

Emerging Artificial Intelligence in Mathematics Education: A Systematic Literature Review

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Keywords	Abstract
Artificial Intelligence, AI integration, mathematics, education, mathematics teaching	The Artificial Intelligence (AI) revolution has affected all of education, including mathematics education. Studies on AI have described how it can be integrated into mathematics learning. However, a challenge exists concerning the teacher's perspective on involving AI in mathematics teaching. Every mathematics teacher is expected to improve students' 21st-century skills, which include problem-solving ability, critical thinking, and creativity. These conditions have driven studies to analyse AI usage in mathematics education. This systematic literature review (SLR) analysed 20 articles according to their research design, research paradigm, data collection methods, topics, participants, and AI tools. Furthermore, it applied an advanced literature search approach to identify relevant scientific sources on the application of AI in mathematics education. The framework utilised in this study is the PRISMA systematic review process. Ultimately, several selected articles that were analysed in this study were found to possess various characteristics. Lastly, the study concludes that AI integration in mathematics education has both benefits and weaknesses.

Introduction

Artificial Intelligence (AI) is among the most transformative technologies and affects virtually every domain of human life (Burlakov et al., 2020), including education. AI enhances human capacity for learning and teaching (Markauskaite et al., 2022), and its adoption accelerated significantly during and after the Covid-19 pandemic (Mele et al., 2022; Tupulu et al., 2024). Mathematics education has been particularly affected, since AI presents opportunities to improve teaching quality (Opesemowo & Ndlovu, 2024), support professional skill development, and advance the field broadly (Li & Zaki, 2024). At the same time, it challenges existing paradigms of mathematics research, teaching, and learning (Biehler et al., 2024; Ellis & Berry III, 2005; Zreik, 2024), and practitioners hold divided perceptions about its value (Zheng et al., 2023).

One key solution is to integrate AI in mathematics teaching and learning (Cirneanu & Moldoveanu, 2024). Such integration spans model design for education systems (Bhardwaj, 2024), assessment instrument development (Wang et al., 2022), and learning strategy implementation (Cunski, 2020). Studies demonstrate that AI-assisted teaching significantly impacts students' mathematical thinking (Van Doc et al., 2023), conceptual understanding



(Canonigo, 2024), and problem-solving skills (Bayaga, 2024). Thus, mathematics education research should examine how AI develops 21st-century competencies, especially in problem-solving, critical thinking, and creativity (Adeoye & Jimoh, 2023; Thornhill-Miller et al., 2023).

Research Questions

The study aimed to systematically analyse the integration of AI in mathematics education by addressing key dimensions of existing research. Specifically, this systematic literature review examined AI use through eight research questions:

RQ1: What research designs are used in these studies?

RQ2: What paradigm approaches are employed?

RQ3: What data collection methods are applied?

RQ4: What mathematics topics are involved?

RQ5: Who are the participants?

RQ6: What AI tools are utilised?

RQ7: What are the challenges of AI implementation?

RQ8: How does AI improve mathematical learning outcomes?

These research questions guided the analysis of selected articles to uncover patterns, benefits, and limitations in AI adoption.

Methods

Search Strategy

This study applied an advanced literature search using the keywords "Artificial Intelligence (AI)" and "Mathematics Education" through the Scopus database. Conducted on December 25, 2024, the initial search yielded 1,032 articles. After excluding conference proceedings, book chapters, and unpublished materials (N = 645), and subsequently applying updated inclusion criteria to capture studies through 2026, 136 peer-reviewed English-language journal articles published between 2020 and 2026 remained for further screening.

Selection Criteria

This study adopted the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Figure 1). The inclusion criteria required articles to: (a) discuss AI integration in mathematics education, (b) describe specific AI technologies, (c) be published in reputable English-language journals, and (d) be published between 2020 and 2026. Non-English articles, pre-prints, and papers not focused on AI in mathematics were excluded.

The quality assessment process removed 36 duplicate articles and 50 articles that did not explicitly address AI in mathematics education. After a comprehensive review of titles, abstracts, methodology, results, and discussion sections of the remaining 86 articles, 66 were eliminated for insufficient focus on AI application. This yielded a final sample of 20 articles. Figure 1 illustrates the PRISMA systematic review process.

