

UTILIZING ARTIFICIAL INTELLIGENCE TOOLS AS SCAFFOLDING IN MATHEMATICS EDUCATION

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Abstract

This systematic review maps research on artificial intelligence (AI) tools used to scaffold mathematics learning. A comprehensive literature search was conducted in the Web of Science and Scopus databases on August 15, 2025. Of 88 records identified, 29 articles met the inclusion criteria. A Data Analysis Form organized extraction around six questions: publication year, methodology, tools, mathematical topics, advantages, and limitations. Categories were derived through content analysis and are reported as frequencies. Nine articles used qualitative methods, ten quantitative, and ten mixed; experimental designs were the most common ($f = 11$). ChatGPT ($f = 15$) and Gemini were the tools reported most often, and problems ($f = 12$) and geometry ($f = 7$) the most studied topics. Immediate feedback ($f = 17$), individualized learning ($f = 13$), and interest, curiosity, and motivation ($f = 11$) were the advantages reported most often. Creative and critical thinking ($f = 11$), reliability and ethics ($f = 10$), and access and infrastructure ($f = 9$) were the most frequent limitations. These counts record what the reviewed studies reported and do not establish effect sizes.

Keywords: artificial intelligence tools, scaffolding approach, mathematics education, systematic review

INTRODUCTION

Research on artificial intelligence (AI) in mathematics education concerns both the tools students use and the support they receive while learning. Generative AI has opened possibilities for adapting instruction to individual learners (National Council of Teachers of Mathematics [NCTM], 2024). Altun (2024) places this development within an interactive learning process involving students' cognitive development. For mathematics teaching, the relevant question is how such support contributes to reasoning and problem solving. A tool may provide an answer or explanation, but its instructional value also depends on the student's opportunity to work through the mathematical ideas. This review examines that supporting role through the concept of scaffolding.

Vygotsky's Zone of Proximal Development (ZPD) distinguishes what a learner does alone from what the same learner does with guidance (Vygotsky, 1978). Scaffolding is the temporary support given inside that gap. In mathematics it can reduce the load of unfamiliar concepts and procedures (Y. R. Kim et al., 2025), and it is withdrawn as the student takes over the task (Cabugwason et al., 2024; Zawacki-Richter et al., 2019). Figure 1 maps the supporting role attributed to AI tools onto this framework.

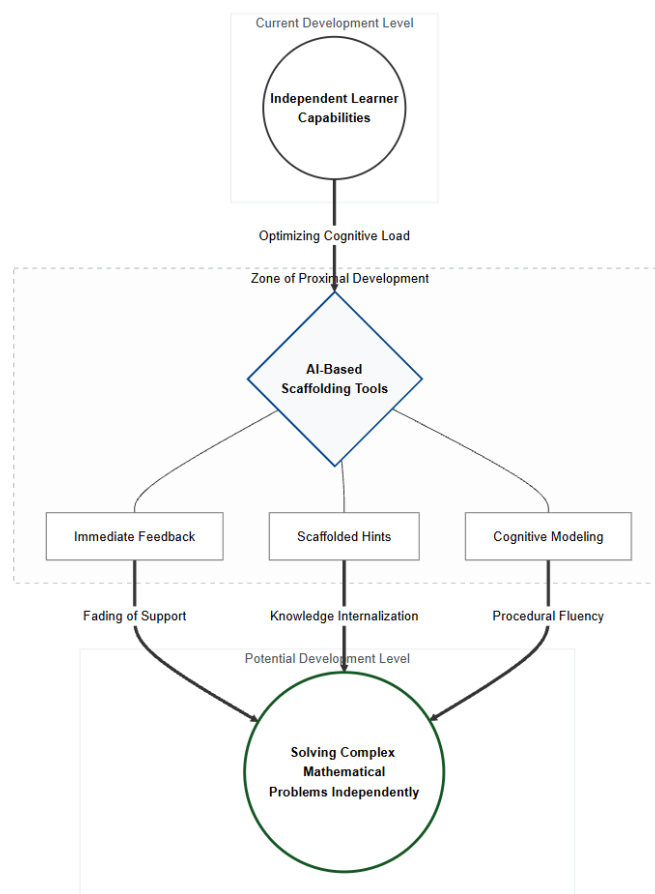


Figure 1. AI tools as scaffolding within Vygotsky's Zone of Proximal Development (ZPD).

