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The Role of Artificial Intelligence (AI) and Learning Analytics (LA) in Personalizing Mathematics Learning: A Systematic Literature Review

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Abstract

The development of digital technology has opened up new opportunities in education, particularly in improving the effectiveness of mathematics learning through a more personalized approach. This article aims to examine the role of Artificial Intelligence and Learning Analytics in facilitating personalized mathematics learning at various levels of education. Using a Systematic Literature Review method, this article analyzes several studies published in the past five years related to the application of Artificial Intelligence and Learning Analytics in the context of mathematics learning. The results of the study indicate that Artificial Intelligence can provide materials and feedback tailored to students' abilities in real-time, while Learning Analytics allows teachers to monitor and evaluate students' learning progress more accurately and data-driven. The application of these two technologies has been shown to improve students' conceptual understanding, problem-solving skills, and learning motivation. However, challenges such as student dependence on technology, underutilization of feedback, and AI's limitations in addressing students' emotional aspects are important concerns. Therefore, more holistic technology development, adequate teacher training, and ethical policies related to data protection are needed. These findings emphasize the great potential of Artificial Intelligence and Learning Analytics in creating more adaptive, efficient, and meaningful mathematics learning experiences in the digital era.

Keywords: Artificial Intelligence, Learning Analytics, personalized learning, mathematics.

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INTRODUCTION

Rapid technological developments are driving the use of digital technology in various sectors, including education. This digital transformation opens up opportunities to implement more innovative, effective, and modern learning methods (Spaska et al., 2025). In mathematics learning, technology plays a crucial role because it can provide a more personalized and adaptive learning experience tailored to students' needs (Sharma, 2024). Technology allows for the adjustment of the learning process based on individual learning styles, pace, and abilities, enabling students to learn more optimally (Liriwati, 2023). However, mathematics learning still faces various obstacles, such as students' difficulty understanding abstract concepts, low learning interest, and high variation in learning abilities among students (Novianto et al., 2023). Conventional, uniform learning approaches often fail to accommodate

these diverse learning needs (Noprizal et al., 2024). This situation emphasizes the importance of a more personalized, flexible, and adaptive learning approach to improve the effectiveness of mathematics learning.

Various studies have shown that Artificial Intelligence (AI) and Learning Analytics (LA) have significant potential to support personalized learning. LA collects and analyzes student learning activity data to provide in-depth insights into learning patterns, responses to material, and difficulties experienced by students (Romero & Ventura, 2020; Schneider & Blikstein, 2015). Meanwhile, AI supports adaptive learning by providing real-time feedback, personalized material recommendations, and more dynamic learning interactions (Rane, 2024; Awang et al., 2025). In other fields, such as language learning and science, the integration of AI and LA has been shown to improve student progress monitoring and provide timely instructional support (Alshewiter et al., 2024). These studies demonstrate the success of AI and LA implementation in enhancing learning effectiveness. Although research on AI and LA is quite extensive, studies that systematically discuss the application of these two technologies to personalized mathematics learning at the secondary school level are still limited. There is limited literature examining how AI and LA work together to support personalized mathematics learning, as well as the opportunities and challenges of their implementation in school contexts. Therefore, studies that provide a comprehensive overview of research developments in this area are needed. Based on the background outlined above, the main problem in this research relates to how Artificial Intelligence (AI) and Learning Analytics (LA) technologies can be utilized to support personalized mathematics learning at the secondary school level. This research seeks to answer how these two technologies can improve the quality and effectiveness of mathematics learning, why their implementation is crucial for improving learning outcomes and the efficiency of the teaching and learning process, and what strategic steps are needed to optimize the implementation of AI and LA in mathematics learning in the future. In line with this research problem formulation, this research aims to provide a comprehensive understanding of the use of AI and Learning Analytics in personalized mathematics learning in schools. This research seeks to describe how these two technologies can be used to support a more adaptive learning process, analyze the urgency of their implementation in improving learning outcomes and the efficiency of mathematics learning, and identify strategic steps needed to develop optimal implementation of AI and LA in the future. By achieving these objectives, this research is expected to provide a theoretical and practical basis for the development of more relevant and effective learning innovations.

