International Journal of Sciences and Innovation Engineering
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
website: www.ijsci.com
Volume 03, Issue 11,November 2026
OPEN ACCESS
E-ISSN : 3049-0251
DOI: https://doi.org/10.70849/ijsci

The Role of Artificial Intelligence in Supporting K-12 Mathematics Teachers: A Systematic Review

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Article Info

Article History:

Published: 04 Nov 2026

Publication Issue:
Volume 03, Issue 11
November 2026

Page Number:
236-242

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Abstract:

Artificial intelligence (AI) is changing how mathematics is taught, but evidence on how school mathematics teachers themselves use AI is scattered. This paper synthesises the evidence base assembled by the PRISMA-based systematic review of Li et al. [1], which screened 330 records from Web of Science, Scopus and arXiv and analysed 18 journal articles published between 2020 and 2024. We reorganise that evidence around five questions (educational stages and countries, research methods, AI tools and frameworks, mathematical content, and challenges), add derived counts and a critical reading, and propose design-level directions. The evidence shows that research is concentrated on pre-service teachers (10 of 18 studies) and on the United States and China; that quantitative (7), qualitative (5) and mixed-methods (6) designs are all used, usually with adoption models such as TPACK, TAM and UTAUT2; that ChatGPT-type tools and intelligent tutoring systems (ITSs) are the prominent tools but are limited by accuracy, procedural tasks and simulation-based rather than classroom use; and that secondary-school mathematics content is scarcely studied. Challenges fall into teacher-specific, tool-specific and systemic groups. We note limitations of the evidence base and outline enhancements for teacher AI competence, answer verification, secondary-level task banks and classroom pilots. The database search and selection described here were carried out and reported by Li et al. [1]; they were not repeated by the present authors.

Keywords: Artificial Intelligence, K-12 Mathematics Education, Mathematics Teachers, Systematic Review, Teacher Professional Development, ChatGPT, Intelligent Tutoring Systems, TPACK.

1. Introduction

Mathematics develops logical thinking and problem solving, but it is hard to learn because of its abstraction, and good teaching depends on teachers who can respond to students' ideas and set up practical activities. AI is now reshaping that relationship: the traditional teacher–student model is becoming an interactive "teacher–AI–student" model in which tools such as ChatGPT, Ernie Bot, adaptive platforms and intelligent tutoring systems offer personalised learning, adaptive feedback and real-time assessment [1]. Successful use, however, depends on ethics, teacher training and teachers' own knowledge and attitudes, and most research examines students rather than teachers.

Teacher-facing initiatives are appearing, such as UNESCO's AI competency framework for teachers [3], yet research on mathematics teachers' use of AI is fragmented across educational stages, regions, tools and instructional models. A structured synthesis is therefore useful to consolidate what is known and to show where evidence is missing. This paper provides such a synthesis from the PRISMA-based review of Li et al. [1], and adds an organised comparison of the 18 studies, derived counts, a critical analysis and proposals for further work. Section 2 gives background, Section 3 explains the method and its provenance, Section 4 presents findings and discussion, Section 5 covers benefits and challenges, Section 6 proposes enhancements, and Section 7 concludes.

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2. Literature Review

2.1 AI in Mathematics Education

AI can support mathematics learning through personalised paths, adaptive feedback and real-time assessment. ITSs such as ALEKS, MATHia and Khan Academy model learners' cognitive states and tailor instruction. Generative AI such as ChatGPT acts as a language model that explains and analyses problems and as a tool for tutoring, automated problem solving and content generation. AI chatbots acting as virtual students and AI-assisted augmented reality (AR) have also been explored [1]. Because students must understand the logic behind answers, transparency and explainability of AI models, and the accuracy of their mathematical output, are recurring concerns.

