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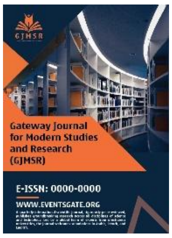

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A Narrative Review of Student-Centered, Data-Driven Approaches for Improving Success in Mathematics Education

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Abstract: Recent international evidence indicates that mathematics achievement remains a challenge across educational settings. At the K–12 level, many students experience low mathematical proficiency and confidence, while higher education institutions continue to face challenges related to student engagement, retention, and academic performance in mathematics. This narrative review examines peer-reviewed studies published between 2020 and 2026 on student-centered learning and the use of artificial intelligence (AI) in mathematics education. Relevant studies were identified through searches of IEEE Xplore, SpringerLink, MDPI, Crossref-indexed journals, and other open-access academic journals, while OECD (PISA 2022) and UNESCO reports were consulted to provide global context. The search used combinations of keywords related to student-centered learning, artificial intelligence, mathematics education, learning analytics, formative assessment, personalized learning, student engagement, and learning outcomes. Only English-language, peer-reviewed studies directly related to mathematics education were included. A total of 15 peer-reviewed studies employing quantitative, qualitative, and mixed-methods designs were analyzed using a thematic synthesis approach, while two institutional reports were used only to provide global context. The findings consistently showed that integrating student-centered teaching with AI-supported tools, including learning analytics, adaptive learning systems, and formative assessment, improved student engagement, motivation, personalized learning, and mathematics achievement. The review also identified common implementation challenges, including limited technological infrastructure, insufficient teacher preparation, ethical concerns, and unequal access to digital resources. Overall, the evidence suggests that AI is most effective when integrated with student-centered pedagogical practices rather than used as a standalone technological tool.
Keywords: Student-Centered Learning, Artificial Intelligence, Mathematics Education, Learning Analytics

1. Introduction

Mathematics is a key area of education that enhances logical thinking, problem-solving, and the analysis of complex information. These skills are relevant not only to mathematics learning but also to a wide range of fields, including science, engineering, technology, and economics. Despite the importance of mathematics, many students continue to struggle with it. Some

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students lack confidence when dealing with challenging concepts, while others show little interest or are unable to relate mathematical concepts to real-life situations. Therefore, improving mathematics teaching methods remains an important concern for teachers and researchers.

Artificial intelligence has become part of this discussion in recent years. Rather than being treated merely as a new educational technology tool, AI is now considered a resource that can support both educators and learners. For example, AI applications can provide immediate feedback, recommend learning activities based on students' progress, and help identify concepts that require further practice.

These applications can be used alongside student-centered teaching to create interactive, flexible, and responsive learning environments. However, the extent to which AI improves mathematics learning outcomes depends on how it is used in education.

Despite substantial efforts in mathematics teaching and learning, improving mathematics education remains a global concern because many students continue to experience difficulties with mathematical understanding, problem-solving, mathematical reasoning, and academic achievement (Soltani & Chellougui, 2026). Results from the Programme for International Student Assessment (PISA 2022) showed that mathematics achievement declined in many participating countries, indicating a need for more effective teaching methods (OECD, 2023). Similarly, UNESCO (2023) highlighted the potential of digital technologies, including artificial intelligence (AI), to enhance teaching and learning when combined with appropriate pedagogical approaches. In response to these challenges, the use of student-centered learning (SCL) and AI as complementary approaches to improving mathematics education has emerged as a growing area of research. SCL fosters engagement, collaboration, critical thinking, and active participation, while AI provides opportunities for personalized learning, adaptive feedback, learning analytics, and data-informed instructional decisions.

Study objectives

The primary objective of this narrative literature review is to examine recent research published between 2020 and 2026 on the integration of student-centered learning and artificial intelligence (AI) in mathematics education. The review aims to provide a comprehensive understanding of how these approaches have been used to improve mathematics teaching and learning across both K–12 and higher education.

The objectives of this paper are to:

1. Examine the contribution of student-centered learning approaches to improving students' mathematical achievement, engagement, critical thinking, and confidence.
2. Explore how artificial intelligence, learning analytics, adaptive learning technologies, and formative assessment support personalized instruction and data-informed decision-making in mathematics education.
3. Identify the reported benefits, implementation challenges, and research gaps related to integrating student-centered learning with AI in mathematics classrooms.

