-driven STEM activities that promote more inclusive and accurate representations of science and scientists [17]. The practical applications of AI-compatible tools are apparent in economical experimental setups, exemplified by the utilization of Arduino technology to quantify the kinetic friction coefficient, illustrating how accessible hardware can enhance AI-driven analysis in STEM education [18]. Inquiry-based laboratory activities have demonstrated the capacity to improve conceptual comprehension of heat and self-efficacy in pre-service teachers, providing significant insights for the incorporation of AI-supported experimentation in teacher education [19]. The investigation of sound wave properties via robotics exemplifies how interactive technologies can enhance AI-driven analysis to augment STEM education [20].

Comprehensive considerations regarding the advancement of physics education highlight the transformative capabilities of AI, transitioning classrooms from conventional chalkboard techniques to AI-enhanced teaching settings [21]. Supplementary evidence demonstrates that AI can directly aid primary school teachers in the planning and implementation of physics experiments, rendering intricate activities more manageable and engaging [22]. For instance, AI-driven virtual laboratories can replicate intricate experiments that may be prohibitively costly, hazardous, or time-intensive to perform in a traditional classroom setting [23]. Likewise, AI-enhanced adaptive assessments can deliver instantaneous feedback, aiding students in honing their comprehension of challenging concepts and facilitating differentiated instruction on a large scale [24].

Nonetheless, the potential of AI in STEM education is coupled with considerable challenges that must be confronted to guarantee equitable and ethical application. Concerns regarding algorithmic bias, data privacy, and the potential to worsen existing educational inequalities persist as significant issues [25], [26]. AI systems trained on restricted or biased datasets may inadvertently perpetuate stereotypes or disadvantage marginalized student populations [27]. Moreover, disparities in technological infrastructure between affluent and underprivileged schools threaten to exacerbate the digital divide, depriving certain students of the advantages of AI-enhanced education [28]. Teacher preparedness constitutes a significant obstacle; educators require specialized professional development to proficiently incorporate AI tools into their instructional methodologies [29]. In the absence of meticulous policy frameworks and ethical guidelines, the implementation of AI in education may unintentionally compromise educational equity rather than improve it [30].

This article examines the opportunities and challenges by providing a thorough review of current literature on AI in STEM education. Utilizing peer-reviewed research from 2015 to 2025, it delineates significant trends in AI adoption, identifies emerging pedagogical practices, and analyzes the policy and ethical implications associated with technological innovation. A conceptual framework is proposed to structure this synthesis, positioning pedagogy, technology, and policy as interdependent facets of AI integration. The article aims to offer practical insights for researchers, educators, and policymakers by examining the interplay of these dimensions, with the goal of leveraging AI's potential while upholding the principles of equity, inclusivity, and academic integrity [31], [32].

Despite the rapid growth of research on AI in STEM education, the existing literature remains fragmented across technologies, disciplines, and educational levels. Prior reviews often describe individual tools—such as intelligent tutoring systems or robotics without critically examining how pedagogical theory, technological affordances, and policy frameworks interact. Moreover, few studies provide a unifying conceptual model that bridges these three dimensions, and investigations focusing specifically on physics education are still scarce. These gaps create an urgent need for an integrative synthesis that not only maps global trends but also proposes a comprehensive pedagogy technology policy framework to guide future research and support equitable, scalable implementation of AI in STEM classrooms.

The integration of AI into STEM education signifies a transformation in the epistemological underpinnings of pedagogy and learning, rather than merely the implementation of new tools. AI-driven platforms not only provide content but also facilitate the processes of inquiry, experimentation, and knowledge construction that characterize STEM disciplines. Comprehending these transformations is crucial for equipping future generations of learners to prosper in an AI-dominated environment, rendering the current investigation both pertinent and imperative.

2. THE COMPREHENSIVE THEORETICAL BASIS

Artificial Intelligence (AI) has integrated into STEM education not just as a set of tools, but as a catalyst for re-evaluating the processes of knowledge generation, instruction, and assessment. The amalgamation of AI with STEM education is most effectively comprehended through a framework of pedagogy, technology, and policy that emphasizes the interrelation of educational theory, technological capabilities, and institutional governance. This theoretical framework is crucial for elucidating how AI transforms learning environments, the processes through which it facilitates inquiry and problem-solving, and the prerequisites for ethical and equitable implementation.