Providing timely, individual guidance becomes difficult when students in the same classroom progress at different rates. Digital scaffolding offers one way of supplementing that guidance. In the framework illustrated in Figure 1, AI tools can provide feedback adapted to the learner while the teacher remains involved in the learning process (Luckin et al., 2016; Nayiroğlu & Tutak, 2024; Vygotsky, 1978). Studies describe systems that follow students' solution steps, identify possible misconceptions, and offer hints in response to their difficulties (Altun, 2024; Nayiroğlu & Tutak, 2024; Mohamed et al., 2022; Nurlaelah et al., 2024; Park, 2020). ChatGPT, Gemini, and intelligent tutoring systems differ in their design, so their use as instructional assistants requires attention to the kind of support each provides.

Attention to generative tools within this literature is increasing (Nguyen & Pham, 2025). Problem solving and geometry are useful settings for studying a scaffolding role, since both require learners to link intermediate steps, representations, and reasoning. Step-by-step guidance may assist with these demands; whether it supports understanding depends on how a student uses it.

Personalization appears in studies of both intelligent tutoring systems and AI-supported lesson planning. These applications adapt task difficulty to students' readiness or provide support when errors occur (Ayeti et al., 2024; Hariyanto et al., 2025; Villegas-Ch et al., 2025). Güreffe et al. (2024) also examine AI as an aid to teachers' planning. Students' and pre-service teachers' perceptions matter in these settings because they shape how the tools are used. Reports of greater interest, curiosity, and motivation coexist with concerns about pedagogical limitations (Altun, 2024; Hacıoğlu Seven & Erümit, 2025; Rizos et al., 2024; Shin et al., 2024). These findings call for attention to the conditions of use as well as the reported benefits.

Three concerns recur: effects on creative and critical thinking, the reliability of generated responses, and data ethics (Hacıoğlu Seven & Erümit, 2025; McKenzie et al., 2024). Reliance on ready-made answers may reduce the independent effort scaffolding is meant to build. Language support and the

accuracy of mathematical visualizations are further difficulties, discussed together with the need for ethical frameworks by Altun (2024) and Boztepe (2025).

Table 1 groups this literature by pedagogical contribution, mathematical application, limitation, and user role. Studies of teacher and student perceptions (Awang et al., 2025; Y. R. Kim et al., 2025) ask different questions from work on algebra, geometry, problem solving, and problem posing (F. Chen et al., 2025; Yanar & Ergene, 2025). Drawing these strands together shows which settings have been examined and which have not (Mohamed et al., 2022). Our main question was: “What are the general trends of research on the use of AI tools as scaffolding in mathematics education?” Six sub-questions guided the review.

- How are the reviewed studies distributed by publication year?
- What research methods, designs, and analysis techniques do the studies use?
- Which AI tools are investigated?
- Which mathematical topics are addressed through AI scaffolding?
- What advantages do the studies report for this use of AI?
- What limitations do they report?

Table 1. Synthesis of the literature on AI-based scaffolding in mathematics education.

Dimension	Key Themes and Findings in the Literature	Representative Studies
Pedagogical Contributions	Feedback on mathematical errors; content adapted to individual pace; curiosity and attitudes toward mathematics; cognitive load management; higher-order thinking.	Getenet (2024); İncemen & Öztürk (2024); Svičević et al. (2025); Nguyen & Pham (2025)
Application Areas and Subjects	Problem solving and problem posing; visualization and spatial reasoning in geometry; procedural steps and conceptual understanding in algebra and fractions; lesson planning and material development.	Kaymak et al. (2025); Yanar & Ergene (2025); Gürefe et al. (2024); Antunes Ribeiro et al. (2024)
Limitations and Challenges	Dependence on generated answers; narrowing of original solution strategies; bias; data privacy; response accuracy; language support; access to tools.	Boztepe (2025); Altun (2024); Yunianto et al. (2024); Yeşilyurt et al. (2024)
User Perceptions and Roles	AI as instructional assistant; TPACK among pre-service teachers; variation in learner trust and acceptance of AI guidance.	Awang et al. (2025); Y. R. Kim et al. (2025); Tapan Broutin (2024)

METHOD

The review procedure comprised study selection, extraction with a common analysis form, and content analysis. The following subsections describe these stages and the checks on coding consistency.

Research Design

To synthesize and evaluate the selected literature, this study employed a systematic review combined with qualitative content analysis. Specifying selection criteria in advance supports a focused synthesis of existing research and the identification of gaps (Munn et al., 2018; Yılmaz, 2021). Systematic review methods also provide a basis for critically examining the studies brought together (Farrow et al., 2020; Newman & Gough, 2020). Here, the review was organized around the six sub-questions so that methodological characteristics, applications, advantages, and limitations could be considered across the same set of articles.

