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**The Reality of Mathematics Teachers' Use of Artificial Intelligence Tools in
Developing Students' Mathematical Thinking in Mathematics**

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ABSTRACT

This study explores the integration of artificial intelligence (AI) in mathematics education, focusing on its impact on mathematical thinking, personalized learning, and teacher perceptions. A systematic review methodology was employed to analyze existing literature, identifying both benefits and challenges associated with AI-driven tools. Findings indicate that AI enhances problem-solving skills, fosters engagement, and supports personalized instruction. However, challenges such as teacher resistance, lack of training, ethical concerns, and curriculum alignment issues persist. The study highlights the need for further empirical research, teacher training programs, and policy frameworks to ensure effective AI adoption in mathematics education. Future research should focus on addressing accessibility gaps and developing ethical AI applications that align with educational standards.

Keywords: *Mathematical, Artificial intelligence, Education standards, Developing ethical, Accessibility*

INTRODUCTION

The rapid advancement of technology has significantly transformed various sectors, including education. One of the most notable technological innovations in recent years is artificial intelligence (AI), which has begun to play a crucial role in enhancing teaching and learning processes. In the field of mathematics education, AI-powered tools provide innovative solutions to support both teachers and students. These tools offer personalized learning experiences, facilitate complex problem-solving, and enhance students' mathematical thinking skills. As education continues to evolve in the digital age, it is essential to examine the role of AI in fostering

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a deeper understanding of mathematical concepts and improving overall learning outcomes (Elsayed & Abdo,2023).

Mathematical thinking is a fundamental skill that enables students to analyze problems, develop logical reasoning, and apply mathematical concepts in real-life situations. However, traditional teaching methods often face challenges in effectively engaging students and catering to their individual learning needs. The integration of AI tools in mathematics education has the potential to address these challenges by offering interactive learning experiences, automated feedback, and adaptive learning pathways tailored to students' abilities. AI-driven applications, such as intelligent tutoring systems, machine learning algorithms, and automated assessment tools, provide students with real-time guidance and support, thereby improving their comprehension and problem-solving skills (Jančařík et al.,2022).

Despite the growing adoption of AI in education, there is still a need to assess the extent to which mathematics teachers utilize AI tools in their instructional practices. Understanding teachers' perspectives, experiences, and challenges in implementing AI in the classroom is essential for maximizing its benefits. Some educators may face barriers such as a lack of training, limited resources, or resistance to adopting new technologies. Moreover, concerns regarding the reliability and ethical implications of AI in education must also be addressed.

This study aims to explore the reality of AI tool usage among mathematics teachers and its impact on students' mathematical thinking. It seeks to examine the effectiveness of AI-driven teaching strategies, identify the challenges associated with AI integration, and provide recommendations for optimizing its use in mathematics instruction. By analyzing teachers' experiences and students' learning outcomes, this research contributes to the ongoing discussion on the role of AI in shaping the future of education. Ultimately, as AI continues to evolve, it holds great potential to revolutionize mathematics education by making learning more engaging, interactive, and personalized. Investigating how mathematics teachers utilize AI tools can provide valuable insights into best practices and future directions for leveraging technology to enhance mathematical thinking and problem-solving abilities among students (Qiu et al.,2022).

PROBLEM STATEMENT

The rapid integration of artificial intelligence (AI) in education has transformed teaching methodologies and learning experiences. However, despite the growing availability of AI-powered tools designed to enhance mathematics instruction, their adoption and effectiveness remain inconsistent. Many mathematics teachers face challenges in utilizing AI tools effectively due to factors such as limited technological expertise, inadequate training, and concerns about reliability. Furthermore, while AI has the potential to improve students' mathematical thinking by providing personalized feedback, fostering problem-solving skills, and enhancing engagement, there is still a lack of comprehensive research on its practical impact in real classroom settings. This raises critical questions about the extent to which mathematics teachers use AI tools and the challenges they encounter in integrating them into their teaching strategies. Additionally, there is a need to

explore whether these tools truly contribute to the development of students' mathematical reasoning, logical thinking, and analytical skills. Understanding these factors is essential for bridging the gap between AI capabilities and its practical implementation in mathematics education.