STEM education is based on constructivist and socio-cultural theories that highlight active participation, collaboration, and the collective creation of knowledge. Constructivism perceives learning as a process wherein students develop comprehension through experience and reflection, a viewpoint that inherently aligns with AI's capacity to offer adaptive feedback and real-time data analytics [33], [7]. Social cognitive theory emphasizes the significance of self-regulation and the reciprocal relationship between learners and their environment, indicating that AI-driven platforms can act as mediating agents that promote metacognition and self-directed learning [34].

AI applications, including intelligent tutoring systems, adaptive assessment platforms, and automated feedback engines, implement these theories by customizing instruction for individual learners. Through the ongoing analysis of performance data, these systems can modify task difficulty, offer scaffolded hints, and suggest resources, thus facilitating differentiated instruction and accommodating diverse learning pathways [3], [4]. In STEM environments where conceptual comprehension and problem-solving abilities are crucial, such responsiveness improves the quality of inquiry-based learning and fosters the development of higher-order thinking skills [5].

Technologically, AI includes machine learning, natural language processing, neural networks, and data analytics. These elements collaborate to identify patterns in student data, forecast performance, and automate feedback systems [29]. AI-enabled virtual laboratories facilitate experiments that may be unfeasible in a physical environment, offering opportunities for iterative testing and instantaneous visualization of outcomes [23]. These technologies expand the limits of conventional classrooms by providing learners at all levels access to sophisticated simulations and extensive data analysis.

The technological aspect encompasses the amalgamation of AI with nascent immersive tools like augmented reality (AR) and virtual reality (VR), thereby establishing extended-reality learning environments in which students can interact with intricate scientific phenomena in real time [27]. When integrated with adaptive analytics, these immersive environments enhance experiential learning and reinforce the link between abstract concepts and practical applications.

The policy dimension offers the regulatory and ethical framework essential for the responsible implementation of AI. Concerns, including algorithmic bias, data privacy, transparency, and equitable access, necessitate proactive governance to prevent AI deployment from perpetuating existing inequalities [25], [26]. National and institutional policies affect infrastructure availability, educator training, and resource allocation, which collectively dictate the scalability and sustainability of AI-enhanced STEM education [28], [30].

Policies must also encompass teacher professional development. Successful AI integration requires educators who possess technological proficiency and the ability to critically assess AI recommendations while preserving pedagogical independence [31]. Professional development programs, ethical standards, and funding initiatives constitute a vital element of the framework, guaranteeing that technological innovation promotes educational equity instead of compromising it.

The interaction among pedagogy, technology, and policy forms a dynamic ecosystem where each element affects and is affected by the others. Pedagogical practices influence the development of AI tools, whereas technological affordances create new opportunities for instructional strategies. Policy mediates these interactions by establishing boundaries and offering incentives for innovation. Examining AI in STEM education through this tripartite perspective demonstrates that effective implementation requires not only the adoption of sophisticated software but also the alignment of technological capabilities with established educational principles and strong ethical oversight [32].

3. RESEARCH METHOD

This study employs a narrative literature review methodology to synthesize and critically evaluate research regarding the incorporation of Artificial Intelligence (AI) in STEM education. A narrative review is especially appropriate for a rapidly evolving field that necessitates a comprehensive conceptual understanding instead of a meta-analytic synthesis of quantitative findings [35]. The objective was to discern theoretical trends, pedagogical patterns, and technological innovations through an analysis of peer-reviewed studies and conference papers concerning AI applications in STEM education [5], [29].

The literature review was performed using Scopus, Web of Science, Google Scholar, and ERIC to obtain both journal articles and reputable conference proceedings. Search strings amalgamated the terms artificial intelligence, STEM education, intelligent tutoring, adaptive learning, and machine learning in education, interconnected with Boolean operators to enhance the results. Publications from January 2015 to June 2025 were examined to emphasize the most recent and pertinent advancements [4]. The initial search retrieved 472 records across the four databases. After removing 104 duplicates, 368 unique records remained for title and abstract screening. Of these, 224 articles were excluded for not meeting the inclusion criteria (e.g., absence of a STEM focus, non-English language, or lack of empirical/theoretical grounding), leaving 144 full-text papers for detailed review. Following full-text assessment, 68 studies met all criteria and were included in the final synthesis. Studies were included if they examined AI in STEM or science education at any educational level, were published in English, and provided either empirical data, conceptual frameworks, or systematic analyses of AI integration. Papers that focused solely on computer science education, devoid of a STEM pedagogical framework, lacking empirical or theoretical support, or consisting of opinion pieces without academic citations were excluded [36].

