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A Systematic Review on AI-enhanced Learning in Mathematics Classroom

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Research Article

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Abstract This research aimed to synthesize and review literature on the application of artificial intelligence in mathematics education. A methodical search was performed on the ERIC database utilizing the keywords “AI Mathematics” or “Mathematics AI,” restricted to publications from 2021 to 2025. From an initial pool of 133 studies, articles were screened, and ultimately five full-text empirical studies were selected for final analysis. The content synthesis revealed that the application of AI in mathematics education serves two main roles: as an intelligent tutoring system to promote personalized learning and as a generative assistant to help teachers design learning activities and content.

The results indicate that AI is effective in improving students' academic performance and helping them have a more positive attitude toward math. Simultaneously, it helps reduce teacher workload and develops their professional skills.

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Introduction

AI is now transforming mathematics education in the age of rapid technological change. Students can learn the appropriate way to solve mathematical problems and bring creativity to their classroom. Despite its organized content, mathematics education is among the fastest disciplines to adopt AI technology. AI in mathematics classrooms is a paradigm shift toward customized, data-driven, and interactive instruction as well as technology-enhanced learning (Strielkowski, Grebennikova, Lisovskiy, Rakhimova, & Vasileva, 2025; Vella, 2025). In this study, AI-enhanced learning in mathematics classrooms is examined in terms of its effects on teaching tactics, learner engagement, cognitive development, and educational equality.Mathematics is a core subject in many educational systems, but its abstract concepts and cumulative nature can be challenging for students. Lectures, solving the math problem, rote memorization, and standardized tests were criticized for students' learning demands (Cai, Liu, Chen, & Wang, 2021). AI-powered tutoring systems, adaptive learning platforms, and automated feedback mechanisms can provide students with novel ways to circumvent these restrictions.

These tools may detect misunderstandings, monitor student performance in real time, and provide customized feedback, facilitating individualized training. According (Luckin, Holmes, Griffiths, & Forcier, 2016; Holmes, Nguyen, Zhang, Mavrikis, & Rienties, 2021), AI in education allows a shift from a "one-size-fits-all" approach to a customized learning paradigm that supports varied learner profiles. AI can enhance learning, but now AI in mathematics classes is challenging despite its potential and students' response to AI-enhanced learning. The issues concerned data privacy, algorithmic bias, teacher readiness, and technological overuse, which are major problems. According to (Clark-Wilson, Donevska-Todorova, Faggiano, Trgalová, & Weigand, 2021), AI can improve instructional efficiency but potentially perpetuate systemic disparities if not deployed ethically and inclusively. For instance, algorithms trained on inadequate or biased datasets may misrepresent students' ability or propagate demographic performance inequalities. Teachers typically struggle to integrate AI technologies into their teaching (Zawacki-Richter, Marín, Bond, & Gouverneur, 2019).

Previous studies focused on pedagogical strategies, but there is less reporting on how to incorporate AI to promote learning tailored to individual needs. Teachers are increasingly becoming learning facilitators, data interpreters, and orchestrators of AI-mediated learning experiences. AI-powered learning analytics dashboards let them track learning progress. This situation requires new data literacy, ethical reasoning, and digital pedagogy skills (Holmes et al., 2019). AI affordances must be balanced with teachers' professional judgment to preserve a human-centered approach that stresses empathy, creativity, and critical thinking. The

incorporation of AI should not replace teachers but rather enhance their instructional abilities and classroom decision-making.

AI-enhanced learning has pedagogical effects beyond efficiency and customization. The idea and assessment of mathematical thinking and problem-solving change. Student exploration and self-regulation are promoted in AI-supported settings. Intelligent systems may help students evaluate their problem-solving methods, compare alternatives, and depict complicated topics using dynamic representations. Such environments support constructivist and socio-cultural learning theories, which stress active engagement, cooperation, and knowledge co-construction. AI-based collaboration platforms can match students with complementary talents to establish adaptive peer groups. It also fosters cooperative problem-solving and deeper conceptual engagement in mathematics learning. This transforms math classrooms into dynamic ecosystems where humans and AI grow.

A recent study shows that AI-enhanced arithmetic training improves learning. Students utilizing adaptive AI systems have increased academic performance, motivation, and self-efficacy (Luo & Du, 2022; Chen, Jensen, Albert, Gupta, & Lee, 2023). AI tutors' automated feedback improves problem-solving accuracy and persistence. AI-powered formative evaluations let teachers detect learning issues more accurately. Many studies emphasize short-term test score increases above conceptual comprehension or metacognitive progress. Critical synthesis and longitudinal study are needed to comprehend AI's long-term influence on mathematics instruction. AI integration may also represent cultural norms about efficiency, objectivity, and measurement, overshadowing emotional and social learning.