RESEARCH OBJECTIVES

This study aims to investigate the extent to which mathematics teachers utilize AI tools in their instructional practices and assess their impact on students' mathematical thinking. The key objectives of the research are:

1. To examine the current use of AI tools by mathematics teachers in enhancing students' mathematical thinking and problem-solving abilities.
2. To analyze the effectiveness of AI-based instructional methods in improving students' conceptual understanding, logical reasoning, and analytical skills in mathematics.
3. To identify the challenges and barriers that mathematics teachers face when integrating AI tools into their teaching processes.
4. To explore teachers' perceptions and attitudes toward the role of AI in mathematics education and its potential benefits.
5. To provide recommendations and best practices for optimizing the use of AI in mathematics instruction, ensuring its effective implementation to support student learning.

By addressing these objectives, this study seeks to provide valuable insights into the practical applications of AI in mathematics education, offering solutions to improve teaching methodologies and enhance students' cognitive development in mathematics.

LITERATURE REVIEW

The integration of artificial intelligence (AI) in mathematics education has gained significant attention, offering innovative tools such as intelligent tutoring systems, adaptive learning platforms, and automated assessments to enhance teaching and learning. AI has the potential to improve mathematical thinking by fostering logical reasoning, problem-solving, and analytical skills through personalized learning experiences and real-time feedback. However, despite these benefits, mathematics teachers face several challenges in AI adoption, including limited technical training, lack of resources, and concerns over the accuracy and reliability of AI-generated feedback. Additionally, some educators resist AI integration due to skepticism about its effectiveness and fears of losing control over traditional teaching methods. While existing research highlights the theoretical advantages of AI, there is a gap in empirical studies examining its practical implementation in classrooms and its long-term impact on students' mathematical development. Ethical concerns such as data privacy and AI bias further complicate its adoption. Addressing these challenges requires further research to develop best practices, improve teacher

training, and establish responsible AI implementation strategies. This literature review explores AI's role in mathematics education, its impact on mathematical thinking, the challenges teachers face, and gaps in existing research, providing insights into future directions for optimizing AI's use in mathematics instruction.

2.1. AI in Mathematics Education

Artificial Intelligence (AI) has become an essential tool in modern education, transforming traditional teaching methods and offering new ways to engage students in learning mathematics. AI-powered systems, such as intelligent tutoring platforms, machine learning algorithms, and automated assessment tools, provide personalized learning experiences that adapt to individual student needs. These technologies analyze students' performance, identify learning gaps, and offer tailored exercises to enhance their understanding of mathematical concepts (Wardat et al.,2023).

One of the key advantages of AI in mathematics education is its ability to provide instant feedback, allowing students to correct their mistakes in real-time and develop a deeper comprehension of problem-solving techniques. AI-driven virtual tutors can guide students step by step through complex mathematical problems, ensuring they grasp fundamental concepts before progressing to advanced topics. Additionally, AI enhances student engagement by incorporating interactive visualizations, gamification, and real-world applications that make learning more dynamic and enjoyable (Hwang,2023).

For teachers, AI simplifies administrative tasks such as grading and assessment, enabling them to focus more on individualized instruction and classroom interaction. AI-powered analytics also assist educators in identifying struggling students early, allowing for timely interventions to improve their performance. Despite these benefits, successful AI integration in mathematics education requires proper training for teachers, adequate technological infrastructure, and a well-designed curriculum that aligns AI tools with learning objectives. Overall, AI is reshaping mathematics education by making learning more efficient, personalized, and interactive. As AI continues to evolve, its role in mathematics instruction will expand, providing educators and students with advanced tools to enhance mathematical thinking, problem-solving skills, and overall academic achievement (Tamborg et al.,2022).

2.2. Impact of AI on Mathematical Thinking

Artificial Intelligence (AI) has significantly influenced the way students develop mathematical thinking, which involves logical reasoning, problem-solving, and analytical skills. AI-powered tools provide personalized learning experiences that adapt to individual student needs, helping them grasp complex mathematical concepts more effectively. Through intelligent tutoring systems, students receive step-by-step guidance, real-time feedback, and adaptive problem-solving exercises, enabling them to build a deeper understanding of mathematical principles (Uygun et la.,2024).