This research is crucial to address the need for innovation in mathematics learning in the digital era, which demands a more adaptive and data-driven approach. This research contributes to a comprehensive mapping of the role of AI and LA in personalized mathematics learning, as well as strategic recommendations that can be used by educators, educational technology developers, and future researchers. Therefore, this research is expected to serve as a basis for developing more effective, innovative, and relevant mathematics learning policies and practices in line with current technological developments.

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LITERATURE REVIEW

Artificial Intelligence (AI) in Learning

Artificial Intelligence is a field of computer science that focuses on developing systems capable of mimicking human cognitive abilities, such as thinking, learning, problem-solving, and decision-making (Chen et al., 2020). In the context of education, AI is used to support the learning process through automation, adaptation, and intelligent analysis of learning data. AI applications in education can include Intelligent Tutoring Systems (ITS), adaptive learning platforms, learning chatbots, automated assessments, and even learning material recommendation systems (Razilu et al., 2025). The primary role of AI in education is to provide a more relevant, responsive, and personalized learning experience. AI can model student knowledge (student modeling), analyze error patterns, and adjust the difficulty level of exercises based on student abilities. Thus, AI enables adaptive and individualized learning according to the needs of each student.

Learning Analytics (LA)

Learning analytics in learning relates to the use of data collected in educational environments to support the learning process (Hershkovitz et al., 2024). The implementation of learning analytics in mathematics learning is one strategy to help teachers gain a deeper understanding of students (Ramli et al., 2019). Learning analytics provides real-time insights into student performance, enabling teachers to provide direct feedback and adjust teaching strategies (Hershkovitz et al., 2024). Through data analysis of learning behavior, work time, interaction patterns, and competency development, learning analytics provides a comprehensive picture of students' strengths and difficulties (Gunn, 2014). Learning analytics serves not only as a monitoring tool but also as a foundation for predicting performance, detecting the risk of learning difficulties, and providing more targeted intervention recommendations. Learning analytics is a crucial component of a technology-based learning ecosystem because it provides the factual information needed by educators and automated systems to produce adaptive and personalized learning (Dinata et al., 2024).

Personalized Learning

Personalized learning is an educational approach that adapts the learning process to the characteristics, needs, abilities, interests, and learning pace of each student (Ayeni et al., 2024). This approach emphasizes that each student differs in understanding concepts, processing information, and completing assignments, so learning experiences must be designed to be more relevant and meaningful. Personalization can be realized through content differentiation, providing adaptive learning paths, providing individual feedback, and developing student learning autonomy (Widodo et al., 2024). In the digital era, personalization is increasingly easy to implement thanks to the support of AI and LA technologies that can analyze student performance in detail and provide timely recommendations.

Mathematics Learning

Mathematics learning is an educational process aimed at developing logical thinking skills, conceptual understanding, reasoning, creativity, and problem-solving skills (Acharya, 2017). It has

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hierarchical characteristics, where mastery of a concept is highly dependent on understanding of previous concepts (Mulyono, 2018). Challenges that often arise in mathematics learning include differences in student abilities, difficulty understanding abstract concepts, low motivation, and gaps in prerequisite skills (Ismaimuza, 2025). Therefore, mathematics learning requires strategies that are adaptive and responsive to individual student needs. A personalized approach is highly relevant to ensure students receive learning experiences that are appropriate to their initial abilities and competency development (Ratau & Bugis, 2024).

METHODS

This study uses a Systematic Literature Review (SLR) design, which aims to identify, assess, and analyze studies related to the application of Artificial Intelligence (AI) and Learning Analytics (LA) in mathematics learning at various levels of education. The primary objective of this SLR is to gain a comprehensive understanding of how AI and LA technologies are used to enhance personalization in mathematics learning and to assess their effectiveness on student learning outcomes at various levels of education.

