

# Research Evolution of Artificial Intelligence in Mathematics Learning: A Bibliometric Review from 2015 to 2026



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- A – Research concept and design
- B – Collection and/or assembly of data
- C – Data analysis and interpretation
- D – Writing the article
- E – Critical revision of the article
- F – Final approval of article



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## ABSTRACT

**Background:** The recent growth of Artificial Intelligence (AI) has attracted increasing attention in mathematics learning research, yet a comprehensive understanding of its development remains limited.

**Objective:** This study aims to explore the research evolution of AI in mathematics learning from 2015 to 2026 using a bibliometric approach.

**Method:** Data were collected from the Scopus database, yielding 169 publications comprising journal articles and conference papers. Analysis was conducted using Bibliometrix and VOSviewer to examine publication trends, leading sources, contributing countries, influential references, keyword co-occurrence, and thematic evolution.

**Results:** The findings reveal a significant growth in publications, particularly after 2021, reflecting expanding research interest. The United States and China are the most productive contributors, while several recent works demonstrate strong citation impact. Keyword and thematic analyses reveal a focus on the intersection of AI and mathematics education, with emerging topics such as generative AI, chatbots, and personalized learning.

**Conclusion:** Overall, the research of AI in mathematics learning has shifted from general technological exploration toward more pedagogically oriented applications. These findings suggest that educators and curriculum developers should prioritize AI tools for personalized and effective learning, while researchers are encouraged to focus empirically evaluating their impact in real classroom contexts.

**Keywords:** Artificial Intelligence, Mathematics Learning, Bibliometric Analysis.

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## INTRODUCTION

The rapid development of digital technologies has significantly transformed the global educational landscape, influencing how knowledge is accessed, constructed, and experienced nowadays (Alam & Mohanty, 2023; Saputro et al., 2025). Among these emerging technologies, Artificial Intelligence (AI) has become one of the most influential innovations in contemporary education, offering substantial potential to enhance teaching and learning processes (Demartini et al., 2024; Nykonenko, 2023).

In mathematics learning, the role of AI is particularly critical due to the abstract nature of the subject (Cho & Kim, 2025). Many students experience difficulties in connecting conceptual understanding with symbolic representations and problem-solving procedures. AI can address the dual cognitive demands of linguistic comprehension and mathematical reasoning, particularly in solving word problems; for instance, generative AI systems such as ChatGPT-based models have been shown to improve students' problem-solving strategies and engagement, making abstract mathematical tasks more manageable (Liu et al., 2025). These challenges highlight the urgency of integrating AI-based approaches that can provide personalized explanations, real-time feedback, and step-by-step scaffolding to support students' mathematical reasoning (Torres-Peña et al., 2024). At the same time, the increasing use of AI in mathematics learning also raises important concerns related to overreliance on automated solutions and the potential decline of deep conceptual understanding (Akçay & Altiner, 2026; Karamuk, 2025). Therefore, understanding how AI research in mathematics learning has developed is essential for ensuring its responsible implementation.

AI technologies have demonstrated potential in facilitating adaptive learning, automating feedback, and improving students' conceptual understanding in mathematics (bin Mohamed et al., 2022; Dabingaya, 2022). In practice, AI is implemented through various systems such as Intelligent Tutoring Systems (ITS), adaptive learning platforms, and more recently, generative AI technologies capable of producing explanations, exercises, and feedback dynamically (Li et al., 2022; Son, 2024). These systems enable personalized learning experiences by analyzing students' responses and adjusting learning pathways according to individual needs (Albuquerque et al., 2025, Lin et al., 2023; Semmouri et al., 2026). The emergence of generative AI, such as ChatGPT, has further expanded the potential of AI by enabling interactive dialogue, multiple solution strategies, and immediate feedback that supports students' reasoning processes (Wardat et al., 2023; Liu et al., 2025).

Despite its potential, the integration of AI in mathematics education also presents several challenges. These include limited teacher readiness, lack of pedagogical frameworks, and ethical concerns such as responsible use of AI (Agarwal et al., 2023; Ramesh, 2025; Susilawati et al., 2025). These issues indicate that the development of AI in mathematics learning is not only a technological matter but also involves pedagogical and ethical considerations that require careful examination.

Over the past decade, several review studies have attempted to explore the application of AI in mathematics learning. For instance, bin Mohamed et al. (2022) examined the applications of AI in mathematics education and identified key themes and benefits. However, their study is limited by a relatively small sample size and the reliability on qualitative synthesis, which does not analyze citation structures, collaboration networks, or the broader intellectual organization of the field. Similarly, Nguyen and Pham (2025) conducted a systematic review to explore trends within this field over a longer period. While their study provides a comprehensive overview of AI tools and applications, it remains constrained by a limited number of selected articles and a predominantly descriptive approach. The study does not examine large-scale publication patterns, citation impact, or network-based

relationships among studies. In addition, absence of longitudinal thematic evolution analysis limits its ability to capture the rapidly evolving nature of AI research, particularly in the era of generative AI.