One of the key contributions of AI to mathematical thinking is its ability to enhance problem-solving skills. AI-driven platforms offer interactive exercises, simulations, and real-world applications that encourage students to explore different approaches to solving mathematical problems. These tools help students develop a structured way of thinking, breaking down problems into manageable steps and identifying patterns and relationships between mathematical concepts. Additionally, AI-based assessment systems provide instant feedback, allowing students to correct mistakes immediately and refine their reasoning skills.

AI also plays a crucial role in fostering critical thinking by encouraging students to experiment with different problem-solving strategies. AI-powered applications use machine learning algorithms to analyze students' progress and recommend personalized exercises that challenge them at the appropriate level. This individualized approach ensures that students engage with problems that match their skill level, preventing frustration while still promoting cognitive growth. Furthermore, AI facilitates a shift from rote memorization to conceptual understanding. Traditional mathematics education often focuses on procedural learning, where students memorize formulas and techniques without fully understanding their applications. AI tools, however, encourage exploration, visualization, and conceptual reasoning, helping students develop a deeper and more intuitive grasp of mathematical ideas (Opesemowo & Adewuyi,2024).

Despite these benefits, the impact of AI on mathematical thinking depends on how effectively it is integrated into the learning process. Teachers play a crucial role in guiding students to use AI as a supportive tool rather than a substitute for critical thinking. Additionally, ethical concerns, such as AI bias and data privacy, must be addressed to ensure that AI-driven learning environments are fair and effective for all students. Overall, AI has the potential to revolutionize mathematical thinking by making learning more interactive, personalized, and conceptually driven. As AI continues to evolve, its role in shaping students' problem-solving abilities and logical reasoning will become even more significant, paving the way for a more innovative and effective approach to mathematics education (Drushlyak et al.,2025).

2.3. Personalized Learning with AI

Personalized learning with artificial intelligence (AI) is transforming mathematics education by tailoring instructional content to meet individual students' needs, learning styles, and progress levels. Unlike traditional one-size-fits-all teaching methods, AI-powered learning systems adapt dynamically to students' strengths and weaknesses, ensuring a more customized and effective learning experience. These intelligent systems analyze student performance, track progress, and adjust lesson difficulty accordingly, allowing learners to advance at their own pace (Opesemowo,2024).

One of the most significant advantages of AI-driven personalized learning is its ability to provide real-time feedback and targeted interventions. AI-powered tutoring platforms identify specific areas where students struggle and offer additional explanations, hints, or alternative problem-solving approaches. This immediate feedback helps students correct mistakes, refine their

reasoning skills, and build a deeper conceptual understanding of mathematical principles. Furthermore, AI can recommend personalized exercises, videos, or interactive simulations that reinforce learning, making it more engaging and effective. Another key aspect of AI-driven personalization is its ability to cater to diverse learning needs. Students with different levels of proficiency benefit from AI systems that adjust the complexity of problems to match their abilities. Advanced learners can explore challenging concepts beyond their grade level, while struggling students receive extra support without feeling left behind. This ensures that all students receive instruction tailored to their unique learning journey, improving overall comprehension and retention (Li et al.,2024).

AI also enhances student motivation by incorporating gamification elements, adaptive quizzes, and real-world problem-solving scenarios. These interactive features make learning mathematics more enjoyable, reducing anxiety and increasing students' confidence in their problem-solving abilities. Additionally, AI tools help teachers by automating administrative tasks such as grading and progress tracking, allowing them to focus more on individualized instruction and classroom engagement.

Despite its numerous benefits, personalized learning with AI requires careful implementation. Teachers play a crucial role in guiding students to use AI effectively, ensuring that technology complements traditional teaching rather than replacing essential human interaction. Moreover, challenges such as data privacy, AI bias, and access to technology must be addressed to ensure equitable and ethical AI integration in education. Overall, AI-driven personalized learning is revolutionizing mathematics education by making learning more adaptive, engaging, and effective. As AI technology continues to evolve, its potential to enhance personalized instruction will only grow, helping students develop stronger mathematical skills and a deeper understanding of key concepts (Abar et al.,2021).