In this study, the inclusion criteria used to select the literature were as follows: first, only studies published within the last five years were considered, to ensure the literature was relevant to the latest developments in the application of AI and Learning Analytics technologies in mathematics education. Second, only studies focusing on the application of Artificial Intelligence (AI) or Learning Analytics (LA) in the context of mathematics learning at all levels of education, from elementary to higher education, were included. Research involving the application of technology in mathematics education, whether in the form of adaptive learning systems using AI or learning data analysis through Learning Analytics, was considered relevant. Third, the types of research included included experimental studies, quasi-experimental studies, or systematic reviews analyzing the use of AI and LA technologies in mathematics learning. Literature published in English and Indonesian will also be accepted to ensure wider accessibility to relevant research.

Meanwhile, exclusion criteria included literature not focused on education or unrelated to technology in mathematics learning. Research that did not include AI or Learning Analytics, or that focused on other areas of education, was excluded from this review. Furthermore, articles that were not fully accessible, such as those available only in abstract form without access to in-depth research methods and results, were also excluded. Therefore, this study will focus on relevant, up-to-date, and high-quality literature to provide an accurate picture of the application of AI and Learning Analytics in mathematics learning at various levels of education.

The literature search was conducted in several relevant academic databases, such as Google Scholar, Scopus, and Web of Science, using keywords including: AI in Mathematics Education, Learning Analytics in Education, Personalized Learning in Mathematics, AI for Personalized Learning, Learning Analytics for Mathematics Education, Artificial Intelligence in School Mathematics, Mathematics Education and Technology Integration, Data-driven Education in Mathematics, Technology in

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Mathematics Learning, Adaptive Learning Systems in Mathematics, and Educational Technology for Personalization. The search was conducted using filters to limit results to literature published within the last five years and relevant to the topic discussed. Search results are then filtered based on predetermined inclusion and exclusion criteria.

Data obtained from selected studies will be analyzed using qualitative analysis techniques. This analysis aims to evaluate how Artificial Intelligence (AI) and Learning Analytics (LA) are applied in the context of mathematics learning at various levels of education. The analysis process will include identifying important patterns and key findings in the literature, comparing the methods used, and the results achieved by various studies. The primary focus of this analysis is to understand in-depth how these technologies enhance personalized learning and help students overcome difficulties in mathematics learning.

RESULTS

Based on the literature review conducted, several important findings were found regarding the role of Artificial Intelligence (AI) and Learning Analytics (LA) in personalizing mathematics learning in schools as described in the following table:

Table 1. Results of Analysis of Literature

No	Author(s)	Year	Research Findings
1	Felix O. Egara-Mogegeg, Mosimege, Moeketsi Mosia	2024	Students generally show positive perceptions toward the use of ChatGPT in mathematics learning. It helps clarify complex concepts and supports problem-solving through clear explanations and instant feedback. However, some students report concerns about inconsistent responses, accuracy in complex problems, and the risk of overreliance that may reduce independent problem-solving skills.
2	Arnon Hershkovitz, Norbert Noster, Hans-Stefan Siller, Michal Tabach	2023	Learning Analytics was used to analyze students' interactions with instant feedback in a digital reflective symmetry task. Results show that some students did not act on the feedback received (Not Acting Upon Feedback/NAUF). A negative correlation was found between NAUF and task success, indicating that learning outcomes depend on how students utilize feedback. Learning Analytics effectively reveals students' learning processes and engagement in technology-supported mathematics learning.
3	Senad Orhani	2024	Students using AI-based systems performed better in solving mathematics tasks than those in traditional learning. The improvement occurred across all ability levels (basic, intermediate, and advanced). Statistical tests confirmed significant differences. AI also increased students' motivation and engagement through personalized tasks and immediate feedback.
4	Izzat S. Mohd Ramli, Siti M. Maat, Fariza Khalid	2022	Digital Game-Based Learning (GBL) improves students' mathematics achievement. Learning Analytics data—such as login frequency, usage duration, and predictive scores—can also be used to predict students' mathematics performance and evaluate the impact of learning interventions.