After the preliminary search, all obtained documents were evaluated for relevance and categorized according to educational context (primary, secondary, or higher education), type of AI technology (including intelligent tutoring systems, learning analytics, or virtual laboratories), pedagogical orientation (such as inquiry-based or project-based learning), and reported outcomes (including student achievement, motivation, teacher practices, or ethical considerations). An iterative thematic analysis was employed to discern recurring concepts and to categorize related ideas in accordance with the pedagogy technology policy framework outlined in the theoretical background [5]. To enhance methodological transparency, the analysis followed a three-step process: (i) open coding, in which key concepts and phrases were identified independently by two researchers; (ii) axial coding, where related codes were grouped into broader categories reflecting pedagogical, technological, and policy dimensions; and (iii) selective coding, during which final themes were refined and linked to the research questions. Coding was carried out manually using a shared spreadsheet to record codes, definitions, and supporting excerpts. Intercoder agreement was established through repeated discussions between the two researchers until complete consensus on all codes and themes was reached.

These procedures of open coding, categorization, and refinement facilitated the emergence of key themes, including personalized learning environments, ethical dilemmas, infrastructure requirements, and professional development needs. To improve reliability, the search and coding were independently validated by two researchers knowledgeable in STEM education and AI technologies, with discrepancies resolved through discussion until consensus was reached [35]. The validity was enhanced by triangulating findings from various databases and ensuring representation of diverse educational levels, geographic regions, and AI applications in the final dataset [29], [4].

4. RESULTS AND DISCUSSION

The examination of the chosen literature uncovers a dynamic and complex array of Artificial Intelligence (AI) applications in STEM education. AI technologies are being utilized across various educational levels and geographic regions to improve personalization, automate assessments, facilitate inquiry-based learning, and broaden access to intricate scientific phenomena. The review organizes the evidence into interconnected themes that highlight both the educational opportunities and the systemic challenges of AI integration, rather than presenting results as isolated findings.

A significant theme pertains to personalized learning environments. Intelligent tutoring systems and AI-driven learning analytics facilitate the ongoing collection and analysis of learner data, permitting instructional content to adjust in real time to students' requirements [3], [4]. These systems offer prompt feedback, pinpoint misunderstandings, and suggest customized learning trajectories, thereby improving engagement and facilitating differentiated instruction. In STEM fields, where both conceptual comprehension and procedural proficiency are essential, the ability to adapt dynamically results in quantifiable enhancements in student performance and motivation [5], [29].

However, not all findings align: while Sun et al. [4] observed substantial gains in problem-solving performance, Nagaraj et al. [5] reported only modest improvements when AI tools were implemented without accompanying teacher training. This contrast suggests that pedagogical support and professional development may moderate the effectiveness of AI-driven personalization. Similarly, whereas Feng et al. [3] highlighted the scalability of intelligent tutoring across diverse STEM topics, Knox [26] cautioned that algorithmic bias and limited datasets can restrict generalizability, indicating that the success of adaptive systems may depend on the cultural and infrastructural contexts in which they are deployed.

These convergences and divergences indicate that personalization through AI is not a universally guaranteed outcome but rather a process contingent on implementation fidelity, teacher expertise, and the equity of technological infrastructure.

A secondary principal theme pertains to AI-assisted evaluation and experimentation. Automated grading systems and virtual laboratories alleviate the administrative burden on educators while offering students opportunities for iterative testing and experimentation. AI-driven virtual laboratories replicate intricate or dangerous experiments that may be unfeasible in a traditional classroom, providing students with a secure environment to investigate scientific concepts and cultivate advanced problem-solving abilities [23], [24]. These tools not only broaden the spectrum of potential learning activities but also furnish comprehensive datasets for educators to track progress and enhance their instructional methodologies.