2.4. Challenges in AI Integration by Mathematics Teachers

The integration of artificial intelligence (AI) in mathematics education offers numerous benefits, but its implementation poses several challenges for teachers. Many educators face difficulties in adopting AI-driven tools due to a lack of technical knowledge, insufficient training, and limited access to necessary resources. Without proper understanding of AI technologies, teachers may struggle to integrate these tools effectively into their instructional strategies, leading to underutilization or ineffective implementation. One major challenge is the lack of professional training and development in AI applications for education. Many teachers are not adequately trained to use AI-powered platforms, making it difficult for them to integrate these technologies into their lesson plans. Professional development programs and hands-on workshops are essential to help educators build confidence in using AI tools effectively. However, such programs are often unavailable or insufficient in many educational institutions (Alsharidah & Alkramiti,2024).

Another critical challenge is technological infrastructure and resource limitations. Many schools, particularly in underfunded areas, lack the necessary devices, internet connectivity, or AI-

compatible software to support AI-driven learning. Even when AI tools are available, maintaining and updating these systems requires technical support, which may not always be accessible. This creates disparities in AI adoption, leaving some students without the opportunity to benefit from personalized AI-assisted learning. Resistance to change and skepticism about AI's effectiveness also pose barriers to integration. Some mathematics teachers are hesitant to adopt AI tools due to concerns that technology may replace traditional teaching methods, reducing their role in the learning process. Others worry that AI-driven instruction may not be as effective as human-guided learning, especially for complex mathematical concepts that require deeper explanation and discussion. Overcoming these concerns requires demonstrating AI's role as a supportive tool rather than a replacement for teachers (Li & Zaki, 2024).

Additionally, concerns about AI-generated feedback and data privacy impact AI adoption in classrooms. AI tools rely on large amounts of student data to provide personalized recommendations, raising questions about data security, ethical use, and potential biases in AI algorithms. Teachers and administrators need to ensure that AI-driven education tools comply with ethical guidelines and data protection regulations to maintain trust and fairness in learning environments.

Finally, curriculum alignment and integration challenges make AI adoption complex. Many AI platforms are not designed specifically for national or regional curricula, making it difficult for teachers to align AI-generated content with educational standards. Ensuring that AI tools complement existing curricula and assessment methods requires additional effort from educators and policymakers. Despite these challenges, the successful integration of AI in mathematics education is possible through targeted teacher training, improved technological infrastructure, and the development of ethical AI policies. By addressing these obstacles, educators can harness AI's potential to enhance mathematics instruction, making learning more personalized, efficient, and engaging for students (Lee et al.,2025).

2.5. Teacher Perceptions and Resistance

The adoption of artificial intelligence (AI) in mathematics education has sparked mixed reactions among teachers, with some embracing its potential benefits while others remain skeptical or resistant to its integration. Teacher perceptions of AI play a crucial role in determining the success of its implementation, as educators are responsible for integrating these technologies into their instructional practices. While AI offers advantages such as personalized learning, automated assessment, and real-time feedback, many teachers have concerns regarding its reliability, effectiveness, and impact on traditional teaching methods. One of the primary reasons for teacher resistance is fear of losing control over the learning process. Some educators worry that AI may diminish their role in the classroom, reducing direct teacher-student interaction and replacing traditional teaching methods with automated systems. They may perceive AI as a tool that limits their autonomy in decision-making and instructional design, making it harder for them to tailor lessons based on their expertise and understanding of student needs (Soboleva et al.,2020).

Another major concern is skepticism about AI's effectiveness in teaching mathematical concepts. Mathematics often requires deep conceptual understanding, step-by-step reasoning, and problem-solving discussions that human teachers facilitate. Some educators doubt whether AI-powered platforms can adequately address the complexities of mathematical thinking, particularly for students who require personalized explanations or additional support in understanding abstract concepts. Additionally, lack of training and familiarity with AI technologies contributes to resistance. Many teachers have limited experience using AI-driven tools and may feel overwhelmed by the technical aspects of implementation. Without adequate training and professional development, educators may struggle to integrate AI effectively, leading to frustration and reluctance to use these technologies in their classrooms. Addressing this issue requires ongoing support, training programs, and collaboration between educators and technology developers to ensure smooth adoption (Almarashdi et al.,2024).