The review synthesizes current evidence from peer-reviewed studies to provide practical recommendations for educators, educational institutions, and researchers interested in improving mathematics education through learner-centered and data-driven instructional practices.

2. Review of Previous Studies

Recent research demonstrates a growing shift from traditional teacher-centered instruction toward student-centered learning in mathematics education. Across the reviewed studies, researchers consistently identified active learning, collaborative learning, project-based

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learning, differentiated instruction, and formative assessment as effective strategies for increasing student participation and improving mathematical understanding. Although these instructional approaches vary in their implementation, most studies reported positive effects on students' engagement, problem-solving ability, confidence, and academic achievement (Ayubovna, 2025; Kristiyuana et al., 2025; Rafa & Pasia, 2025).

Several studies further emphasized the importance of formative assessment as an essential component of student-centered instruction. For example, Ngoveni and Machaba (2025) found measurable improvements in students' mathematical reasoning and self-confidence through the Five-Pillar Formative Assessment Framework.

The reviewed literature also shows that artificial intelligence and learning analytics are increasingly being integrated into mathematics education to complement student-centered teaching rather than replace it. Intelligent tutoring systems, adaptive learning platforms, predictive analytics, and personalized feedback have been widely reported to support individualized instruction and facilitate the early identification of students who may require additional academic support (Lara et al., 2025; Ouyang et al., 2023; Lestari et al., 2025). However, the reviewed studies also identified several common challenges, including limited technological resources, insufficient professional development for teachers, concerns about student data privacy, and difficulties integrating AI technologies into existing curricula (Dhakal, 2025; Ajayi & Letseka, 2026).

Examples from Tanzania and Indonesia further demonstrate that student-centered instructional reforms can successfully improve mathematics learning when supported by appropriate educational policies and technology integration (Rajab & Mwila, 2025; Kristiyuana et al., 2025). Nevertheless, these studies also highlighted persistent barriers, particularly in resource-constrained educational settings where limited infrastructure, funding, and teacher training reduce the effectiveness of implementation.

Overall, the reviewed literature presents broad agreement that combining student-centered learning with AI-supported instructional practices can improve mathematics education. However, differences in research design, educational context, participant populations, and implementation strategies make direct comparisons difficult. The review therefore identifies a continuing need for longitudinal studies and stronger empirical evidence to evaluate the long-term effectiveness of these approaches across diverse educational settings.

3. Research Methodology and Methods

This study employed a narrative literature review to examine recent research on student-centered learning and the use of artificial intelligence (AI) in mathematics education. Peer-reviewed studies published between 2020 and 2026 were reviewed to provide an up-to-date overview of developments in the field. The final evidence base consisted of 15 peer-reviewed studies using quantitative, qualitative, and mixed-methods research designs, supplemented by two institutional reports used only to provide global context.

The reviewed literature addressed student-centered learning, artificial intelligence, mathematics education, formative assessment, personalized learning, student engagement, learning outcomes, and learning analytics. Studies were selected from peer-reviewed international journals available through IEEE Xplore, SpringerLink, MDPI, Crossref-indexed journals, and other open-access academic journals. OECD (PISA 2022) and UNESCO reports were also consulted to provide global context for the research problem.

In this review, data-driven approaches refer to the use of artificial intelligence, learning analytics, adaptive learning systems, and formative assessment data to support instructional decision-making and improve student learning outcomes in mathematics.

The search was conducted using combinations of the following keywords: "student-centered learning," "artificial intelligence," "mathematics education," "learning analytics," "formative assessment," "personalized learning," "student engagement," and "learning outcomes."

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Only English-language, peer-reviewed studies directly related to mathematics education and published between 2020 and 2026 were included. Studies unrelated to mathematics education, unpublished literature, and publications not written in English were excluded. The selected studies used quantitative, qualitative, and mixed-methods designs. They were analyzed thematically, compared, and synthesized to identify common themes, reported benefits, implementation challenges, and emerging trends in the integration of student-centered learning and AI in mathematics education.

4. Results

Student-Centered Pedagogical Approaches

The reviewed studies showed positive outcomes associated with student-centered mathematics teaching strategies. Common practices included active learning, collaborative learning, formative assessment, peer assessment, instructional scaffolding, and personalized learning. These methods were associated with improvements in students' interest, conceptual understanding, mathematical reasoning, and performance (Ayubovna, 2025; Ngoveni & Machaba, 2025; Rafa & Pasia, 2025). In the study by Ngoveni and Machaba (2025), the students' mean mathematics score increased from 7.9/20 before implementation of the Five-Pillar Formative Assessment Framework to 11.5/20 afterward, indicating improved mathematics achievement following implementation of the framework.