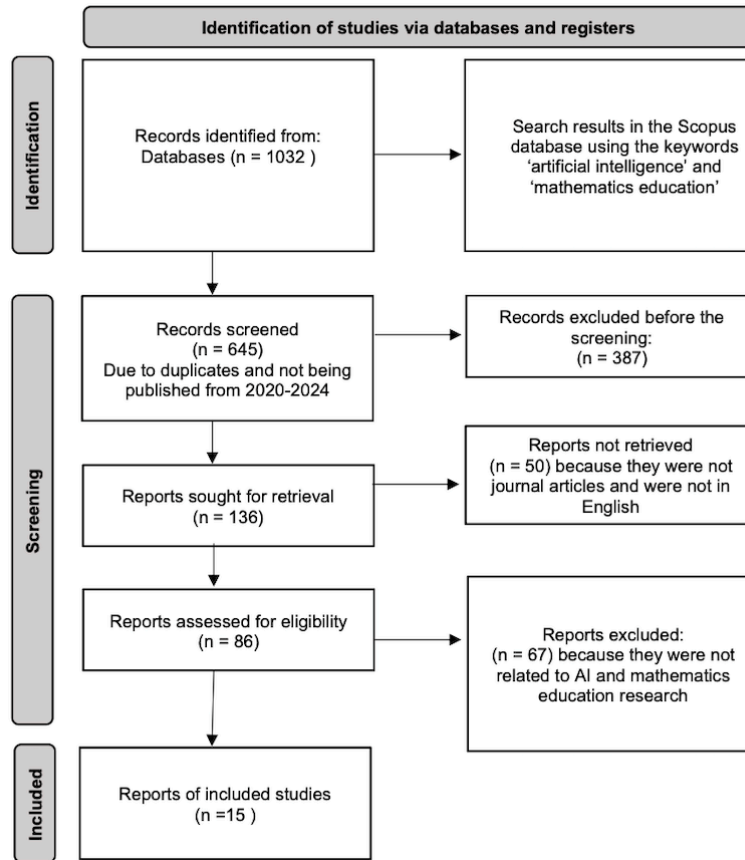


Figure 1: PRISMA systematic review process

Results and Discussion

The review findings are organised according to the eight research questions. Table 1 presents a comprehensive summary of all 20 analysed articles.

Table 1: SLR Results Resume

No.	Author	Title	Data Collection	Research Design	Topics	Respondent	AI Tool	Paradigm Tendency
1	Zhang (2024)	An Innovative Model of Higher Mathematics Curriculum Artificial Intelligence Technology Education Incorporating	Pretest - Posttest	Quasi-experimental	Optimisation	University Students (financial management major)	Not specified	Post-positivist
2	Han, et al. (2024)	Applying Artificial Intelligence-Based Adaptive Learning on Mathematical Attitudes and Self-Directed Learning	Pretest - Posttest	Quasi-experimental	Basic Mathematics	University Students	AI-based customised learning system	Positivist
3	Wardat, et al. (2023)	ChatGPT: A revolutionary tool for teaching and learning mathematics	Interviews	Instrumental case study	Geometry	Students; Teacher (High School)	ChatGPT	Critical