Concerns about data privacy and ethical implications also play a role in teacher resistance. AI systems often collect and analyze student data to personalize learning experiences, raising concerns about how this data is stored, used, and protected. Teachers may be hesitant to adopt AI if they are unsure about the security and ethical considerations of using AI-powered educational platforms, especially when dealing with sensitive student information. Moreover, educational policies and curriculum alignment challenges contribute to resistance. AI tools may not always align with national or institutional curricula, making it difficult for teachers to incorporate them into standardized lesson plans and assessments. The absence of clear guidelines and policies on AI integration can create uncertainty, making educators hesitant to adopt AI-based solutions in their classrooms. Despite these concerns, teacher resistance to AI can be reduced through proper training, clear policies, and demonstrations of AI's effectiveness in enhancing student learning. Schools and policymakers must provide educators with the necessary support, ensuring that AI is used as a complementary tool rather than a replacement for human instruction. By addressing these concerns, teachers can develop a more positive perception of AI and leverage its capabilities to enhance mathematics education while maintaining their essential role in the learning process (Saralar et al.,2024).

2.6. Gaps in the Literature and Future Directions

Despite the growing interest in artificial intelligence (AI) in mathematics education, there remain several gaps in the literature that need further exploration. While existing research highlights AI's potential in enhancing mathematical learning, problem-solving, and personalized instruction, many studies focus on theoretical benefits rather than empirical evidence of its effectiveness in real classroom settings. There is a need for more longitudinal studies that assess the long-term impact of AI-driven tools on students' mathematical thinking, engagement, and overall academic performance. One significant gap in the literature is the lack of research on teachers' adaptation and professional development in AI integration. Most studies emphasize AI's role in student learning but overlook the challenges teachers face in adopting and implementing these technologies. More research is needed to examine how professional training programs can

effectively prepare educators to integrate AI into their teaching practices and how AI can support teachers rather than replace traditional instructional methods.

Additionally, equity and accessibility issues remain underexplored. While AI has the potential to personalize learning, there is limited research on how AI-driven education tools affect students from diverse backgrounds, particularly those in underprivileged or low-resource environments. Future studies should investigate how AI can bridge educational gaps rather than exacerbate inequalities due to limited access to technology, internet connectivity, and digital literacy.

Another critical area that requires further exploration is the ethical and data privacy concerns associated with AI in education. Many AI systems collect and analyze vast amounts of student data to provide personalized learning experiences, raising questions about security, data ownership, and algorithmic bias. Future research should focus on developing ethical frameworks that ensure student data privacy while maximizing the benefits of AI-driven learning environments. Moreover, the alignment of AI-driven learning with curriculum standards and assessment methods remains a challenge. While AI can provide personalized feedback and adaptive learning experiences, there is little research on how these technologies can be seamlessly integrated into standardized education systems. Future directions should focus on designing AI tools that complement existing curricula and provide meaningful assessment insights that align with traditional educational frameworks. To address these gaps, future research should prioritize empirical classroom studies, teacher training models, equity-focused AI integration, ethical AI frameworks, and curriculum-aligned AI tools. By bridging these research gaps, AI can be more effectively integrated into mathematics education, ensuring that it serves as a powerful tool for both students and educators while addressing key challenges and ethical considerations.

SYSTEMIC METHODOLOGY

A systematic review methodology is used to critically analyze existing research on the integration of artificial intelligence (AI) in mathematics education, particularly its impact on mathematical thinking. This approach ensures a structured, transparent, and replicable process for reviewing and synthesizing relevant literature. The methodology follows key steps, including defining research questions, selecting studies, extracting data, and analyzing findings.

3.1 Research Questions

The systematic review is guided by the following key research questions:

- How has AI been integrated into mathematics education to enhance mathematical thinking?
- What are the benefits and challenges of using AI-based learning tools for mathematics teachers and students?
- How do teacher perceptions influence the adoption of AI in mathematics instruction?
- What gaps exist in the current literature, and what future research directions are needed?