AI and Data-Driven Technologies

The reviewed studies described various AI applications used to support mathematics teaching and learning. The most frequently cited technologies included intelligent tutoring systems (ITS), adaptive learning management systems (ALMS), learning analytics dashboards, AI performance-prediction models, adaptive learning platforms, predictive analytics, automated problem-solving assistants, and generative AI tools such as ChatGPT. These technologies were used to personalize learning pathways, provide immediate feedback, monitor student progress, identify at-risk students, and facilitate data-driven decision-making (Ouyang et al., 2023; Michelle & Miranda, 2025; Nindia et al., 2026).

In addition, several studies reported the use of AI-assisted learning media and tools, including EdCafe AI, GeoGebra, Scratch, and Canva, to improve students' conceptual understanding of mathematics, problem-solving skills, and critical thinking (Lestari et al., 2025).

Combined Approaches

The reviewed studies suggest that AI technologies were most effective when used to complement student-centered teaching rather than as standalone tools. Across the included studies, collaborative learning, formative assessment, personalized instruction, and adaptive AI technologies were associated with higher student engagement, stronger conceptual understanding, and improved mathematics achievement (Randver, 2025; Tang, 2026; Ouyang et al., 2023). However, because the studies differed in design, context, and outcome measures, these findings should be interpreted cautiously.

Although the reviewed studies examined different technologies, they shared a common goal. Typical AI applications included personalized feedback, adaptation of learning activities to students' needs, and learning analytics or performance-prediction models that enabled instructors to monitor progress. These technologies rarely replaced classroom teaching; instead, they supported individualized learning within learner-centered environments. The reviewed studies also identified implementation challenges associated with the use of AI in mathematics education (Ouyang et al., 2023; Tang, 2026; Nindia et al., 2026; Ajayi & Letseka, 2026).

The reviewed studies also identified several challenges associated with the use of artificial intelligence in mathematics education. Common concerns included insufficient professional

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development for educators, limited technological infrastructure, unequal access to technology, data-privacy risks, and difficulties integrating AI technologies into existing curricula (Lara et al., 2025; Tang, 2026; Ajayi & Letseka, 2026).

5. Discussion

The findings indicate that student-centered learning and AI can be combined to support student learning. Student-centered approaches provide opportunities for participation, collaboration, feedback, and reflection, while AI can support these processes through adaptive learning, learning analytics, and timely feedback.

Personalization was one of the most evident benefits across the reviewed studies. Intelligent tutoring systems, adaptive learning platforms, and generative AI tools can personalize content, pacing, and feedback according to students' progress and learning needs. These tools can support self-regulated learning (SRL) by helping students identify errors, monitor their progress, and decide what to practice. For example, Nindia et al. (2026) found that intelligent tutoring systems, adaptive learning management systems, and generative AI can adapt learning pathways to individual learner profiles. However, personalization must involve more than assigning different digital activities to different students. Its value depends on whether feedback and recommendations help students explain their reasoning, address misunderstandings, and become more independent learners.

It is important to distinguish between AI as pedagogical support and AI as a technological 'wrapper.' AI functions as a wrapper when it is added to an unchanged teacher-centered lesson without modifying student engagement, feedback, or mathematical sense-making. By contrast, AI serves as pedagogical support when it is integrated into an explicit learning model. This distinction is illustrated by two examples from the reviewed literature. Ouyang et al. (2023) used a closed feedback loop involving performance prediction and learning analytics, teacher feedback, and collaborative activity. The Five-Pillar Formative Assessment Framework follows a similar iterative, student-centered process. These models show that AI can support learners' feedback, assessment, collaboration, and reflection processes.

Teacher preparedness involves more than the ability to use digital tools. Teachers need sufficient AI literacy to evaluate the accuracy of AI-generated responses, interpret AI-generated learning analytics, recognize potential bias, and apply appropriate technologies and strategies. Inadequate teacher preparation was a recurring issue in the reviewed studies and remains a barrier to successful implementation. Lestari et al. (2025) identified teacher preparedness and difficulties using AI tools within existing curricula as important concerns. Without adequate preparation, increased use of technology may not improve the quality of mathematics instruction.