No.	Author	Title	Data Collection	Research Design	Topics	Respondent	AI Tool	Paradigm Tendency
4	Taani & Alabidi (2024)	ChatGPT in education: benefits and challenges of ChatGPT for mathematics and science teaching practices	Questionnaire	Mixed methods	STEAM	High School Teacher	ChatGPT	Pragmatic
5	Huang & Qiao (2022)	Enhancing Computational Thinking Skills Through Artificial Intelligence Education at a STEAM High School	Pretest - Posttest	Experimental design	STEAM	High School Students	Not specified	Positivist
6	Gouia-Zarrad & Gunn (2024)	Enhancing students' learning experience in mathematics class through ChatGPT	Questionnaire	Descriptive quantitative	Numerical Methods	Undergraduate mathematics Students	ChatGPT	Post-positivist
7	Egara & Mosimege (2024)	Exploring the Integration of Artificial Intelligence-Based ChatGPT into Mathematics Instruction: Perceptions, Challenges, and Implications for Educators	Questionnaire; Interviews	Mix methods	Not Specified (several mathematics topics)	Secondary school mathematics Teacher	ChatGPT	Post-positivist
8	Zhou (2023)	Integration of Modern Technologies in Higher Education on The Example of Artificial Intelligence Use	Pretest - Posttest	Quasi-experimental	Not specified (Conducted in several majority)	University Students (mathematics, computer science, management, English, and sociology)	Not specified	Post-positivist
9	Getenet (2024)	Pre-service teachers and ChatGPT in multistrategy problem-solving: Implications for mathematics teaching in primary schools	Single Test	Comparative study	Algebra	Pre-Service teacher	ChatGPT	Critical
10	Cunška (2022)	Prototype of Project AI4Math: Interdisciplinary and Innovative Technology for Accelerated Learning of Mathematics	Questionnaire	Development research	Not Specified (several mathematics topics)	Students (not specified in Latvian School)	AI4Math prototype	Pragmatic
11	Norberg, et al. (2024)	Rewriting Content with GPT-4 to Support Emerging Readers in Adaptive Mathematics Software	Pretest - Posttest	Experimental design	Algebra	Students (not specified)	MATHia and ChatGPT	Positivist

No.	Author	Title	Data Collection	Research Design	Topics	Respondent	AI Tool	Paradigm Tendency
12	Schindler, et al. (2022)	Small number enumeration processes of deaf or hard-of-hearing students: A study using eye tracking and artificial intelligence	Single Test; Observation	Mixed Methods	Small number enumeration	Elementary students (3rd, 4th, and 5th grades) consisting of hearing group and hard-of-hearing group)	Not specified	Pragmatic
13	Alomari & Jabr (2020)	The effect of the use of an educational software based on the strategy of artificial intelligence on students' achievement and their attitudes towards it	Single Test	Quasi-experimental	Plural form of subtraction unit	Second grade student	Not specified	Positivist
14	Wahba, et al. (2024)	The impact of ChatGPT-based learning statistics on undergraduates' statistical reasoning and attitudes toward statistics	Pretest - Posttest	Quasi-experimental	Statistics	Undergraduate elementary school teachers' course	ChatGPT	Positivist
15	Jančarič, et al. (2023)	Using AI Chatbot for Math Tutoring	Interviews	Descriptive qualitative	Social Arithmetics	Elementary student	Custom AI Chatbot	Interpretivist
16	Brasken et al. (2025)	Students' Use of ChatGPT in an Algebra Class: A Case Study of Prompts and Attitudes	Pre- and post-questionnaire	Case study	Algebra	Upper-secondary students	ChatGPT (GPT-4)	Positivist
17	Atirbek et al. (2026)	Enhancing Pre-Service Mathematics Teachers' Digital Pedagogy through a Two-Rotation AI-Integrated Blended Learning Model for Critical and Reflective AI Use	Pre- and post-questionnaire	Quasi-experimental	Algebra	Pre-service mathematics teachers	ChatGPT, GeoGebra, Desmos, Copilot, Perplexity	Positivist
18	Xuan et al. (2025)	Evaluating the Impact of Generative AI in Mathematics Education: A Comparative Study in Vietnamese High Schools	Pre- and post-questionnaire	Comparative Study	Algebra	High school students	ChatGPT 3.5	Positivist
19	Atuahene and Boateng (2026)	Mathematics teachers' awareness, perceptions, and challenges in using ChatGPT	Structured questionnaire	Survey research	Not specified (General Mathematics Education)	Senior High School mathematics teachers	ChatGPT	Positivist
20	Kuzu (2025)	Mathematics teachers' AI literacy, anxiety, and perceptions of AI integration in mathematics education: a mixed-methods study	Survey	Mixed methods	Not specified (General Mathematics Education)	Mathematics teachers	ChatGPT, Photomath, Mathletics, Mathspace, Mathway, Wolfram Alpha	Post-positivist

RQ1: Analysis of Research Design

As seen in Figure 2, the 20 articles encompass diverse research designs: comparative, descriptive qualitative, descriptive quantitative, development, experimental, case study, mixed methods, and quasi-experimental. Quasi-experimental was most prevalent, reflecting a preference for evidence-based approaches (Atirbek et al., 2026; Xuan et al., 2025). Two experimental studies developed AI-based teaching designs (Huang & Qiao, 2024; Norberg et al., 2024).