Data Collection Process

The database search took place on 15 August 2025. Web of Science (WoS) and Scopus were selected due to their comprehensive and rigorous coverage of peer-reviewed scientific literature. Table 2 records the databases, keywords, Boolean query, subject categories, and publication types used to define the search.

Table 2. Data collection criteria.

Criterion	Value
Databases	Web of Science (WoS) and Scopus
Keywords	artificial intelligence, AI, generative AI, machine learning, ChatGPT, educational technology, mathematics education, math education, mathematics teaching, mathematics learning, scaffolding, teacher support, guidance
Search Query	("artificial intelligence" OR "AI" OR "generative AI" OR "ChatGPT" OR "machine learning" OR "educational technology") AND ("mathematics education" OR "math education" OR "mathematics teaching" OR "mathematics learning") AND ("scaffolding" OR "guidance" OR "teacher support")
Categories	Education & Educational Research and Education Scientific Disciplines
Publication Type	Article and Early Access

Keyword selection followed a review of the relevant literature, with attention to the importance of search terms and their combination in identifying suitable studies (Çakmak, 2024). The query in Table 2 joins three groups: AI and educational technology terms, mathematics education terms, and scaffolding or guidance terms. Alternatives within each group are connected by OR; AND links the three groups. This structure reflects the need to combine terms in accordance with the research focus (Çakmak, 2024). The listed education categories and publication-type filters narrowed the retrieved material, after which the remaining studies were screened for relevance to the review. Figure 2 records the sequence of selection stages. The full keyword list and query are retained in Table 2.

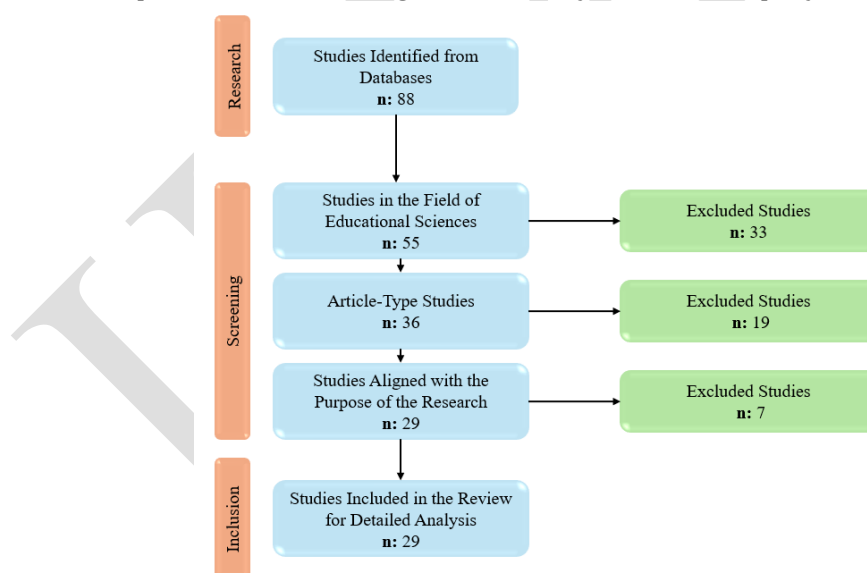


Figure 2. Data collection process flowchart.

The selection process shown in Figure 2 left 29 studies for analysis against the six sub-questions.

Data Analysis

As shown in Table 3, a data analysis form was developed to record uniform information for each study. Its items correspond to the six sub-questions.

Table 3. Data analysis form.

Title of the Study:
1. Year of Publication:
2. Adopted Methods:
• Research Method:
• Research Design:
• Data Analysis Technique:
3. Artificial Intelligence Tools Used for Scaffolding:
4. Mathematical Topic(s) for Which AI Tools Were Used as Scaffolding:
5. Advantages of Using Artificial Intelligence Tools as Scaffolding in Mathematics Education:
6. Limitations Encountered in the Use of Artificial Intelligence Tools:

Each study was systematically reviewed, and the corresponding data analysis form was completed. A month later we repeated the evaluation in full, which gave us a second pass to check against the first. The completed forms were then subjected to content analysis and organized into codes, categories, and themes to ensure a clear and systematic presentation (Creswell & Poth, 2018; Lyhne et al., 2025).

To enhance the credibility of the findings, a peer debriefing process was conducted with an expert in qualitative research. After that evaluation we discussed the categories and themes developed for Items 5 and 6 of the data analysis form until we reached consensus. The Results section presents the final findings as figures, graphs, and tables with frequency values, so that the data can be read and interpreted directly.