2.2 Teachers, AI Literacy and Adoption Frameworks

Teachers' expertise, motivation and attitudes strongly affect technology integration. AI literacy is tied to professional development because teachers must update their content and pedagogical knowledge, and frameworks such as UNESCO's competency framework [3] help to set learning goals. To study adoption, researchers use general models: the Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK) [4] and Stages of Concern (SoC), and recent adaptations such as UTAUT2 [5], the Will-Skill-Tool (WST) model and Expectation and Misconception Tailoring (EMT). Most of these models are not AI-specific.

2.3 Systematic Reviews and PRISMA

A systematic review identifies, screens and synthesises studies transparently; PRISMA [2] prescribes identification, de-duplication, screening, eligibility checking and inclusion, shown in a flow diagram. Li et al. [1] follow PRISMA and use an integrative review that combines quantitative, qualitative and mixed-method studies, with descriptive statistics for the descriptive question and qualitative content analysis for the rest.

3. Methodology

3.1 Provenance of the Evidence

This paper is a secondary synthesis. The search, screening and selection were designed and carried out by Li et al. [1] and are reported here as their work: the search ended in December 2024 and used the string ("AI" OR "Artificial Intelligence") AND ("Mathematics/Math Teacher" OR "Math instructors" OR "Mathematics Education") with a later K-12 restriction in Web of Science, Scopus and arXiv. We did not repeat the database search. Our own contribution is the re-organisation of the 18 selected studies by research question, derived counts computed from their summary table (marked "derived"), a critical reading of the evidence, and the proposals in Section 6.

3.2 Selection Process Reported in [1]

The search returned 98 records from Web of Science, 232 from Scopus and none from arXiv (330 in total). After 32 duplicates were removed, 298 records were screened against the criteria (2020–2024, English, journal research articles, relevant fields), and 179 were excluded, leaving 119. Of these, 69 were excluded on title and abstract (for example no AI in mathematics education, K-12 only described broadly, students rather than teachers as subjects), and 32 more were excluded after full-text checking, leaving 18 articles (Fig. 1). The counts are internally consistent ($330 - 32 = 298$; $298 - 179 = 119$; $119 - 69 = 50$; $50 - 32 = 18$).

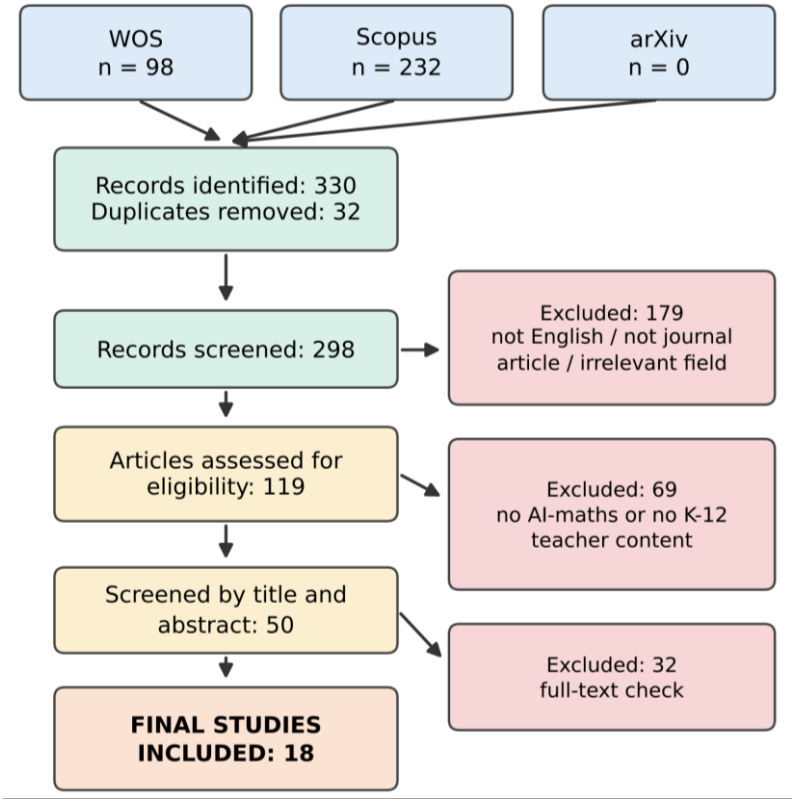


Fig. 1. PRISMA-style selection flow reported in [1] (redrawn)