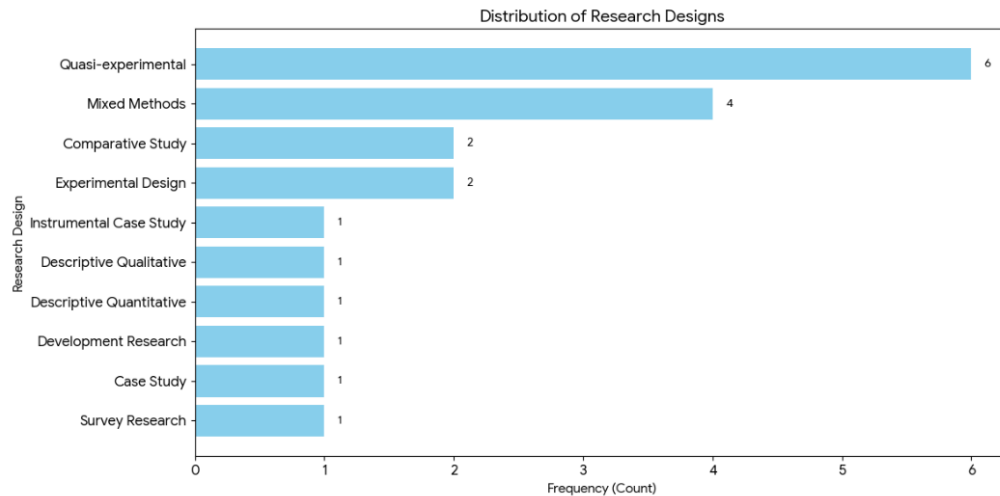


Figure 2: Distribution of research designs

RQ2: Analysis of Research Paradigm

Research paradigms define the epistemological and ontological orientation of a study (Khatri, 2020; Kivunja & Kuyini, 2017). Five paradigms are discussed: positivist, post-positivist, interpretivist, critical, and pragmatic, with the characteristics summarised in Table 2.

Table 2: Characteristics of Each Paradigm

	Reality	Validity	Result	Epistemology	Ontology	Methodology	Axiology
Positivist	Understood in whole	Internal validity, external validity, reliability, and objectivity	Objective	Objective	Naïve realism	Experimental	Beneficent (maximising outcomes)
Post-Positivist	Cannot be Understood fully, but approximated only	Internal validity, external validity, reliability, and objectivity	Objective	Objective	Naïve realism	Experimental	Beneficent (maximising outcomes)
Interpretivist	Socially Constructed	Credibility, dependability, confirmability and transferability	Subjective	Subjective	Relativist (can be constructed by researcher and subject interactions)	Naturalist (through interview, etc.)	Balance (balance between finding and researcher value)

	Reality	Validity	Result	Epistemology	Ontology	Methodology	Axiology
Critical	Social justification	Transactional	Subjective	Transactional	Historical realism	Dialogic	Respect to cultural norms
Pragmatic	Practicability	Combination of Positivist and interpretivist based on Practicability oriented	Objective	Relational	Non-singular reality (no single reality)	Mixed Methods (Quantitative and Qualitative)	Value laden (a benefit to people)

The diagram, which shows the analysis of the paradigms used in the selected articles ($N = 15$), can be seen in Figure 3 below. The result was obtained by the criteria presented in Table 2.

Based on Figure 3, five paradigms were identified: positivist (nine articles), post-positivist (four articles), interpretivist (Jančařík et al., 2023), critical (Getenet, 2024; Wardat et al., 2023), and pragmatic (three articles). The positivist dominance reflects the field's orientation toward measurable impact evidence. Notably, Kuzu (2025) employed mixed methods to capture both quantitative outcomes and qualitative teacher perceptions of AI literacy and anxiety.