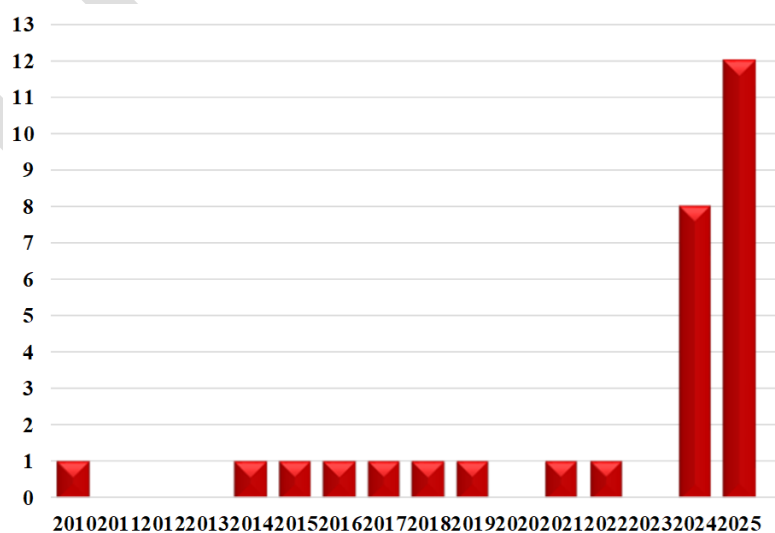
Validity and Reliability

Two distinct measures were employed to ensure analytical consistency. First, we analyzed the data twice, a month apart, and compared the two passes. Second, we compared our coding with that of an experienced field expert; agreement reached 96%. Miles et al. (2018) treat agreement of 80% or higher between coders as the threshold for reliable analysis, so our coding clears it comfortably. Reporting the data collection and analysis steps in the detail given above also makes the review replicable, which strengthens validity further.

RESULTS

We report below what the 29 articles show, following the order of the sub-questions.

Figure 3 shows how these studies are distributed across years, which was our first sub-question.


Figure 3. Distribution of the 29 reviewed studies by publication year.

The selected articles span 2010 to 2025. One article was published in each of 2010, 2014, 2015, 2016, 2017, 2018, 2019, 2021, and 2022. Most articles in the set appeared in 2024 and 2025, with the highest count in 2025 (Figure 3).

The methodological profile is presented in three parts: research methods in Figure 4, designs in Figure 5, and analysis techniques in Figure 6.

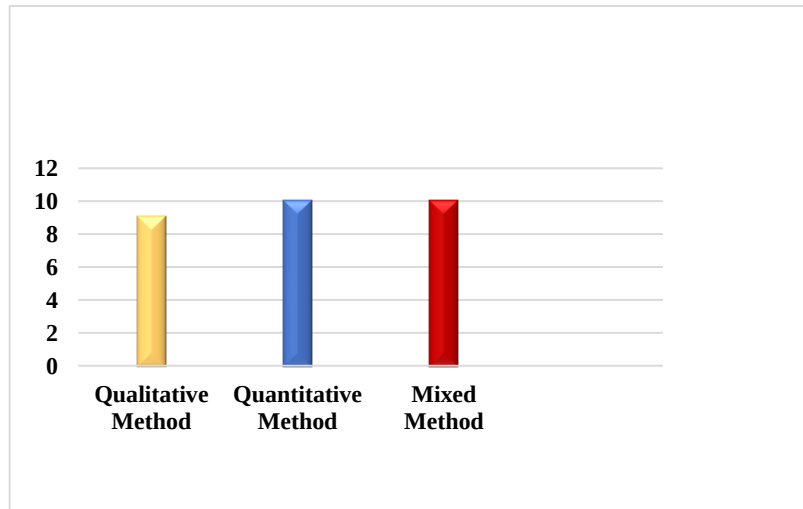


Figure 4. Distribution of the 29 reviewed studies by research method.

Nine studies were classified as qualitative, ten as quantitative, and ten as mixed methods (Figure 4). The three categories are therefore similar in frequency within this review.