The literature underscores substantial ethical and equity challenges. Issues regarding data privacy, algorithmic bias, and the potential exacerbation of existing inequalities are prevalent in numerous studies [25], [26]. AI systems developed using biased datasets may inadvertently perpetuate stereotypes or marginalize underrepresented groups. The disproportionate allocation of technological infrastructure between affluent and disadvantaged schools jeopardizes exacerbating the digital divide, resulting in inequalities in access to AI-enhanced educational opportunities [28], [30]. Recent research offers a concentrated analysis of the intersection between AI and personal data management in education, highlighting the necessity for stringent privacy safeguards and explicit regulatory frameworks [37]. Resolving these issues necessitates transparent data governance, inclusive design methodologies, and supportive policy frameworks that emphasize equity.

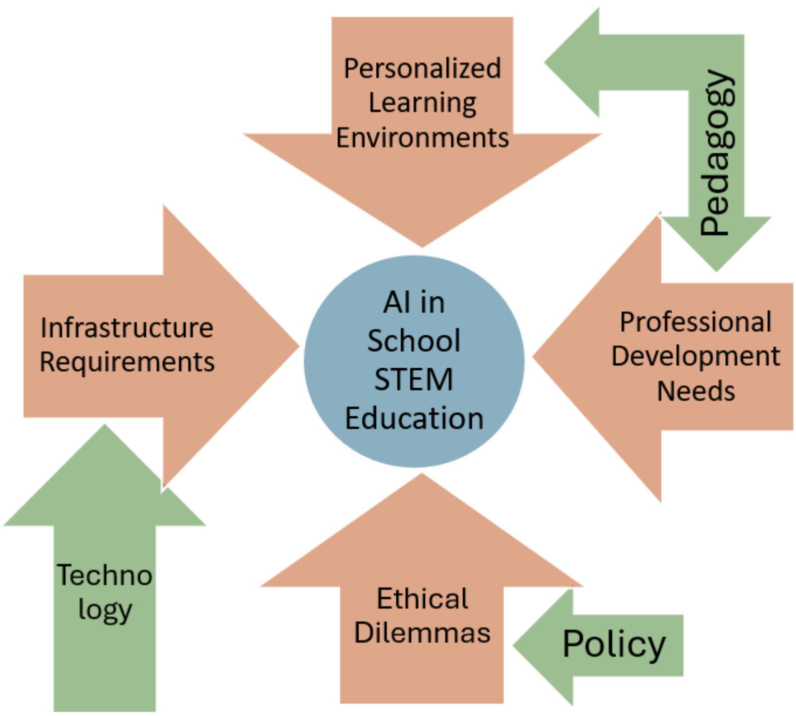

Figure 1. Concept map showing the four major themes of the review (personalized learning environments, ethical dilemmas, infrastructure requirements, and professional development needs) and their alignment with the Pedagogy Technology Policy framework. Themes are positioned around the central concept of AI in School STEM Education.

A persistent observation pertains to teacher preparedness and professional advancement. The successful implementation of AI relies not only on technological availability but also on educators' ability to incorporate these tools into teaching practices. Empirical classroom evidence indicates that AI can assist primary school teachers in the planning and implementation of physics experiments, illustrating how intelligent systems can alleviate preparation burdens and promote innovative practices [22]. Further research indicates that ChatGPT can produce comprehensive physics experiment worksheets specifically designed for primary education instructors, exemplifying the role of large language models as collaborative designers of educational resources [38]. Data from secondary education similarly suggests that AI can be incorporated into high school science instruction, offering organized frameworks for lesson planning and classroom execution [39], [40]. Numerous studies highlight the necessity for specialized professional development programs that furnish educators with the technical competencies and critical insights required for effective AI utilization while preserving pedagogical independence [32]. In the absence of adequate preparation, the advantages of AI may be underexploited or misaligned with educational objectives.

The emergence of these themes is significant because they highlight leverage points for transforming school physics education. Personalized learning environments demonstrate how AI can tailor physics instruction to individual learners, while ethical dilemmas and infrastructure requirements underscore the need for policy safeguards and equitable resource allocation. Professional development needs to point directly to teacher preparation as a critical driver of successful AI integration. Together, these themes reveal that technological innovation alone is insufficient; sustainable progress depends on coordinated pedagogical and policy strategies.