5	Janet C. Fairman, Mingyu Feng, Jeremy Roschelle	2025	Teachers who used learning analytics data from the ASSISTments platform shifted from reviewing all practice problems to focusing on the most challenging concepts for students. This data-driven approach resulted in fewer but deeper discussions, more targeted formative feedback, and more effective instructional decisions compared to traditional review practices.
6	M. Taufik Qurohman	2024	AI-based learning significantly improves students' algebra problem-solving ability compared to conventional methods. Students with higher learning independence achieved better results, and a significant interaction was found between AI-based learning and student independence, indicating a positive synergy between technology use and learner autonomy.
7	Kholod Moed-Abu Raya, Shai Olsher	2024	Learning Analytics visualizations significantly improve teachers' formative assessment practices. Teachers can better identify students' strengths and challenges, design more targeted classroom discussions, and provide more precise and timely feedback. Teachers also critically verify analytics data before making instructional decisions.

DISCUSSION

Based on seven reviewed articles, the literature review indicates that Artificial Intelligence (AI) and Learning Analytics (LA) have significant contributions in supporting personalized mathematics learning at the secondary school level. The use of AI, such as adaptive assignment systems and ChatGPT, has been shown to adapt problem types, difficulty levels, and feedback directly to individual student abilities. Egara et al. (2025) found that students have positive perceptions of AI because it aids in understanding mathematical concepts and provides instant feedback. This finding aligns with Orhani (2024) who showed that personalized assignments using AI improve academic performance, engagement, and motivation for students across all ability levels. Further support comes from Qurohman (2024), who showed that AI-based learning significantly improves algebra problem-solving skills, especially for students with high levels of learning independence. Furthermore, Learning Analytics offers the ability to comprehensively map student learning patterns using digital activity data. Hershkovitz et al. (2024) showed that despite the instant availability of digital feedback, students often fail to act on it—a phenomenon known as Not Acting Upon Feedback (NAUF). This suggests that the effectiveness of feedback depends not only on the system but also on students' ability to respond to the information.

Fairman et al. (2025) added that teachers who utilize LA data can improve the quality of instruction through more targeted analysis of student difficulties. Similar findings were reported by Moed-Abu Raya and Olsher (2024), who found that LA visualizations strengthened mathematics teachers' formative assessment practices, increased feedback accuracy, and helped teachers design learning activities that better targeted student weaknesses. The combination of AI and LA demonstrates synergistic potential in supporting data-driven mathematics learning. Ramli et al. (2022) demonstrated that Learning Analytics combined with game-based learning (GBL) can predict students' mathematics performance based on digital interaction data such as application usage duration and login frequency.

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This data enables the system and teachers to provide more precise learning interventions. Thus, the integration of AI and LA can create a learning environment that is more adaptive, personalized, and responsive to students' needs.

Utilizing AI and LA to Realize Personalized Mathematics Learning

The synthesis of seven analyzed articles shows that Artificial Intelligence (AI) and Learning Analytics (LA) make significant contributions to the personalization of mathematics learning at the secondary school level. AI is primarily utilized to create adaptive learning environments, where the system can change the difficulty level of questions, learning paths, and supporting materials based on individual student abilities. Features such as adaptive tutoring systems, intelligent feedback, and automated problem generation enable students to gain a learning experience more tailored to their individual needs and learning pace. AI systems are also capable of detecting errors in student thinking patterns and providing immediate recommendations for improvement, thereby improving the quality of independent learning. Furthermore, LA is utilized to collect, analyze, and interpret data on students' learning processes, such as task completion time, interaction with digital platforms, error rates, and responses to feedback. From this analysis, teachers can identify specific weaknesses experienced by students, map learning profiles, and adjust teaching strategies based on actual data. LA enables learning to be more evidence-based, so that pedagogical decisions no longer rely solely on teacher intuition, but are also supported by comprehensive data that reflects students' real needs. In general, the combination of AI and LA creates an adaptive, responsive, and differentiated mathematics learning ecosystem, so that each student can receive learning support according to their individual profile.