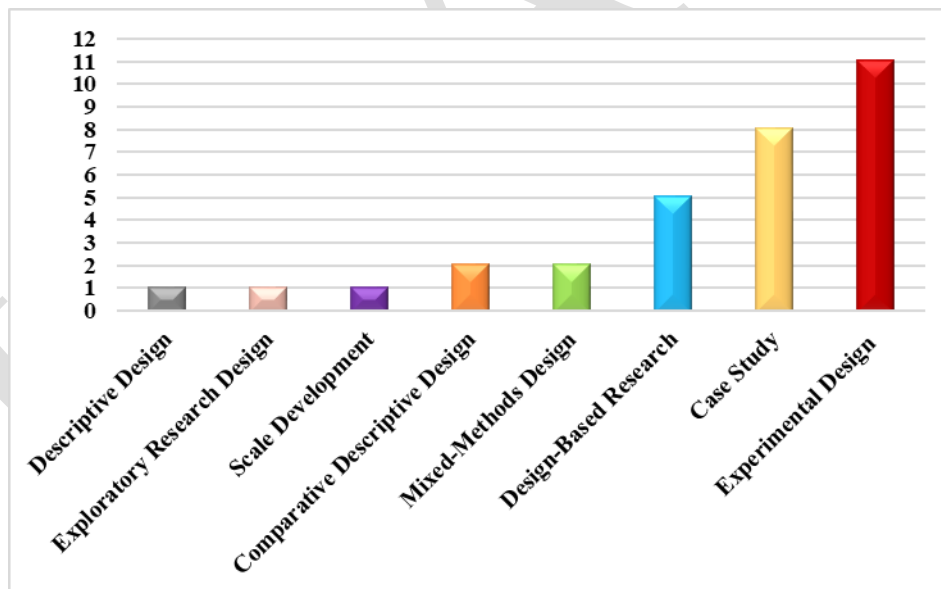


Figure 5. Distribution of the 29 reviewed studies by research design.

Figure 5 records eight design labels: descriptive, exploratory, comparative descriptive, mixed-methods, experimental, scale development, design-based research, and case study. Experimental design occurred most often ($f = 11$), followed by case study ($f = 8$) and design-based research ($f = 5$).

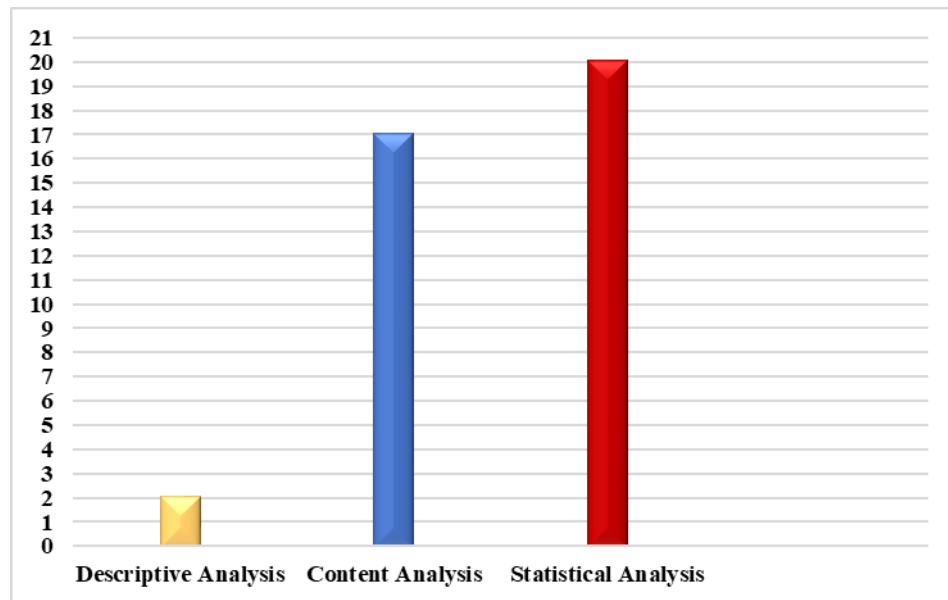


Figure 6. Distribution of the 29 reviewed studies by data analysis technique.

Three analysis techniques appear in Figure 6: descriptive, content, and statistical. Statistical analysis was the most frequent ($f = 20$), followed closely by content analysis ($f = 17$). Descriptive analysis was rare ($f = 2$). The first two counts reflect the mix of quantitative, mixed, and qualitative studies in the set.

Our third sub-question asked which AI tools the studies used. Figure 7 reports the distribution.