Collectively, these themes illustrate that AI in School STEM education transcends mere technological innovation, catalyzing systemic transformation. The results emphasize the necessity of synchronizing AI implementation with established educational principles, strong ethical standards, and supportive institutional frameworks.

This conceptual map (Figure 1) underscores how these interrelated themes converge to shape the implementation of AI in school STEM education. It visually reinforces the idea that successful adoption requires not only technological innovation but also coordinated pedagogical strategies and policy safeguards. This study affirms the significance of the pedagogy technology policy framework, elucidating the interaction between technological affordances, instructional practices, and governance structures in influencing the implementation of AI in educational contexts.

Despite the comprehensive scope of this review, several limitations must be acknowledged. The reliance on English-language sources may have excluded relevant studies published in other languages, and the inclusion of studies up to mid-2025 means that very recent developments may not be captured. Furthermore, the narrative review method synthesizes themes qualitatively rather than providing a statistical meta-analysis; therefore, the findings should be interpreted as conceptual trends rather than effect-size estimates.

5. CONCLUSION

This review highlights four key themes in applying artificial intelligence (AI) to school physics education personalized learning, ethical concerns, infrastructure needs, and teacher professional development showing that AI is a systemic transformation, not just a technological upgrade. AI tools like intelligent tutoring, adaptive assessments, and virtual labs can enhance inquiry-based learning, motivation, and conceptual understanding, but challenges such as data privacy, algorithmic bias, unequal access, and teacher readiness remain critical. Sustainable implementation requires balanced strategies that integrate sound pedagogy, reliable infrastructure, continuous teacher training, and supportive policy. Future research should employ longitudinal, cross-cultural, and mixed-method approaches to capture long-term impacts and inform equitable, ethical, and scalable practices.

REFERENCES

[1] S. C. Kong, H. Ogata, J.-L. Shih, and G. Biswas, "The role of artificial intelligence in STEM education," in *Proc. 29th Int. Conf. Comput. Educ. (ICCE)*, vol. II, 2021, pp. 774–776. [Online]. Available: https://library.apsce.net/index.php/ICCE/article/view/4336

[2] [2] M. J. Reiss, "The use of AI in education: Practicalities and ethical considerations," *London Rev. Educ.*, vol. 19, no. 1, p. 5, 2021, doi: 10.14324/LRE.19.1.05.

[3] S. Feng, A. J. Magana, and D. Kao, "A systematic review of literature on the effectiveness of intelligent tutoring systems in STEM," in *2021 IEEE Frontiers Educ. Conf. (FIE)*, 2021, doi: 10.1109/FIE49875.2021.9637240.

[4] D. Sun, G. Cheng, P. L. H. Yu, J. Jia, Z. Zheng, and A. Chen, "Personalized STEM education empowered by artificial intelligence: A comprehensive review and content analysis," *Interact. Learn. Environ.*, pp. 4419–4441, 2025, doi: 10.1080/10494820.2025.2462156.

[5] B. K. Nagaraj, A. Kalaivani, S. R. Begum, S. Akila, H. K. Sachdev, and N. Senthil Kumar, "The emerging role of artificial intelligence in STEM higher education: A critical review," *Int. Res. J. Multidisciplinary Technovation*, vol. 5, no. 5, pp. 1–19, 2023, doi: 10.54392/irjmt2351.

[6] L. Gavrilas and K. T. Kotsis, "The evolution of STEM education and the transition to STEAM/STREAM," *Aquademia*, vol. 9, no. 1, p. ep25002, 2025, doi: 10.29333/aquademia/16313.

[7] L. Gavrilas and K. T. Kotsis, "Integrating learning theories and innovative pedagogies in STEM education: a comprehensive review," *Eurasian J. Sci. Environ. Educ.*, vol. 5, no. 1, pp. 11–17, 2025, doi: 10.30935/ejsee/16538.

[8] V. Samara and K. T. Kotsis, "The use of STEM as a tool for teaching the concept of magnetism in kindergarten," *J. Res. Environ. Sci. Educ.*, vol. 2, no. 1, pp. 1–17, 2025, doi: 10.70232/jrese.v2i1.1.

[9] V. Samara and K. T. Kotsis, "The use of new technologies and robotics (STEM) in the teaching of sciences in primary education: The concept of magnetism: a bibliographic review," *Eur. J. Educ. Stud.*, vol. 10, no. 2, pp. 51–64, 2023, doi: 10.46827/ejes.v10i2.4652.