Infrastructure and access also influence the equitable implementation of AI-supported learning. Not all schools and communities have reliable internet access, appropriate tools, technical support, or suitable platforms. Lara et al. (2025) identified differences in access across urban, semi-urban, and rural settings, as well as inadequate infrastructure and insufficient teacher training, as major challenges. Institutions therefore need to consider who will benefit from AI-assisted learning, when and how it will be used, and who will support its implementation. Otherwise, personalized learning technologies may worsen inequities among students and institutions.

Ethical issues are closely related to these equity concerns. AI systems can collect extensive data on student performance and behavior, including learning engagement and learning patterns. This raises concerns about privacy, consent, transparency, data ownership, and the use of predictive labels. For example, an algorithm may identify a student as 'at risk' so that additional support can be provided; however, the classification may be incorrect or may influence how the student is treated. Ajayi and Letseka (2026) also highlight the need for transparency, data governance, and context-sensitive implementation when AI is used for

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learning analytics. Ethical use therefore requires more than data protection. Institutions should establish procedures for data collection, human review of automated recommendations, and student appeals against such recommendations.

Equitable implementation also requires cultural responsiveness. AI tools may be built using information, language, examples, and assumptions specific to particular educational contexts. When applied in different cultural, linguistic, or socioeconomic settings, their recommendations may be less suitable. Mathematics may be universal in many respects, but the contexts in which it is presented, the language used to explain it, classroom expectations, and students' prior experiences are not. Therefore, AI-generated content and personalized recommendations should remain under teachers' guidance. Local educators are better positioned to determine whether an explanation, example, or learning pathway is appropriate for their students.

The teacher remains central to this process. Although AI can recognize patterns, generate practice problems, and provide immediate feedback, it cannot replace teachers' expertise, rapport, encouragement, or responsiveness to students' emotional experiences with mathematics. Tang (2026) also warns that excessive reliance on AI may tempt students to accept AI-generated answers without sufficient effort, thereby weakening active problem-solving. A balanced approach is needed in which AI supports analysis and personalization while instructors continue to emphasize reasoning, discussion, creativity, and mathematical communication.

The studies included in this review indicate that AI has the potential to improve student performance in student-centered mathematics learning when it is guided by clear instructional objectives. The effectiveness of AI depends less on the sophistication of the technology than on how it is integrated into teaching and learning. Effective implementation requires well-trained educators, adequate technological resources, ethical policies, and learning environments responsive to students' needs. When these conditions are met, AI can supplement effective teaching and help create more engaging, responsive, and supportive mathematics classrooms while teachers continue to guide student learning.

6. Conclusion and Recommendations

This paper reviewed recent studies on the implementation of student-centered teaching approaches and artificial intelligence in mathematics education. Most of the reviewed studies reported that integrated approaches positively influenced student performance. Methods combining AI with formative assessment, collaboration, and differentiation were associated with higher levels of student motivation, engagement, and academic improvement in mathematics.

The findings also show that, to maximize benefits for student learning, educators need training in how to integrate AI effectively with their teaching practices, students need access to appropriate technology, and educational institutions need clear ethical policies. Unless these barriers are addressed, the scalability and sustainability of AI-assisted, student-centered mathematics learning will remain constrained, particularly in resource-limited contexts.

Furthermore, policymakers and educational leaders must ensure that increasing use of AI tools does not overshadow the human dimension of education. Teachers' pedagogical expertise, socio-emotional support, and ability to encourage critical thinking remain indispensable. A balanced approach to AI-assisted learning should also prevent learners from becoming overly dependent on AI systems in ways that could weaken their critical thinking and agency.

In conclusion, student-centered pedagogies supported by AI and data analytics represent a promising direction for mathematics education. When implemented effectively, this approach can empower learners to take greater ownership of their learning, increase engagement, promote more equitable learning opportunities, and equip students with the skills needed for lifelong learning and problem-solving in an increasingly complex world.

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Based on the findings of this review, the following recommendations are proposed:

- Invest in teacher professional development focusing on both active pedagogy and AI literacy.
- Develop equitable technological infrastructure and curricula aligned with AI tools.
- Establish ethical policies addressing data privacy, bias, and human-AI collaboration.
- Encourage institutional flexibility to integrate innovative, student-driven pedagogies with technology.

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