AI-enhanced mathematics learning is a technological breakthrough and a pedagogical reimagination. It allows for customization, engagement, and accuracy in education while posing important problems regarding justice, ethics, and epistemology. This review will argue that AI in mathematics education must balance technological advances and humanistic ideals. Educators and educational policy makers should engage AI technologies in curriculum and instruction. Thus, this critical review synthesizes existing research, evaluates empirical data, and discusses upcoming trends and difficulties to inform the responsible and successful incorporation of AI technology in mathematics classrooms.

Methodology

This study uses systematic literature review. Its objective is to gather, scrutinize, and amalgamate data from studies on the application of artificial intelligence to enhance students' mathematics learning.

Data sources and keywords

The literature search was conducted using the ERIC (Education Resources Information Center) database, a highly respected and authoritative source in the academic community. The search was limited to publications between 2021 and 2025 to ensure the data is current and reflects recent advancements in technology. The following keywords were used for the search: "AI Mathematics" or "Mathematics AI."

Inclusion and exclusion criteria

The studies were selected for analysis based on the following inclusion criteria. Type of research: The research must be an empirical study that collected original data, such as experimental, quasi-experimental, or survey research. The study's target population must include students ranging from secondary school to university. Content: The content must be directly related to the use of AI technology to promote learning or assess academic achievement in mathematics. Accessibility: The full-text document must be accessible and written in English. Conversely, studies were excluded if they were unrelated to mathematics education, were general academic or review articles, or did not specify a target population at the secondary or university level based on their title and abstract.

This study uses systematic literature review. The objective of this study is to conduct screening and data extraction.

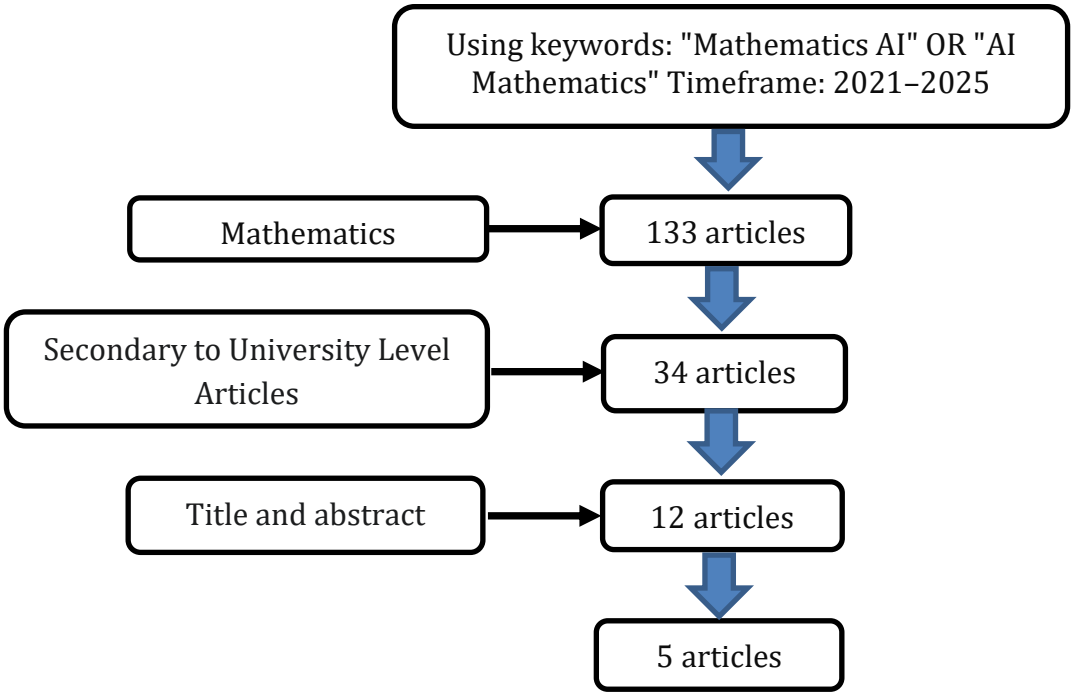


Figure 1 Screening and data extraction

Figure 1 illustrates the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines that guided the article selection process. We designed this guideline

to enhance the quality, clarity, and transparency of reporting meta-analyses and systematic reviews. With a PRISMA flow diagram to keep tabs on the studies that were found, evaluated, and ultimately included, and a checklist to verify that all important details of the review were documented, this procedure can be completed. An initial search of the ERIC database using the specified keywords and a time frame of 2021-2025 yielded a total of 133 articles. After applying a filter to include only studies related to mathematics education, 34 articles were identified as potentially relevant.