3.3 Research Questions

The questions are: RQ a, educational stages and countries studied; RQ b, research methods; RQ c, AI tools, models and frameworks; RQ d, mathematical tasks and content; RQ e, challenges of integrating AI. Counts for RQ a were obtained by descriptive statistics; RQ b to e by content analysis [1].

4. Results and Discussion

4.1 The Evidence Base

Table 1 lists the 18 studies analysed in [1] with the method, AI tool or framework and key result of each, as reorganised by the present authors.

Study	Method	AI tool / framework	Key result
Mao [6]	Quant. (PLS-SEM)	TAM, TPACK	Attitudes and TPACK shape adoption
Zhang et al. [7]	Mixed	AI virtual students	Improves responsive teaching; hard to transfer
Egara & Mosimege [8]	Mixed	ChatGPT	Useful but reliability doubted
Sapkota & Bondurant [9]	Qual.	ChatGPT	Tasks procedural, low cognitive demand
Mukuka [10]	Quant. (PLS-SEM)	TAM, TPACK	Proficiency varies; support critical
Wijaya et al. [11]	Quant. (SEM)	Chatbots; UTAUT2	Performance expectancy drives intention

Study	Method	AI tool / framework	Key result
Nordby et al. [12]	Qual.	Not specified	Limited knowledge of computational thinking
Getenet [13]	Qual.	ChatGPT	Less accurate than PSTs; some support value
Shin [14]	Mixed	ITS; TPACK, SoC	ITS as servant 55%, partner 39%
Nongni [15]	Qual.	Not specified	Tool choice follows mathematics taught
Dilling & Herrmann [16]	Qual.	LLMs, ChatGPT	Patterns in geometry proof construction
Copur-Gencturk et al. [17]	Mixed (RCT)	ITS; TPACK	Improved CK and PCK
Wijaya et al. [18]	Quant. (LPA)	AI literacy, trust	High trust linked to dependency, lower 21st-C skills
Uygun et al. [19]	Mixed	ChatGPT, AR	Geometric thinking rose to Levels 3–4
Pörn et al. [20]	Quant. (survey)	WST	Open to AI; concerned about risks
Tashtoush, Wardat et al. [21]	Quant. (SEM)	Not specified	Workload and technical support issues
Alissa & Hamadneh [22]	Quant.	Not specified	Moderate use; females higher
Lee & Yeo [23]	Mixed (DBR)	IBM Watson chatbot	Covered 97% of questions

Table 1. The 18 studies analysed in [1]

4.2 Stages and Countries (RQ a)

The 18 studies come from 13 countries: the United States (4), China (3) and one each from Nigeria, Jordan, Finland, the United Arab Emirates, Turkey, Zambia, Norway, Australia, South Korea, Canada and Germany. Ten studies concern pre-service teachers (three primary, five secondary, one primary and middle, one K-12); the other eight concern in-service teachers (two primary, two secondary, four K-12) (Fig. 2). The emphasis on preparing future teachers is clear, but in-service practice is thinly covered.