[10] L. Gavrilas and K. T. Kotsis, "Investigating perceptions of primary and preschool educators regarding incorporation of educational robotics into STEM education," *Contemp. Math. Sci. Educ.*, vol. 5, no. 1, p. ep24003, 2024, doi: 10.30935/conmaths/14384.

[11] L. Gavrilas and K. T. Kotsis, "A theoretical framework for the effective STEM educator: Integrating literacy, knowledge, collaboration, and self-efficacy," *J. Math. Sci. Teacher*, vol. 5, no. 4, p. em085, 2025, doi: 10.29333/mathsciteacher/16857.

[12] V. Samara and K. T. Kotsis, "Robotic christmas activities with beebot: a STEM application for preschool education," *J. Sci. Educ. Res.*, vol. 7, no. 2, pp. 21–31, 2025, doi: 10.21831/jser.v9i1.77862.

[13] V. Samara and K. T. Kotsis, "Use of artificial intelligence in teaching the concept of magnetism in preschool education," *J. Digit. Educ. Technol.*, vol. 4, no. 2, p. ep2419, 2024, doi: 10.30935/jdet/14864.

[14] K. T. Kotsis, "Integrating artificial intelligence in science education: benefits and challenges," *Int. J. Educ. Innov.*, vol. 6, no. 3, pp. 39–49, 2024, doi: 10.69685/ICAS1772.

[15] G. Vakarou, G. Stylos, and K. T. Kotsis, "AI for enhancing physics education: practical tools and lesson plans," *Int. J. Sci. Math. Technol. Learn.*, vol. 31, no. 2, pp. 159–176, 2024, doi: 10.18848/2327-7971/CGP/v31i02/159-176.

[16] G. Vakarou, G. Stylos, and K. T. Kotsis, "Probing students' understanding of Einsteinian physics concepts: a study in primary and secondary Greek schools," *Phys. Educ.*, vol. 59, no. 2, p. 025004, 2024, doi: 10.1088/1361-6552/ad1768.

[17] G. Stylos, I. Theocharis, E. Gkaltemi, D. Panagou, and K. T. Kotsis, "Exploring stereotypical perceptions of scientists among Greek primary school students: Insights from the draw-a-science-comic test," *Res. Sci. Technol. Educ.*, pp. 1–28, 2025, doi: 10.1080/02635143.2025.2543270.

[18] G. Stylos, E. Evangelou, V. Nousis, K. Georgopoulos, and K. T. Kotsis, "Measurement of kinetic friction coefficient using an Arduino," *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 13, no. 7, 2024, doi: 10.15680/IJIRSET.2024.1307098.

[19] N. Kyriazis, G. Stylos, and K. T. Kotsis, "Impact of inquiry-based laboratory activities on understanding heat concepts and self-efficacy in pre-service teachers," *J. Pedagogical Res.*, vol. 9, no. 1, pp. 161–181, 2025, doi: 10.33902/JPR.202530426.

[20] V. Ladas, G. Stylos, and K. T. Kotsis, "Explore the properties of sound waves by using robotics," *Sci. School*, vol. 73, pp. 1–14, 2025. [Online]. Available: https://scienceinschool.org/article/2025/explore-the-sound-waves-by-using-robotics/

[21] K. T. Kotsis, "From chalkboard to chatbot: the future of physics education through artificial intelligence integration," *EIKI J. Eff. Teach. Methods*, vol. 3, no. 2, pp. 74–79, 2025, doi: 10.59652/jetm.v3i2.515.

[22] K. T. Kotsis, "Artificial intelligence helps primary school teachers to plan and execute physics classroom experiments," *EIKI J. Eff. Teach. Methods*, vol. 2, no. 2, pp. 1–9, 2024, doi: 10.59652/jetm.v2i2.158.

[23] O. Tuyboyov, N. Sharipova, L. Ergasheva, and S. Nasirdinova, "The role and impact of AI-enhanced virtual laboratories in mechanical engineering education," in **Proc. IV Int. Conf. Adv. Sci., Eng., Digit. Educ.: ASEDU-IV 2024**, vol. 3268, p. 070019, 2025, doi: 10.1063/5.0257378.