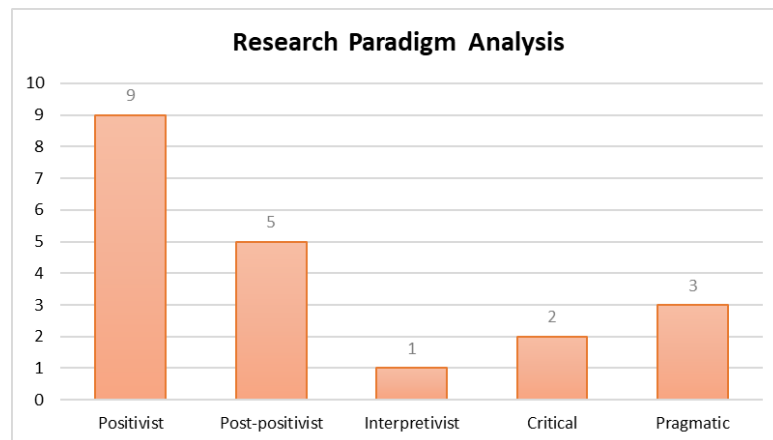


Figure 3: Distribution of research paradigms

RQ3: Analysis of Data Collection

Based on Figure 4, pretest-posttest was the most common strategy (six articles), used to validate AI-based learning models (Han et al., 2024; Huang & Qiao, 2024; Norberg et al., 2024; Wahba et al., 2024; Zhang, 2024; Zhou, 2023). Single tests were used for comparisons (Alomari & Jabr, 2020; Getenet, 2024; Schindler et al., 2022). Questionnaires captured AI perceptions (Cunská, 2022; Egara & Mosimege, 2024; Gouia-Zarrad & Gunn, 2024; Taani & Alabidi, 2024); interviews and observation complemented quantitative data (Schindler et al., 2022). Recent studies (Atirbek et al., 2026; Atuahene & Boateng, 2026; Brasken et al., 2025; Kuzu, 2025; Xuan et al., 2025) consistently employ pre- and post-questionnaires, indicating a shift toward holistic attitudinal measurement.

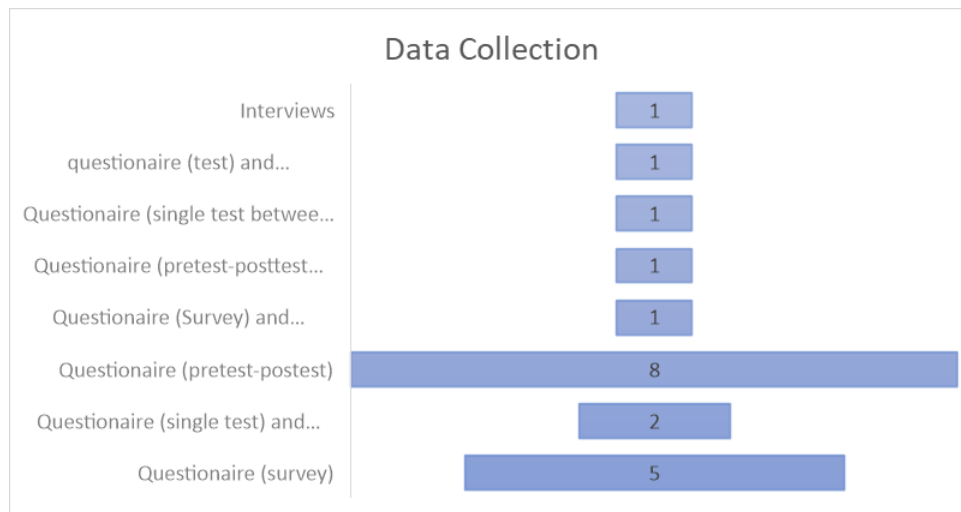


Figure 4: Data collection strategies distribution

RQ4: Analysis of Mathematics Topics

Algebra emerged as the most represented topic across the 20 articles, featured in five studies (Atirbek et al., 2026; Brasken et al., 2025; Getenet, 2024; Norberg et al., 2024; Xuan et al., 2025). AI-assisted algebra learning benefits from logic-based prompting, as algebraic reasoning aligns naturally with AI's structured response capacity (Azaria et al., 2024). STEAM was another recurring topic (Huang & Qiao, 2024; Taani & Alabidi, 2024). Other topics included geometry, optimisation, statistics, numerical methods, and social arithmetic. Three articles focused on general AI perceptions without specifying a mathematics topic (Cunskas, 2022; Egara & Mosimege, 2024; Zhou, 2023). The concentration on algebra and STEAM suggests promising avenues for AI integration, while calculus, number theory, and probability remain underexplored.