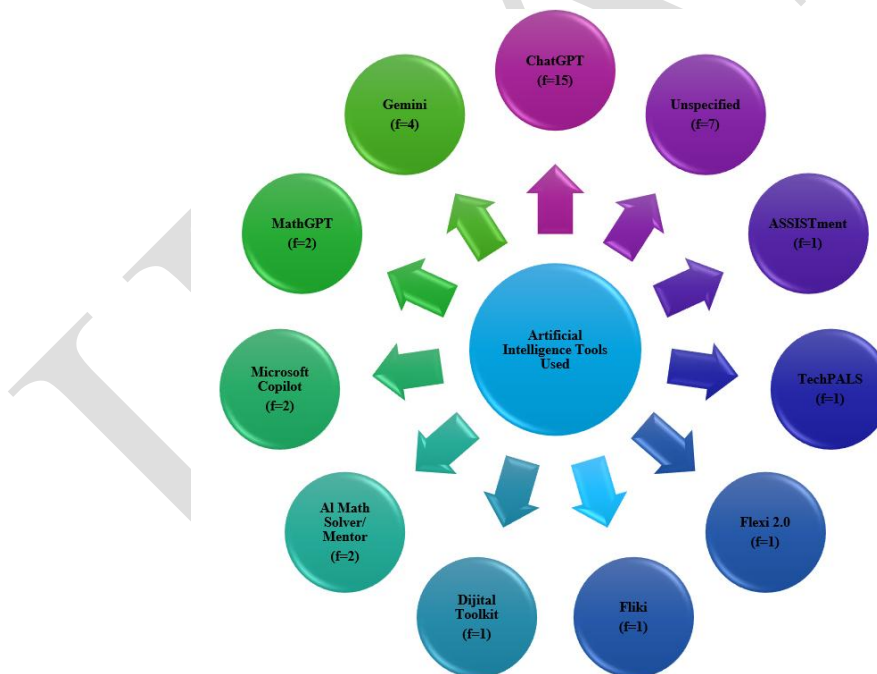


Figure 7. Types of AI tool used for scaffolding across the reviewed studies.

Ten named tools appear across the reviewed studies, together with a category for studies that left the tool unnamed (Figure 7). The named tools are ChatGPT, Gemini, MathGPT, Microsoft Copilot, AI Math Solver/Mentor, Digital Toolkit, Fliki, Flexi 2.0, TechPALS, and ASSISTments. ChatGPT is far ahead of the rest ($f = 15$), with Gemini second among the named tools ($f = 4$). In seven studies ($f = 7$) the tool used was never identified, which is a reporting gap worth noting.

Our fourth sub-question concerned mathematical content. Table 4 reports the topics in which AI tools were used to provide scaffolding.

Table 4. Mathematical topics in which AI tools provided scaffolding.

Topics	Subtopics	f
Problems	-Problem Posing -Problem Solving	12
Geometry	-Geometric Shapes -Circle and Disk -Transformational Geometry -Spatial Thinking	7
Algebra		4
Numbers and Operations		4
Fractions	-Fraction Problems -Operations with Fractions	3
Exponential Expressions		1
Ratio and Proportion		1
Fractals		1
Calculus-1		1
Not Specified	-Lesson Plan Development -Instructional Material Development	5

Note. f = frequency reported in the reviewed studies.

The studies cover nine mathematical topics (Table 4): problems, geometry, algebra, numbers and operations, fractions, exponential expressions, ratio and proportion, fractals, and Calculus I. Two of these account for most of the work, namely problems ($f = 12$) and geometry ($f = 7$). Studies concerned with lesson planning and instructional material development named no specific topic at all.

Our fifth sub-question asked what advantages the studies reported. Table 5 summarizes them.

Table 5. Advantages reported for AI tools used as scaffolding.

Advantages	f
Providing Immediate Feedback	17
Supporting Individualized Learning	13
Enhancing Interest, Curiosity, and Motivation Toward Mathematics	11
Pedagogical Support	8
Gradual Scaffolding	6
Supporting Problem Solving	5
Concretizing and Modelling Abstract Concepts	3
Identifying Conceptual Misconceptions	2
Providing Rapid Access to Information	2

Note. f = frequency reported in the reviewed studies.

Immediate feedback is the advantage reported most often ($f = 17$). Support for individualized learning comes second ($f = 13$), and gains in interest, curiosity, and motivation toward mathematics third ($f = 11$). Table 5 lists the remainder: pedagogical support, gradual scaffolding, support for problem solving, concretizing and modelling abstract concepts, identifying conceptual misconceptions, and rapid access to information.

Our sixth and final sub-question concerned limitations. Table 6 reports these.

Table 6. Limitations reported for AI tools used as scaffolding.