[24] A. Bayaga, "Advancing STEM cognition with current AI landscape and systems," in *2024 Conf. Inf. Commun. Technol. Soc. (ICTAS)*, pp. 20–25, 2024, doi: 10.1109/ICTAS59620.2024.10507138.

[25] E. Kasneci et al., "ChatGPT for good? on opportunities and challenges of large language models for education," *Learn. Individ. Differ.*, vol. 103, p. 102274, 2023, doi: 10.1016/j.lindif.2023.102274.

[26] J. Knox, "Artificial intelligence and education in China," *Learn., Media Technol.*, vol. 45, no. 3, pp. 298–311, 2020, doi: 10.1080/17439884.2020.1754236.

[27] I. U. Haq et al., "AI in the network of extended reality-enabled laboratories for STEM education: current applications and future potential for adaptive learning," in *Mech. Mach. Sci.: Proc. I4SDG Workshop 2025*, vol. 180, pp. 373–382, 2025, doi: 10.1007/978-3-031-91179-8_39.

[28] M. Hakimi and A. K. Shahidzay, *Transforming education with artificial intelligence: Potential and obstacles in developing countries*, Preprint, 2024. doi: 10.20944/preprints202407.2542.v1.

[29] F. Ouyang, P. Jiao, A. H. Alavi, and B. M. McLaren, "Artificial intelligence in STEM education: current developments and future considerations," in *Artif. Intell. STEM Educ.: Paradigmatic Shifts Res., Educ., Technol.*, F. Ouyang, P. Jiao, B. M. McLaren, and A. H. Alavi, Eds. Boca Raton, FL, USA: CRC Press, 2022, pp. 1–12, doi: 10.1201/9781003181187.

[30] W. Holmes and I. Tuomi, "State of the art and practice in AI in education," *Eur. J. Educ.*, vol. 57, no. 4, pp. 542–570, 2022, doi: 10.1111/ejed.12533.

[31] K. T. Kotsis, "Artificial intelligence and the scientific process: A review of ChatGPT's role to foster experimental thinking in physics education," *Eur. J. Contemp. Educ. E-Learn.*, vol. 3, no. 3, pp. 183–198, 2025, doi: 10.59324/ejceel.2025.3(3).14.

[32] P. Nuangchalerm and V. Prachagool, "AI-driven learning analytics in STEM education," *Int. J. Res. STEM Educ.*, vol. 5, no. 2, pp. 77–84, 2023. [Online]. Available: https://eric.ed.gov/?id=ED634109

[33] A. Bandura, "Social cognitive theory: an agentic perspective," *Annu. Rev. Psychol.*, vol. 52, no. 1, pp. 1–26, 2001, doi: 10.1146/annurev.psych.52.1.1.

[34] B. J. Zimmerman and A. R. Moylan, "Self-regulation: where metacognition and motivation intersect," in *Handbook of Metacognition in Education*, D. J. Hacker, J. Dunlosky, and A. C. Graesser, Eds. New York, NY, USA: Routledge, 2009, pp. 299–315, doi: 10.4324/9780203876428.

[35] M. J. Grant and A. Booth, "A typology of reviews: an analysis of 14 review types and associated methodologies," *Health Inf. Libr. J.*, vol. 26, no. 2, pp. 91–108, 2009, doi: 10.1111/j.1471-1842.2009.00848.x.

[36] S. K. Boell and D. Cecez-Kecmanovic, "On being 'systematic' in literature reviews in IS," *J. Inf. Technol.*, vol. 30, no. 2, pp. 161–173, 2015, doi: 10.1057/jit.2014.26.

[37] K. T. Kotsis, "ChatGPT develops physics experiment worksheets for primary education teachers," *Eur. J. Educ. Stud.*, vol. 11, no. 5, pp. 1–20, 2024, doi: 10.46827/ejes.v11i5.5274.

[38] K. T. Kotsis, "Integrating artificial intelligence for science teaching in high school," *LatIA*, vol. 3, p. 89, 2025, doi: 10.62486/latia202589.

[39] K. T. Kotsis, “Artificial intelligence as a catalyst for changes in university-level science education,” *EIKI Journal of Effective Teaching Methods*, vol. 3, no. 3, pp. 99–109, 2025, doi: 10.59652/jetm.v3i3.618