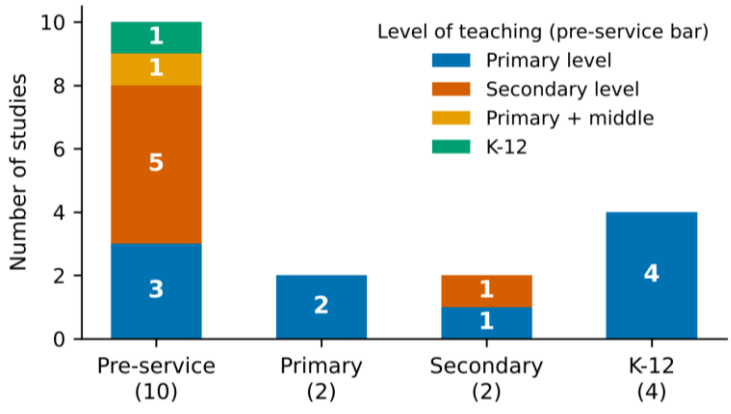


Fig. 2. Teaching stage of the mathematics teachers studied (from [1])

4.3 Methods, Tools and Frameworks (RQ b and c)

Seven studies were quantitative (PLS-SEM, SEM, regression, latent profile analysis), five qualitative (thematic and comparative analysis) and six mixed-methods. From the summary table we derive that TPACK is named in four studies, TAM in two, and UTAUT2, SoC and WST in one each, while twelve studies name no framework; ChatGPT or other LLMs appear in six studies, ITSs in two, chatbots or virtual students in two, and eight concern attitudes without a named tool (derived). ITSs, built for students, were turned towards teachers in two studies: pre-service teachers used them as a servant (55%) more often than a partner (39%) [14], and an ITS simulating mentor dialogue improved teachers' content and pedagogical content knowledge [17]. Virtual-student chatbots let pre-service teachers practise diagnosing fraction misconceptions [23], and AI-assisted AR with ChatGPT advanced geometric thinking [19]. Research on AI robots is represented by a single study.

4.4 Mathematical Content (RQ d)

Content coverage is thin (Table 2). Primary-level topics dominate, middle school appears through ratio and proportion, geometry proofs and solids are used for geometric thinking, and high-school content is not specifically studied. Many studies examine attitudes and acceptance without mathematics content.

Level	Content	Tool
Primary	Area model for fractions; word problems; computational thinking	ChatGPT; not specified
Primary / middle	Fraction misconceptions; thinking skills with generative AI	Chatbot; generative AI
Middle (grades 6–7)	Ratio and proportion	ITS mentor simulation
Geometry (various)	Angle-theorem proofs; Platonic solids	ChatGPT; AI-assisted AR
Secondary / high school	Not specifically studied	–

Table 2. Mathematical content reported by school level

4.5 Challenges (RQ e)

Pedagogical barriers include difficulty moving from traditional to AI-supported teaching and ChatGPT tasks of low cognitive demand [9]. Technological limits include inaccurate answers, weak performance on complex problems and proofs that need manual correction [8], [16]. Training gaps, increased workload and varying proficiency limit adoption [10], [21]. Ethical and equity concerns include data security, over-reliance that may reduce problem solving and creativity [18], and unequal access to resources [22]. Li et al. group these into teacher-specific, tool-specific and systemic challenges (Fig. 3) and call for professional development, better tools and systemic frameworks.