Limitations	f
Creative and Critical Thinking	11
Reliability and Ethics	10
Access and Infrastructure	9
Language-Related Issues	8
Insufficient Teacher Support and Role	8
Pedagogical Limitations	2
Visualization Limitations	2

Note. f = frequency reported in the reviewed studies.

Table 6 groups the reported limitations into seven categories. Creative and critical thinking was the most frequent category ($f = 11$), followed by reliability and ethics ($f = 10$) and access and infrastructure ($f = 9$). Language-related issues and insufficient teacher support and role were each reported with $f = 8$. Pedagogical and visualization limitations complete the table. These frequencies indicate how often concerns appeared in the reviewed material; they do not measure their severity.

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

Selected articles cluster in 2024 and 2025. Greater accessibility of AI tools is one explanation discussed in the literature (Awang et al., 2025; Hwang & Tu, 2021), though publication counts alone cannot establish a cause. Other reviews report comparable growth across AI applications in mathematics education (Boztepe, 2025; Demircioğlu et al., 2024; Nguyen & Pham, 2025; Yeşilyurt et al., 2024). Our figures describe the articles selected here and the literature available on 15 August 2025.

The distribution of nine qualitative, ten quantitative, and ten mixed-methods studies shows that the selected literature draws on several research approaches. Hwang and Tu (2021) likewise describe methodological variety in their review of AI in mathematics education. Güzey et al. (2023), whose content analysis covers educational sciences more broadly, report a greater concentration of quantitative work. Differences in disciplinary scope and the periods covered may contribute to these contrasting distributions. The counts in our review describe methodological choices; they do not by themselves indicate the strength of the resulting evidence.

Experimental designs were the most frequent design category, followed by case studies and design-based research. The emphasis on experiments is consistent with research that examines relationships between instructional interventions and outcomes (Creswell & Plano Clark, 2018; Slavin, 2020). Case studies and design-based work provide opportunities to examine how scaffolding is used in particular learning settings. Scale development was less represented. Research methods and research designs were recorded separately in this review, so the frequency of the mixed-methods design label should not be treated as the number of studies using mixed methods overall. Further work that integrates qualitative accounts of learning with quantitative outcomes could clarify how students use the support they receive. Statistical analysis was the most common analysis technique, alongside content and descriptive analysis, consistent with the presence of quantitative and mixed-methods studies.

The reviewed studies identify 10 named AI tools and an unspecified-tool category. ChatGPT and Gemini appear most often, a pattern also reported by Demircioğlu et al. (2024) and Opesemowo and Adewuyi (2024). Their availability and natural-language interaction may help explain their use, although the review did not test why researchers selected particular tools. Frequency of use should therefore be distinguished from evidence of pedagogical suitability. The unnamed category also limits how precisely the applications can be compared.

Problems ($f = 12$), geometry ($f = 7$), algebra, and numbers and operations account for most of the topics studied, a pattern also reported in other reviews of AI in mathematics education (Awang et al., 2025; Hacıoğlu Seven & Erümit, 2025). The distribution shows where research has been done. It says little about other mathematical domains, and it does not show that the most-studied topics gain most from AI scaffolding.

Immediate feedback was the most frequently reported advantage. Awang et al. (2025) and Hwang and Tu (2021) discuss its potential to help learners recognize errors before misconceptions persist. Individualized learning was also prominent, consistent with accounts by Awang et al. (2025), Boztepe (2025), and Nayıroğlu and Tutak (2024). Reports concerning interest, curiosity, and motivation extend the discussion to affective aspects of learning (Hwang & Tu, 2021). In this review, these categories record reported advantages, rather than comparable estimates of improvement. Pedagogical support, gradual scaffolding, and problem-solving assistance also feature in the studies. Together, they are consistent with treating AI as a means of supporting the teacher's work in structuring learning (Cope et al., 2020).

Creative and critical thinking was the limitation reported most often ($f = 11$). Hacıoğlu Seven and Erümit (2025) raise the same concern for mathematics education, and related work questions how much room prescribed approaches leave for autonomous, creative, and original thinking (du Boulay, 2023; Voskoglou & Salem, 2020; Zawacki-Richter et al., 2019). Teacher or parental guidance may help learners weigh suggestions and look for alternatives; this review cannot show that it removes the risk. Reliability and ethics ($f = 10$) form a second category, largely concerning users' data. Access and infrastructure ($f = 9$) follow. Continued technical development may resolve some of these, but the frequencies give no basis for assuming they will disappear.