We screened the articles based on their titles and abstracts, specifically focusing on the specified educational levels from secondary school to university. This step aimed to exclude studies that were not directly relevant or were theoretical in nature, resulting in 11 articles that met the preliminary criteria. The full-text versions of the 11 articles were then thoroughly read to assess their eligibility based on the established inclusion and exclusion criteria. This thorough review found that five studies met all the criteria. The final 5 studies were selected and included for the data synthesis process in the final stage of the literature review.

Data analysis

The data from the five selected studies was extracted and organized using a document analysis matrix. This study concentrated on essential elements: research objectives, methodology, sample size, instruments, variables, and research findings. Subsequently, the researchers employed content analysis to synthesize the extracted data and identify common themes or trends across all studies. These themes included the application of AI to enhance learning outcomes, students' perceptions and attitudes towards learning with AI, the role of generative AI in mathematics education, and the positive impacts and limitations of using AI in the classroom context. The researchers performed an inter-rater reliability examination to confirm that the data synthesis was accurate and trustworthy. An independent reviewer was enlisted to jointly access and screen the articles. This process was performed to minimize potential biases in the selection and interpretation of the data.

Results and Discussion

The synthesis of five selected empirical studies revealed the dynamic application of artificial intelligence in secondary-level mathematics education. The content analysis identified three key themes: the forms of AI application, its effectiveness in teaching and learning, and its limitations along with future development trends.

The analysis found that AI is applied in two main roles. In the first role, AI serves as a direct support tool for students (Capinding, 2023). In the second role, AI acts as a tool to

support teachers and students in creating learning content. This is reflected in research by (Soesanto, Dirgantoro, & Priyantim, 2022; Rizos, Foykas, & Georgakopoulos, 2024), which used generative AI to create customized exercises for students, especially those with special needs. Studies have also looked at how well different AI chatbot platforms can help with math problems (Ergene & Ergene, 2025) and how well AI can help teachers plan lessons (Yanar & Ergene, 2025). This shows how flexible technology is when it comes to being used in different educational settings. In terms of effectiveness, the synthesis consistently shows a positive trend, particularly in enhancing learning outcomes and fostering positive attitudes among students. (Capinding, 2023) research demonstrated that using AI led to a statistically significant improvement along with heightened confidence and interest in mathematics.

(Soesanto, Dirgantoro, & Priyantim, 2022) said that most students had a good attitude toward learning with AI. In the post-pandemic era, Indonesian high school students generally have a positive view of learning math with AI. Regarding the performance of AI models, (Ergene & Ergene, 2025) found that chatbot was the most accurate in solving problems, though its capability decreased with the increasing complexity of the mathematical problems. Furthermore, AI played a significant role in developing teachers' professional skills by helping them design more creative and effective lesson plans (Yanar & Ergene, 2025).

Across the studies, AI can improve student achievement, motivation, and confidence. Students generally hold favorable attitudes toward AI-based learning, and teachers benefit from AI’s assistance in designing creative and effective instruction. AI also helps teachers grow professionally by making their jobs easier and encouraging new ideas. It has the potential to promote students' learning in both cognitive and affective domains (Ahmed, Hassan, & Saeed, 2024). However, the reviewed studies also revealed common methodological limitations, such as small sample sizes and short study durations, which restrict the generalizability of the findings and the evaluation of long-term effects. The success of AI implementation also remains dependent on prompt engineering skills and the teacher's supervisory role.

Meanwhile, the synthesis highlights significant future development trends for artificial intelligence in mathematics education. It focused on the use of generative AI to personalize learning experiences. The synthesis emphasizes the use of AI as an efficient teacher assistant, not as a replacement. In sum, the synthesis of knowledge from these five studies strongly confirms that AI plays a crucial role in elevating the quality of mathematics learning. It serves as a tool that promotes critical thinking, fosters engagement, and motivates students, while also opening up new dimensions of lesson planning and assessment for 21st-century teachers.

Conclusion

The synthesis of selected empirical studies revealed that artificial intelligence plays a significant role in mathematics education. The application of AI can be categorized into two main roles: an intelligent tutoring system, which helps students solve problems in a personalized way, and a generative assistant, which supports teachers in creating customized learning content and exercises for their students. The use of AI has a positive impact on student learning. It is important to enhance academic achievement and foster positive attitudes and confidence toward mathematics. Furthermore, AI acts as a supportive tool that reduces the workload for teachers and helps them develop professional skills in instructional design. Policymakers and administrators should promote AI in the classroom and support teachers in achieving success through a combination of learning-coupled AI and practical learning methods. The successful implementation of AI also remains dependent on the teacher's proficiency in prompt engineering and their supervisory role. AI is not just a supplementary technology but a powerful tool that can elevate the quality of mathematics education in the 21st century. It is a key asset for creating adaptive and personal learning experiences.

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