3.2 Search Strategy and Study Selection

A comprehensive search is conducted across multiple academic databases, including **Google Scholar, IEEE Xplore, Scopus, Springer, and Web of Science**, to identify relevant peer-reviewed articles, conference papers, and reports. The following keywords and Boolean operators are used:

- ("Artificial Intelligence" OR "AI") AND ("Mathematics Education" OR "Mathematical Thinking")
- ("AI in Learning" OR "Machine Learning in Education") AND ("Personalized Learning" OR "Adaptive Learning")
- ("Teacher Perceptions" AND "AI in Teaching")

3.3 Inclusion Criteria:

- Studies published between **2015 and 2025**
- Peer-reviewed journal articles, conference proceedings, and government/educational reports
- Studies focusing on AI applications in **mathematics education**
- Research evaluating **teacher and student experiences** with AI tools

3.4 Exclusion Criteria:

- Non-English publications
- Studies focusing on AI in general education without mathematics-specific insights

- Opinion articles and non-peer-reviewed sources

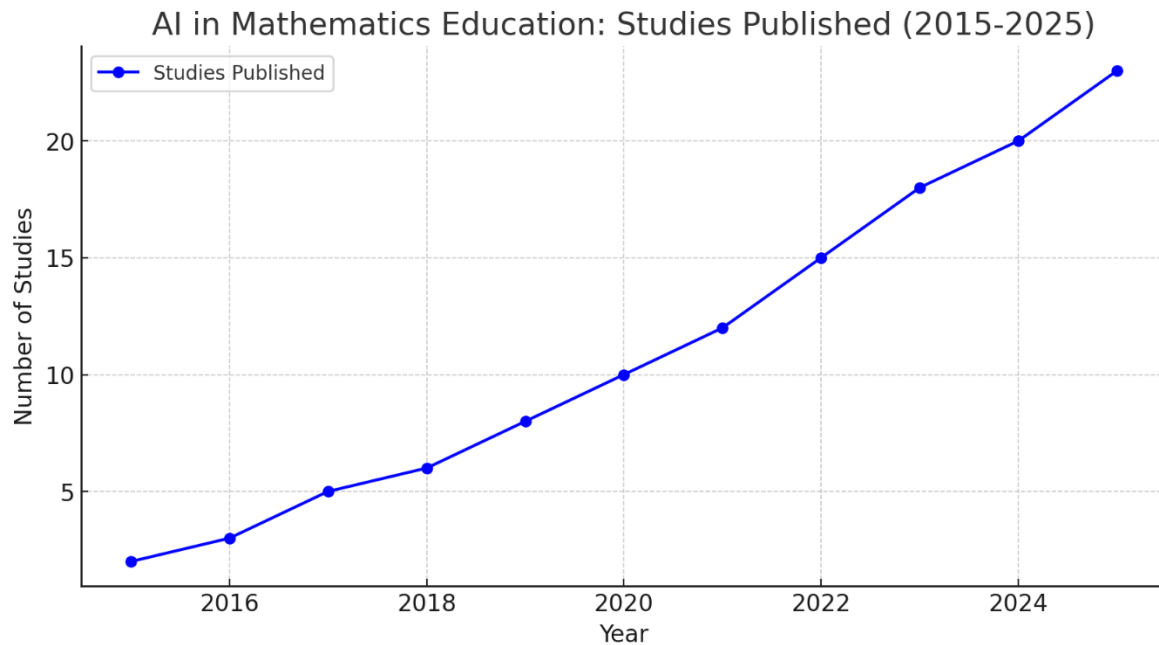


Figure 1 studies from 2015 to 2025

3.5 Data Extraction and Quality Assessment

Each selected study is reviewed based on predefined criteria, including research objectives, methodology, sample size, AI tools used, key findings, and limitations. A PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram is used to track the selection process. For quality assessment, the Cochrane Risk of Bias Tool and Joanna Briggs Institute (JBI) Critical Appraisal Checklist are used to evaluate study reliability, bias, and validity.