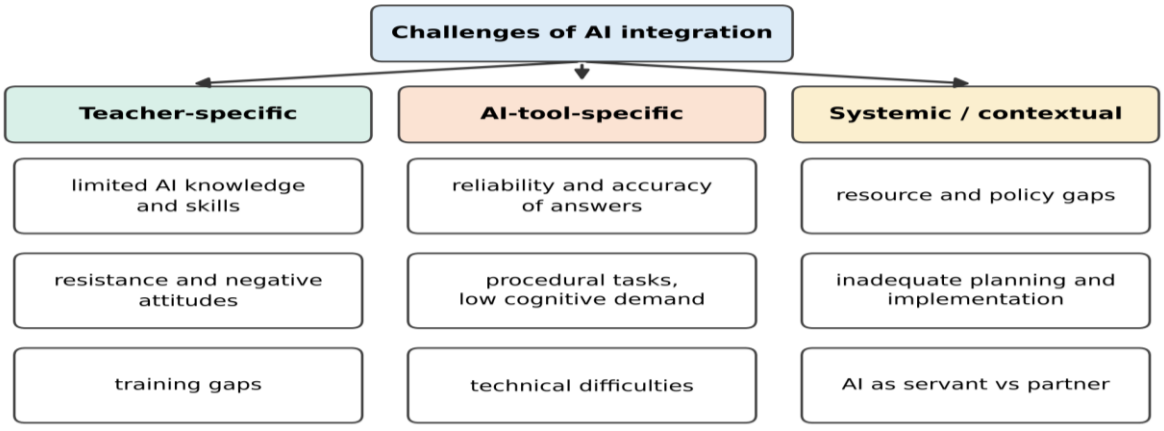


Fig. 3. Three types of challenges identified in [1]

4.6 Critical Discussion

Three points stand out. First, the evidence is early-stage: 18 studies, mostly on pre-service teachers and often simulation-based, so conclusions about classroom practice are tentative. Second, frameworks are broad and mostly not AI-specific, so adoption factors are known better than learning effects. Third, mathematics itself is under-examined: few studies test whether AI-generated solutions, tasks or proofs are correct and cognitively demanding. We also note small inconsistencies in the source: one study cited in its discussion is not in its summary table, and its flow diagram labels the post-de-duplication box with the number of duplicates; we used the text counts, which are consistent. No study-quality appraisal was reported, so weak and strong studies weigh equally.

5. Benefits and Challenges of the Evidence Synthesis

Benefits. The PRISMA process makes selection transparent and repeatable; the five questions give a broad map of stages, countries, methods, tools, content and challenges; and the findings translate into clear priorities for teacher education and research planning. **Challenges.** The evidence rests on only three databases, English journal articles and a narrow search string; arXiv returned no records; the field changes quickly and the search ended in December 2024; and the synthesis here inherits these limits because it depends on [1].

6. Proposed Enhancements

The following are design-level suggestions of the present authors, derived from the gaps above; they are not findings of [1] and have not been implemented or tested.

Gap	Proposed enhancement	Expected benefit
Teacher training gap	TPACK-based AI competence units aligned with the UNESCO framework [3]	Raises teacher knowledge and confidence
Unreliable AI answers	Answer-checking helper that compares AI solutions and proofs with a verified solver	Safer classroom use
Secondary content gap	Curriculum-aligned algebra and proof task bank with higher-order prompts	Fills secondary-level evidence gap
No quality appraisal	Add study-quality scoring and risk-of-bias checks when updating the review	More reliable synthesis
Few regions	Repeat the review and a teacher survey for the Indian K-12 setting	Adds an under-studied region
Simulation-only evidence	Classroom pilot with in-service teachers over a term	Evidence beyond simulation

Table 3. Proposed enhancements

A suitable next step is to run an independent, updated PRISMA search with an appraisal stage and, in parallel, a small classroom pilot of the competence units and answer-checking helper.

7. Future Scope and Conclusion

Li et al. [1] recommend expanding databases and countries, studying secondary teachers and specific content such as algebra and proof, broadening teacher demographics, and carrying out cross-cultural and longitudinal studies with attention to ethics and data authenticity. The enhancements in Section 6 extend these directions.

AI integration among K-12 mathematics teachers is at an early stage. The evidence assembled in [1] shows research concentrated on pre-service teachers and on a few countries, ChatGPT-type tools and ITSs with promise but limited by accuracy and hypothetical use, widely used but general adoption frameworks, thin mathematical content, and challenges that are teacher-specific, tool-specific and systemic. Closing these gaps needs targeted professional

development, more accurate and cognitively demanding AI tools, and systemic frameworks for resources and policy, together with classroom-based, cross-cultural and longitudinal studies.

Source and licence note. The systematic review summarised here is by D. Li, S. Osman, N. S. A. Alhassora, J. A. Kumar and S. K. S. Husain [1], published in IEEE Access under the Creative Commons Attribution 4.0 licence; figures in this paper are redrawn or derived by the present authors from the information in [1].

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