To address this gap, this study proposes a bibliometric analysis as a novel approach to systematically map the development of AI research in mathematics learning. Unlike previous studies, this research utilizes a larger dataset and applies quantitative techniques to analyze citation structures, keyword co-occurrence networks, and thematic evolution (Aria & Cuccurullo, 2017). This approach enables a more comprehensive understanding of the intellectual structure and dynamic development of the field.

Therefore, the purpose of this study is to investigate the evolution of research on AI in mathematics learning from 2015 to 2026 using a bibliometric approach. Specifically, this study aims to (1) analyze publication trends, (2) identify leading journals, countries, and influential references, (3) examine collaboration networks, and (4) explore keyword co-occurrence patterns and thematic evolution in the field.

The findings of this study are expected to contribute both theoretically and practically. Theoretically, this study provides a comprehensive and data-driven mapping of the intellectual structure and research trends in AI-based mathematics learning. Practically, the results offer insights for researchers, educators, and policymakers in understanding emerging topics, identifying research opportunities, and guiding the effective integration of AI technologies in mathematics learning.

## METHODS

### Data Source and Search Strategy

To collect publications on artificial intelligence (AI) in mathematics education, the data were extracted from the Scopus database (<https://www.scopus.com>) on 23 February 2026. Scopus was selected because it is one of the most comprehensive and widely used academic databases, providing reliable bibliographic information, extensive journal coverage, complete citation data, and compatibility with various bibliometric analysis tools (Gao et al., 2022). Its structured metadata and export features facilitated systematic data retrieval and subsequent bibliometric processing.

In particular, Scopus was chosen because it effectively indexes publications related to AI in mathematics education, including studies on intelligent tutoring systems, adaptive learning, learning analytics, and AI-driven instructional tools, which are commonly published across both education and technology-focused outlets. Furthermore, Scopus offers well-structured and standardized metadata, which supports accurate data cleaning, analysis, and visualization in bibliometric studies.

The query string used for the database search was: (TITLE-ABS-KEY ("artificial intelligence" OR AI) AND TITLE-ABS-KEY ("mathematics education" OR "mathematics learning" OR "didactics of mathematics")) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA , "SOC")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO ( PUBSTAGE , "final" )) AND (EXCLUDE (EXACTKEYWORD , "Engineering Education") OR EXCLUDE (EXACTKEYWORD , "Education Computing") OR EXCLUDE (EXACTKEYWORD , "Science Technologies") OR EXCLUDE (EXACTKEYWORD , "Science Education")) AND (LIMIT-TO (LANGUAGE , "English")).

The TITLE-ABS-KEY field was applied to ensure that the search terms appeared in the title, abstract, or keywords of the publications, thereby increasing the relevance of the retrieved documents.

## Data Screening and Selection

The search was limited to publications between 2014 and 2026 within the subject area of “SOCl” (Social Sciences). Only document categorized as journal articles (ar) and conference papers (cp) were included, and the publication stage was restricted to final publications written in English. Several exact keywords unrelated to the focus of this study were excluded to refine the dataset.

After applying all inclusion and exclusion criteria, a total of 169 English-language documents were retrieved and considered eligible for bibliometric analysis. These documents consisted of 144 journal articles and 25 conference papers published from 2015 to 2026 and formed the final dataset for the present study.

## Bibliometric Analysis Procedure

Furthermore, study employed bibliometric analysis to examine the development of research on AI in mathematics learning. Bibliometric analysis provides a systematic approach to mapping research productivity, citation patterns, collaboration networks, and thematic evolution within a specific research domain. The procedure followed the stages of bibliometric analysis proposed in prior literature, which included: (1) defining the objectives and scope of the study, (2) selecting appropriate bibliometric techniques, (3) collecting and refining bibliographic data, (4) performing bibliometric analysis, and (5) presenting and interpreting the findings.

To ensure data consistency and avoid redundancy in the analysis, a normalization process was applied to the keywords. Similar terms with different expressions (e.g., “AI” and “artificial intelligence”) were merged using a thesaurus file in VOSviewer. This step helped minimize overlaps in the keyword co-occurrence network and produced more accurate and interpretable visualizations.

## Data Analysis Tools

The data analysis was conducted using Bibliometrix software version 5.2.1 and VOSviewer version 1.6.18. Bibliometrix is an R package for bibliometric analysis that enables performance analysis and science mapping. It was used to examine analysis such as publication trends, influential sources, country productivity and thematic mapping. Meanwhile, VOSviewer was employed to construct and visualize keyword co-occurrence networks, providing graphical representations of relationships among research themes.