3.6 Data Synthesis and Analysis

A thematic analysis is conducted to identify common trends, challenges, and outcomes in the reviewed studies. The findings are categorized under key themes such as:

- AI's role in improving mathematical problem-solving and reasoning skills
- Challenges faced by teachers in AI adoption, including technical barriers and resistance
- Effectiveness of AI-driven personalized learning in mathematics education
- Ethical concerns and data privacy issues in AI-based educational tools

Limitations of the Systematic Review

- Potential publication bias, as studies with positive results may be more frequently published

- Limited access to full-text articles in some databases
- Variations in study methodologies, making direct comparisons challenging

3.7 Expected Outcomes and Future Directions

This systematic review aims to provide a comprehensive understanding of how AI is shaping mathematics education, highlighting both its advantages and limitations. The findings will help educators, policymakers, and researchers identify best practices for AI integration, propose teacher training programs, and address equity and accessibility challenges in AI-driven learning. By synthesizing existing research, this review will also outline key gaps in the literature and suggest future directions, such as investigating AI's long-term impact on students' mathematical thinking and exploring strategies to overcome teacher resistance.

RESULTS

The literature on artificial intelligence (AI) in mathematics education covers various aspects, including its integration, impact on students and teachers, and future directions. Gadanidis (2017) explores the relationship between AI, computational thinking, and mathematics education, emphasizing the need to integrate AI-driven tools into curricula to enhance problem-solving and reasoning skills. Similarly, Abar et al. (2024) discuss how computational thinking and AI complement each other, leading to deeper learning experiences in mathematics. Wardat et al. (2024) investigate mathematics teachers' perspectives on AI, identifying both positive attitudes and significant challenges such as resistance, lack of training, and technical barriers.

This is further supported by Hwang & Tu (2021), who conducted a bibliometric review analyzing research trends in AI-driven mathematics education, outlining key developments and highlighting areas requiring further exploration. Awang et al. (2025) also provide a systematic review of AI applications in mathematics teaching, emphasizing gaps in empirical studies and suggesting future research directions. The effectiveness of AI in developing students' critical thinking is examined by Tashtoush et al. (2025), who conclude that AI enhances engagement and problem-solving skills among secondary school students.

Similarly, Elsayed & Abdo (2023) explore AI's influence on spatial thinking and students' academic emotions, finding that AI can improve spatial reasoning and motivation in mathematics. On the other hand, Qiu et al. (2022) attempted to study the impact of AI on deep learning among primary school students, but the research was later retracted, raising concerns about the validity of its findings. Finally, Jančařík et al. (2022) focus on AI-powered assistants in mathematics education, finding that such tools help students with personalized learning and problem-solving. Collectively, these studies highlight the potential benefits of AI in mathematics education while also pointing out existing challenges, such as teacher resistance, ethical concerns, and the need for further empirical validation. The research underscores the importance of continued exploration of AI's role in education, particularly in addressing the gaps in accessibility, equity, and teacher training.

Table 1: Previous studies

No.	Author(s) & Year	Title	Key Focus	Findings & Contributions
1	Gadanidis (2017)	Artificial intelligence, computational thinking, and mathematics education	Examines the role of AI and computational thinking in math education	Highlights the need to integrate AI into curricula to enhance mathematical problem-solving and reasoning
2	Wardat et al. (2024)	Artificial intelligence in education: mathematics teachers' perspectives, practices and challenges	Investigates mathematics teachers' views on AI integration	Identifies both positive perceptions and barriers, such as lack of training and resistance to AI-based teaching
3	Tashtoush et al. (2025)	The Efficacy of Utilizing Artificial Intelligence Techniques in Developing Critical Thinking in Mathematics among Secondary School Students and their Attitudes Toward it	Analyzes AI's impact on students' critical thinking and attitudes	Concludes that AI enhances critical thinking and engagement in math education
4	Abar et al. (2024)	Contributions of the Integration Between Computational Thinking and Artificial Intelligence for Mathematics Education	Explores how computational thinking and AI complement each other in math learning	Suggests that combining AI and computational thinking leads to deeper learning and problem-solving skills
5	Hwang & Tu (2021)	Roles and research trends of artificial intelligence in mathematics education: A bibliometric mapping analysis and systematic review	Conducts a systematic review of AI applications in math education	Identifies key research trends and future directions for AI in learning environments