RQ5: Analysis of Participants

Participants ranged from elementary students to in-service teachers. University students were the most frequently studied, as they tend to provide more sophisticated AI prompts (Wu & Yu, 2024). Five articles focused on teachers or pre-service teachers (Egara & Mosimege, 2024; Getenet, 2024; Taani & Alabidi, 2024; Wahba et al., 2024; Wardat et al., 2023), while five involved high school or lower-level students, where academic integrity concerns were prominent (Grant & Üngör, 2024; Septiani et al., 2022). Studies on teacher AI literacy (Atirbek et al., 2026; Atuahene & Boateng, 2026; Kuzu, 2025) highlight teacher capacity as equally critical as student outcomes.

RQ6: Analysis of AI Tools

Figure 5 shows that ChatGPT was the dominant tool (12 of 20 articles), studied from perspectives of teacher experience (Wardat et al., 2023), student experience (Gouia-Zarrad & Gunn, 2024), statistical reasoning impact (Wahba et al., 2024), and integration challenges (Egara & Mosimege, 2024; Taani & Alabidi, 2024). Custom AI tools were developed in three studies (Cunskas, 2022; Han et al., 2024; Jančařík et al., 2023). Recent studies signal a shift toward multi-tool ecosystems: Atirbek et al. (2026) examined ChatGPT, GeoGebra, Desmos, Copilot, and Perplexity, and Kuzu (2025) examined six tools including Photomath and Wolfram Alpha.

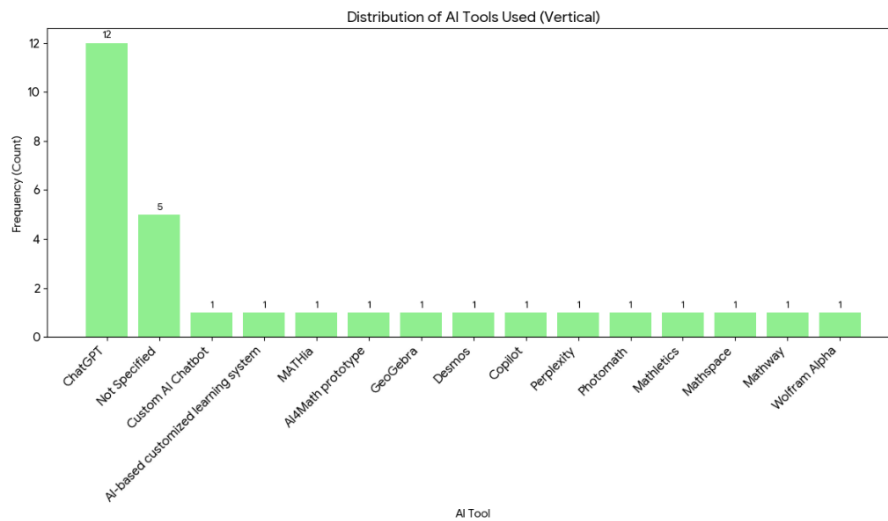


Figure 5: AI tools distribution

Discussion and Implications

Contextual Contributions and Positioning of this Review

This PRISMA-compliant review of 20 peer-reviewed empirical studies offers a multifaceted analytical framework encompassing research design, paradigmatic orientation, data collection methods, mathematical topics, participant profiles, and AI tool applications (Jallali et al., 2026; Li, D. et al., 2025; Lindner et al., 2026; Tsakeni et al., 2025). The findings affirm that AI-driven educational interventions substantially enhance mathematics achievement and engagement (Hwang, 2022; Tlili et al., 2025; Zhu et al., 2026), and chart the field's progression from single-tool explorations to structured multi-tool pedagogical paradigms.

