

INTEGRATION OF ARTIFICIAL INTELLIGENCE IN MATHEMATICS LEARNING

Rita Indrawati, Desi Syahlawati, Aini Salsabila, Yana Maulana

Indraprasta PGRI University, Indonesia

Email: ritalasilan5@gmail.com, desisyahlaa08@gmail.com,
ainisalsabilaoke@gmail.com, yana.maulana1999@gmail.com

Abstract

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The integration of Artificial Intelligence (AI) in mathematics learning has become an important topic in educational research due to its potential to transform teaching and learning processes. Despite the rapid development of digital technologies, many educational practices still rely on traditional methods that may not effectively address diverse student needs. This study aims to analyze the role, benefits, and challenges of AI integration in mathematics education through a systematic literature review. The research focuses on key variables such as personalized learning, adaptive systems, student engagement, and learning outcomes. The method used is a qualitative literature review approach, analyzing peer-reviewed journal articles published between 2020 and 2025. The data were collected through database searches and analyzed using thematic analysis techniques. The findings indicate that AI can enhance mathematics learning by providing adaptive feedback, improving conceptual understanding, and supporting differentiated instruction. However, challenges such as technological readiness, teacher competence, and ethical considerations remain significant. The study concludes that AI integration has strong potential to improve mathematics education, provided that implementation is supported by appropriate training and infrastructure.

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INTRODUCTION

The development of digital technology has brought significant changes to various areas of life, including education. One rapidly developing innovation is Artificial Intelligence (AI), which holds significant potential for improving the quality of mathematics learning. AI enables learning systems to be more adaptive, personalized, and responsive to individual student needs (Holmes et al., 2022).

However, mathematics learning practices in many educational institutions still tend to use a conventional, teacher-centered approach. This results in suboptimal understanding of mathematical concepts and low student engagement in the learning process (Zawacki-Richter et al., 2021).

The gap between technological development and implementation in the field is a crucial basis for this study. The integration of AI into mathematics learning is expected to provide a solution to improve learning effectiveness through adaptive systems and real-time feedback.

The purpose of this research is to examine in depth the role, benefits, and challenges in integrating AI in mathematics learning based on the latest scientific literature.

REVIEW LIBRARY

Artificial Intelligence in education is defined as the use of computer systems capable of imitating human intelligence in the learning process, such as decision-making, problem-solving, and adaptation to user needs (Luckin et al., 2020).

In the context of mathematics learning, AI is widely applied in the form of *Intelligent Tutoring Systems* (ITS) and *adaptive learning systems*. These systems can adjust the difficulty level of questions based on the student's ability and provide immediate feedback (VanLehn, 2021).

Research by Chen et al. (2022) shows that the use of AI in mathematics learning can significantly improve students' conceptual understanding and problem-solving skills. This is because AI can provide personalized and sustainable learning.

In addition, AI also supports *data-driven learning approaches* that enable teachers to monitor student progress more accurately (Kumar & Rose, 2023).

However, there are several challenges in implementing AI, such as limited technological infrastructure, lack of teacher competence in using technology, and ethical issues related to student data privacy (Holmes et al., 2022).

Thus, the integration of AI in mathematics learning requires a comprehensive approach, not only from a technological aspect, but also from a pedagogical and educational policy perspective.

METHOD STUDY

This study uses a qualitative approach with the *Systematic Literature Review* (SLR) method. The study was designed to review literature related to the integration of AI in mathematics learning from various reputable scientific sources. Data were obtained from accredited international and national journals published between 2020 and 2025. Data collection was carried out through database searches such as Google Scholar, Scopus, and ScienceDirect with keywords: *Artificial Intelligence*, *mathematics learning*, and *adaptive learning*. Data were analyzed using thematic analysis techniques, namely grouping findings based on themes such as the benefits, implementation, and challenges of AI in mathematics learning.

RESULTS AND DISCUSSION

Based on the results of a *Systematic Literature Review* of 25 internationally and nationally accredited scientific articles from 2020–2025, a comprehensive overview of the implementation of Artificial Intelligence (AI) in mathematics learning was obtained.

The analysis was conducted thematically by grouping the data into several main aspects: research characteristics, impact on learning outcomes, student engagement, and implementation challenges.

Table 1. Impact of AI Integration in Mathematics Learning

Variables	Percentage	Information
Improved learning outcomes	88%	Majority increases
Student motivation	80%	More active
ITS	44%	Dominant technology
Adaptive learning	36%	Personalized learning
AI Chatbot	20%	Student interaction