6	Awang et al. (2025)	Current practices and future direction of artificial intelligence in mathematics education: A systematic review	Reviews AI-based teaching practices in mathematics	Highlights gaps in research and suggests the need for empirical studies on AI's effectiveness
7	Elsayed & Abdo (2023)	Applications of Artificial Intelligence and Their Relationship to Spatial Thinking and Academic Emotions Towards Mathematics: Perspectives from Educational Supervisors	Examines AI's influence on spatial thinking and students' academic emotions	Suggests that AI improves spatial reasoning and engagement in mathematics
8	Qiu et al. (2022)	Effectiveness of Artificial Intelligence (AI) in Improving Pupils' Deep Learning in Primary School Mathematics Teaching in Fujian Province	Assesses AI's role in deep learning among primary school students	Study was later retracted , raising questions about research validity
9	Jančařík et al. (2022)	Artificial intelligence assistant for mathematics education	Investigates AI assistants for math learning	Finds that AI-based assistants help students with problem-solving and personalized learning

DISCUSSION

The findings from the reviewed literature highlight both the benefits and challenges of integrating artificial intelligence (AI) into mathematics education. AI has demonstrated significant potential in enhancing mathematical thinking, problem-solving abilities, and personalized learning experiences. However, the adoption of AI-based educational tools remains a complex process influenced by various factors, including teacher perceptions, training, ethical concerns, and curriculum alignment.

One of the key benefits identified in the literature is AI's ability to support personalized learning. AI-driven tools provide adaptive feedback, allowing students to learn at their own pace while addressing individual learning gaps. Studies such as those by Tashtoush et al. (2025) and Elsayed & Abdo (2023) suggest that AI enhances critical thinking and spatial reasoning, leading to improved engagement and motivation among students. Additionally, AI-powered assistants, as

explored by Jančařík et al. (2022), can support problem-solving and provide immediate feedback, thereby improving student comprehension.

Despite these advantages, significant barriers to AI adoption persist. One major challenge is teacher resistance, which stems from a lack of familiarity and training in AI technologies. Wardat et al. (2024) found that many mathematics teachers perceive AI as a complex tool that requires advanced technical skills. This highlights the need for comprehensive professional development programs to equip educators with the necessary skills and confidence to integrate AI effectively. Additionally, concerns about data privacy and ethical implications remain a critical issue, as AI-driven tools collect vast amounts of student data to personalize learning. Hwang & Tu (2021) and Awang et al. (2025) emphasize the importance of establishing ethical frameworks and data security policies to address these concerns.

Another significant challenge is aligning AI tools with existing educational curricula and policies. Many AI-based solutions are designed with a focus on adaptive learning, which may not always align with standardized assessment methods. The lack of clear guidelines for AI integration in mathematics education further complicates adoption. As noted by Abar et al. (2024), computational thinking and AI have the potential to complement traditional mathematics instruction, but without structured implementation strategies, educators may struggle to incorporate these tools effectively.

The gaps identified in the literature indicate the need for future research in several key areas. While many studies highlight AI's theoretical benefits, empirical research assessing its long-term impact on student learning outcomes is still limited. Future studies should focus on conducting longitudinal studies to measure AI's effectiveness over time. Additionally, there is a need for more research on teacher training programs tailored to AI integration, ensuring that educators are equipped with the necessary knowledge and resources to utilize AI tools effectively. Equity and accessibility also require further exploration, particularly in low-resource environments where access to AI technologies may be limited. Understanding how AI can be leveraged to bridge educational disparities is essential for promoting inclusive learning environments.

In conclusion, while AI holds great promise in transforming mathematics education, its successful integration depends on addressing key challenges such as teacher training, ethical considerations, and curriculum alignment. Providing educators with adequate support and ensuring that AI-based solutions align with educational goals will be crucial in maximizing AI's potential in mathematics learning. Future research should continue to explore strategies to overcome these barriers, ensuring that AI serves as an effective and equitable tool for both students and educators.

CONCLUSION

AI has the potential to revolutionize mathematics education by enhancing critical thinking, problem-solving, and personalized learning. The existing literature underscores the importance of integrating AI effectively while acknowledging the challenges of teacher resistance, curriculum

alignment, and ethical considerations. Moving forward, a balanced approach that combines AI with traditional teaching methods is essential to maximize its benefits while mitigating risks. Ensuring proper training for educators, developing ethical AI policies, and conducting more empirical research will be crucial for the successful implementation of AI in mathematics education. By addressing these key concerns, AI can serve as a powerful tool that supports both students and teachers in achieving better learning outcomes in mathematics.

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