Implications in Relation to the Research Review Findings

In the Introduction, we discussed several advanced research studies that mention teaching quality, a mathematics education paradigm, and professional development. Three claims from the Introduction received empirical corroboration. First, AI has become a core pedagogical instrument, with 20 studies documenting significant gains in achievement, attitudes, self-efficacy, and 21st-century skills (Cao et al., 2026; Recio et al., 2026). Second, paradigmatic diversity from positivist to interpretivist designs validates the claim that AI is reshaping mathematics education research (Burbage & Styron, 2026; Opesemowo & Ndlovu, 2024). Third, teacher readiness is empirically confirmed as a critical mediator of AI efficacy, with the challenges being fundamentally pedagogical and professional rather than technological (Dehen et al., 2026; Wang & Zhang, 2026).

Implications for Policy, Curriculum, and Pedagogy

The disproportionate concentration of studies on algebra and STEAM (while calculus, number theory, probability, and proof-based reasoning remain absent) constitutes a curricular asymmetry with direct policy implications. Educational authorities should mandate structured AI-integrated modules across the full spectrum of mathematics, and formalise prompt engineering and critical evaluation of AI outputs as mathematical competencies at all levels (Le et al., 2026; Murray, 2025; Mustafa et al., 2024). Curriculum standards should further articulate tool-specific

competencies—for example, ChatGPT for algebraic reasoning versus GeoGebra for geometric visualisation—rather than generic AI (Hossein-Mohand et al., 2025; Velandar et al., 2026)

From a pedagogical standpoint, the most efficacious AI integrations identified in this review were those that utilised AI as a scaffolding tool rather than as an omniscient repository of knowledge (Lindner et al., 2026). Jančařík et al. (2023) demonstrated that progressively provided AI-assisted hints fostered independent problem-solving, whereas Atirbek et al.'s (2026) two-rotation blended learning model promoted critical AI utilisation through the alternation of AI-mediated and human-facilitated instructional phases. Both models operationalise Vygotskian principles of mediated learning and the Zone of Proximal Development, underscoring the necessity of theoretical alignment between AI deployment and pedagogical objectives for optimal effectiveness (Al-Hamadi & Yousif, 2025). Teacher educators are therefore advised to develop pre-service and continuing professional development programmes that conceptualise AI not merely as a technical proficiency but as an integral pedagogical competency, incorporating the creation of AI-resistant tasks, the critical evaluation of AI-generated outputs, and the exemplification of reflective AI application for students (Jallali et al., 2026). Institutions should establish professional learning communities centred on AI to supplant the predominant informal discovery approaches (Chung et al., 2026).

Implications for Assessment and Technology-Enabled Learning

AI's capacity for immediate formative feedback and personalised task generation constitutes a substantial pedagogical asset (Alsaiani et al., 2026; Tang, W.K-W., 2025). However, the academic integrity challenges documented in this review necessitate a decisive shift towards process-oriented, performance-based assessment formats inherently resistant to AI substitution—oral examinations, collaborative problem-solving, and portfolio documentation of mathematical reasoning (Evangelista, 2024; Xia et al., 2024). Institutional policies must explicitly distinguish productive AI assistance from academically dishonest substitution.

Ethical Considerations

AI integration raises ethical imperatives including academic dishonesty, data privacy concerns with minors, algorithmic bias, and digital exclusion in under-resourced contexts (Alfiras et al., 2025). Researchers, policymakers, technology developers, and institutions should collaborate to establish guidelines guaranteeing equitable access, stringent data privacy protections, and the preservation of the developmental and relational dimensions of mathematics education that cannot be reduced to algorithmic optimisation.

Limitations

This SLR examined six analytical dimensions across 20 articles. Results are generalisable only to the selected articles and should not be treated as universal conclusions about AI in mathematics education. The study was also limited to Scopus-indexed publications, potentially excluding important studies in non-indexed or regional journals. Future studies should expand the scope of articles analysed, diversify database sources, and extend the review to additional research dimensions.

Directions for Further Research

Six research priorities emerged from this review: (1) longitudinal studies tracking sustained AI effects beyond single-semester interventions; (2) equity studies examining differential outcomes across socioeconomic, geographic, linguistic, and disability dimensions; (3) comparative studies evaluating the relative efficacy of specific AI tools within mathematical domains; (4) research

expanding to underrepresented areas including calculus, combinatorics, and proof; (5) interpretivist and critical paradigm studies capturing lived classroom experiences; and (6) governance research developing institution-specific AI policy frameworks addressing accountability, equity, and privacy.

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