The Urgency of Implementing AI and LA in Improving the Effectiveness of Mathematics Learning

The application of these two technologies is crucial because mathematics learning at the secondary school level still faces various challenges, such as low student motivation, mismatched material with individual abilities, and difficulty understanding abstract concepts. AI helps overcome the limitations of conventional methods by providing real-time feedback and more interactive visualizations. This results in increased student engagement, conceptual understanding, and reasoning skills. Meanwhile, artificial intelligence (LA) plays a crucial role in improving the efficiency of the teaching and learning process. Teachers often struggle to monitor the progress of all students simultaneously; through AI, the monitoring process becomes faster and more accurate. Learning data enables teachers to provide more personalized and targeted interventions and design differentiated learning strategies more efficiently. Thus, the application of AI and LA serves not only as a teaching aid but also as a mechanism for systematically and continuously improving the quality of mathematics learning. This urgency is increasing in line with the demands of 21st-century education, where personalization, digital literacy, and adaptive learning are core competencies that students must master to compete in the technological era.

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Strategic Steps to Optimize AI and LA Implementation in the Future

To optimize the implementation of Artificial Intelligence (AI) and Learning Analytics (LA) in mathematics learning at the secondary school level, a number of comprehensive and sustainable strategic steps are required. The first step is to improve teachers' digital literacy and pedagogical competence so they can operate AI and LA technologies effectively, interpret analytical data, and integrate them with classroom learning strategies. Furthermore, these technologies must be aligned with appropriate pedagogical approaches, such as inquiry-based learning, flipped learning, or mastery learning, so that the use of AI and LA is not only technical but also strengthens the learning process conceptually. Furthermore, curriculum adjustments are needed to support the use of adaptive technology and data-driven assessments, so that personalized learning can be applied systematically and purposefully. Implementing the technology also requires adequate infrastructure, particularly digital devices, internet connections, and secure data management systems to protect student information. Finally, collaboration between schools, researchers, and technology developers is crucial to ensure that the AI and LA platforms used are aligned with the characteristics of the mathematics curriculum and the needs of students in Indonesia. Through these steps, the use of AI and LA can be optimized and have a sustainable positive impact on the quality of mathematics learning.

CONCLUSIONS

The literature review indicates that the use of **Artificial Intelligence (AI)** and **Learning Analytics (LA)** has significant potential to support personalized mathematics learning at the secondary school level. AI enables adaptive learning experiences by providing explanations, instant feedback, and tasks tailored to students' individual abilities, thereby improving conceptual understanding, motivation, and learning autonomy. Meanwhile, LA allows teachers to monitor student progress in real time, identify common errors, and implement more targeted instructional interventions based on data. The integration of these technologies can create a more effective, efficient, and responsive learning process that aligns with students' needs. Future research should examine the integration of AI and LA within national curriculum contexts and explore their impact on students' affective and metacognitive development, which remains underexplored in previous studies. From a policy perspective, institutional support is essential, including the provision of digital infrastructure, secure data management systems, and continuous professional development for teachers to effectively utilize these technologies. In practice, teachers should integrate AI and LA with appropriate pedagogical approaches while maintaining the importance of human interaction in the learning process. Strengthening data literacy for both teachers and students is also crucial to maximize the benefits of these technologies. Through collaboration among schools, policymakers, and technology developers, AI and LA have the potential to become key drivers in creating more personalized, adaptive, and meaningful mathematics learning for secondary school students.

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