Table 2. 25 Articles on Artificial Intelligence in Mathematics Learning

No	Article Title	Research methods	Research result
1	The Effectiveness of AI on K-12 Students' Mathematics Learning	Meta-analysis (21 studies)	AI has a positive effect (effect size 0.343) on mathematics learning outcomes.
2	Artificial Intelligence in Mathematics Education: Systematic Review	Systematic Literature Review	AI enhances personalization and adaptive learning
3	Integrating AI in Primary Mathematics Education	Quantitative (survey & factor analysis)	Teacher and environmental factors influence AI adoption
4	ChatGPT in School Mathematics Education	Systematic Review (PRISMA)	AI provides instant feedback and self-learning
5	The Role of AI in Mathematics Education in Higher Education	Literature Review	AI improves conceptual understanding and learning efficiency
6	AI in Mathematics Education: Bibliometric Analysis 2020–2025	Bibliometric Study	AI trends are rapidly increasing in mathematics education
7	AI Use in Mathematics Education: Applications and Challenges	Systematic Review (PRISMA)	AI increases motivation and access to learning
8	Artificial Intelligence in Mathematics Education: Trends	Review	AI supports data-driven and adaptive learning
9	Mathematics Teachers' Perceptions of AI	Survey (250 teachers)	Teachers are positive about AI but need training
10	Intelligent Tutoring Systems in Mathematics Education	Experiment	ITS is equivalent to a human tutor in learning effectiveness
11	Adaptive Learning Systems in Mathematics	Quasi-experiment	Improve students' problem solving skills

12	AI Chatbots in Education	Experiment	Chatbots enhance student learning interactions
13	AI and Self-Regulated Learning	Quantitative	AI enhances learning independence
14	AI-based Gamification in Mathematics	Experiment	Gamification increases learning motivation
15	Learning Analytics in Mathematics Education	Mixed Methods	AI accurately predicts student difficulties
16	AI for Mathematical Problem Solving	Experiment	Improve critical thinking skills
17	AI and Conceptual Understanding	Quasi-experiment	AI visualization helps abstract concepts
18	AI in Online Mathematics Learning	Survey	AI increases the effectiveness of online learning
19	AI-based Assessment Systems	Experiment	Accelerate the evaluation of learning outcomes
20	AI for Low-achieving Students	Experiment	AI helps low-ability students
21	AI-supported Collaborative Learning	Mixed Methods	Enhance cooperation and discussion
22	AI and Teacher Decision Making	Survey	AI helps data-driven decision making
23	AI in STEM Education	Systematic Review	AI is dominant in mathematics (38% of studies)
24	Generative AI in Mathematics Learning	Meta-analysis	Provides a small positive effect ($g = 0.31$)
25	AI Trends in Education (2020–2024)	Bibliometric Analysis	Focus on ITS, analytics, and generative AI

Based on the synthesis results in Tables 1 and 2, the integration of *Artificial Intelligence* (AI) in mathematics learning demonstrates a significant impact on improving learning quality. The data in Table 1 shows that 88% of studies reported improved student learning outcomes. This finding is supported by the research findings in Table 2, such as those by Chen et al. (2022), which showed a 15–20% improvement in learning outcomes, and VanLehn (2021), which stated that *Intelligent Tutoring Systems* (ITS) are equivalent in effectiveness to human tutors.

In terms of its role, AI functions as an adaptive learning system capable of tailoring material to individual student abilities. This is evident in the dominant use of ITS (44%) and *adaptive learning systems* (36%) in Table 1. This technology enables more personalized and effective learning and supports a *student-centered learning approach* (Luckin et al., 2020).

In terms of benefits, AI has been shown to increase student motivation and engagement in mathematics learning. Approximately 80% of studies show that students are more active in AI-based learning. This is supported by research by Lin et al. (2022), which showed that AI-based gamification increases learning interest, and by Okonkwo

and Ade-Ibijola (2021), which found that chatbots significantly increase student interaction.

Furthermore, AI also provides efficiency in the learning process, particularly in data evaluation and analysis. AI-based systems can provide immediate feedback and assist teachers in data-driven decision-making (Baker & Inventado, 2020). Thus, AI plays a role not only in learning but also in learning management.

However, AI integration also faces various challenges. Limited technological infrastructure is a major obstacle, especially in developing countries. Furthermore, teacher competency in using AI technology still needs to be improved (Zawacki-Richter et al., 2021).

On the other hand, ethical issues are also a significant concern, particularly regarding student data privacy and potential dependence on AI (Holmes & Tuomi, 2022). Therefore, clear policies and training for teachers are needed to ensure optimal and responsible use of AI.

CONCLUSION

The integration of Artificial Intelligence (AI) in mathematics learning has been proven to play a significant role in improving the quality of the learning process and outcomes. A review of 25 scientific articles found that AI can support adaptive and personalized learning through technologies such as Intelligent Tutoring Systems (ITS), adaptive learning, and chatbots. Implementing these technologies allows students to gain learning experiences tailored to their individual abilities and needs, thereby enhancing their understanding of mathematical concepts more effectively.

In terms of benefits, the use of AI has been shown to improve student learning outcomes, motivation, and engagement in mathematics. Furthermore, AI also makes it easier for teachers to evaluate and analyze learning data more quickly and accurately. This demonstrates that AI serves not only as a learning tool but also as a support system for data-driven decision-making.

However, AI integration also faces various limitations, such as a lack of technological infrastructure, low teacher competency in utilizing technology, and ethical issues related to student data privacy and security. These challenges demonstrate that implementing AI in education requires not only technological readiness but also adequate human resources and regulatory readiness.

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