Conclusion

This review covers 29 articles on AI scaffolding in mathematics education indexed in Web of Science and Scopus. It maps publication years, methodologies, tools, mathematical topics, reported advantages, and reported limitations. The strongest concentrations are ChatGPT and Gemini, problems and geometry, and immediate feedback. These patterns describe the selected research, not the effectiveness of any tool.

The reports of teacher-related and pedagogical limitations support retaining an active role for teachers when AI is used as scaffolding. The educational purpose remains to help learners progress toward independent work. The findings therefore favor considering AI support in relation to classroom guidance and the learner's own reasoning, with attention to both the assistance offered and the limitations reported.

Limitations and Recommendations

The review covers journal articles retrieved from WoS and Scopus at the search date. It does not include theses, book chapters, or full-text conference proceedings. A wider search could examine material available through ERIC, TR Dizin, Google Scholar, ResearchGate, and the National Thesis Center of the Council of Higher Education (YÖK), allowing comparison with the present article-based dataset. The findings are also time-bound: they reflect the literature available on 15 August 2025 in a rapidly changing field.

The following recommendations concern the less examined topics, range of tools, and implementation needs identified in the review.

- Extend middle school research to probability and statistics, radical numbers, and equations. At undergraduate level, examine scaffolding in analytic geometry, linear algebra, and abstract mathematics.
- Investigate a wider range of AI tools and evaluate the support each provides during mathematical tasks.

- Offer teachers and academics training on using AI to scaffold learning within their teaching practice.
- Direct further tool development toward the limitations reported in the studies.

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Ethics and Conflict of Interest

This study was conducted using the systematic review method on previously published, publicly available journal articles. It involves no human or animal participants and no collection of personal data; therefore, ethics committee approval is not required under the TR Dizin ethical criteria. All procedures were nevertheless carried out in accordance with the relevant ethical principles, guidelines, and regulations governing scientific research and publication. The authors declare that they have no conflict of interest. All three authors contributed equally to the design of the study, the data extraction and analysis, and the writing of the manuscript. All authors read and approved the final version of the manuscript. Artificial intelligence-based tools were used solely for language support. The authors are fully responsible for the accuracy and integrity of the manuscript.

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Author Contribution

All authors contributed equally to the research. All authors read and approved of the final manuscript

Data Availability

The data analysis forms and coding files supporting this review are available from the corresponding author upon reasonable request.

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APPENDIX A. STUDIES INCLUDED IN THE REVIEW

No	Author(s) and year	Journal
1	Acosta-Gonzaga & Walet (2018)	Assessment & Evaluation in Higher Education
2	Albano & Dello Iacono (2019)	International Journal of Educational Technology in Higher Education
3	Alvarez (2024)	Jurnal Ilmiah Ilmu Terapan Universitas Jambi
4	Antunes Ribeiro et al. (2024)	Revista Pesquisa Qualitativa
5	Awi et al. (2025)	Cogent Education
6	Cayton-Hodges et al. (2015)	Journal of Educational Technology & Society
7	F. Chen et al. (2025)	Psychology in the Schools
8	Y. Chen (2025)	International Journal of Web-Based Learning and Teaching Technologies
9	Dasari et al. (2024)	Frontiers in Education
10	Ergene & Çaylan Ergene (2025a)	Education and Information Technologies
11	Ergene & Çaylan Ergene (2025b)	Digital Experiences in Mathematics Education
12	Foster et al. (2016)	Journal for Research in Mathematics Education
13	Getenet (2024)	International Electronic Journal of Mathematics Education
14	Goldenberg & Carter (2021)	British Journal of Educational Technology
15	Gürefe et al. (2024)	Behavioral Sciences
16	Y. Kim et al. (2017)	Educational Technology Research and Development
17	Y. R. Kim et al. (2025)	School Science and Mathematics
18	Korkmaz Güler & Yıldız (2025)	The Journal of Educational Research
19	Kubsch et al. (2022)	Frontiers in Education
20	Liu et al. (2025)	Computers and Education: Artificial Intelligence

No	Author(s) and year	Journal
21	Memiş (2025)	Journal of Pedagogical Research
22	Roschelle et al. (2010)	Educational Technology Research and Development
23	Svičević et al. (2025)	Computer Applications in Engineering Education
24	Tapan Broutin (2024)	Yükseköğretim Dergisi
25	Wilkerson-Jerde (2014)	Educational Technology Research and Development
26	Witherspoon et al. (2024)	AERA Open
27	Yanar & Ergene (2025)	Journal of Pedagogical Research
28	Yunianto et al. (2024)	International Journal of Education in Mathematics, Science and Technology
29	Zhang et al. (2025)	British Journal of Educational Technology