## RESULTS

Through a bibliometric approach, this study aims to examine and map the research evolution of AI in mathematics learning. The analysis is divided into six main areas: publication trends and development, leading journals and proceedings, top contributing countries, frequently cited references, keyword co-occurrence, and thematic evolution. The detailed findings are presented in the subsequent sections.

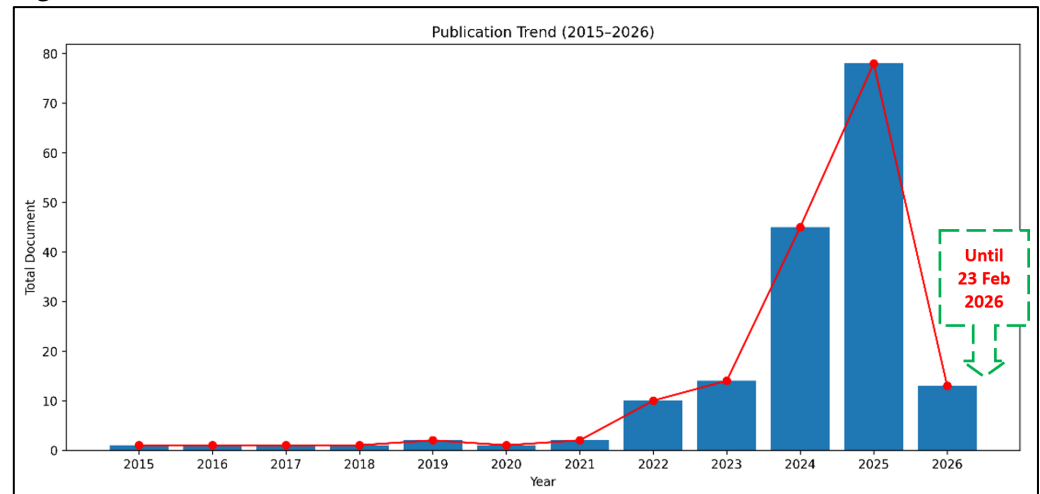
### Publication Trends & Development

Analyzing publication trends is essential to understand the development pattern of research on artificial intelligence (AI) in mathematics learning. The main characteristics of the dataset are summarized in **Table 1**.

**Table 1** Main Information of the Dataset

Description	Results
Timespan	2015:2026
Sources (Journals & Proceedings)	98
Documents	169
Annual Growth Rate %	26,26
Document Average Age	1,88
Average citations per doc	11,96
Author's Keywords	509
International co-authorships %	21,3
References	1465

A detailed trajectory of the annual publication volume is visually illustrated in Figure 1.



**Figure 1** Overview of the search query process and the retrieved data from the Scopus database

The temporal distribution of publications, presented in **Figure 1**, reflects the development of research on AI in mathematics learning over time and reveals a non-linear growth pattern. During the period 2015–2020, a low-output phase, research output in this field remains relatively low with minor annual fluctuations, indicating limited publication activity. Starting from 2021, the number of studies on AI in mathematics learning increases more consistently and continues to rise through 2023, which shows a moderate growth phase. A more pronounced increase occurs between 2024 and 2025, where the number of publications grows sharply and reaches its peak in 2025, representing the highest level of publication within the dataset. This progression shows a gradual transition from a relatively stable phase to a period of accelerated growth, with a substantial increase in publication intensity in the most recent years.

### Leading Journals and Proceedings

Analyzing the distribution of publication sources provides insight into where research on AI in mathematics learning is most frequently disseminated. The main information regarding the leading journals and proceedings is presented in **Table 2**.

**Table 2** 10-Leading Sources (Journals and Proceedings)

Source	TC	NP	PY-Start
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Eurasia Journal of Mathematics, Science and Technology Education	366	6	2016
Sustainability (Switzerland)	94	5	2021
ZDM - Mathematics Education	133	6	2022
British Journal of Educational Technology	46	4	2025
Education and Information Technologies	26	5	2025
15th International Conference on Learning Analytics and Knowledge, Lak 2025	6	2	2025
Asian Journal for Mathematics Education	11	2	2024
Behavioral Sciences	21	2	2023
Computers and Education	148	2	2022
Education Sciences	67	9	2023

Note: TC (Total Citation), TP (Total Publication), PY-Start (Year of First Publication on Math Edu-AI)

In terms of productivity, Education Sciences records the highest number of publications (9 documents), followed by Eurasia Journal of Mathematics, Science and Technology Education and ZDM – Mathematics Education (6 publications each). Other sources, including Sustainability (Switzerland) and Education and Information Technologies, contribute a moderate number of publications, indicating a relatively uneven distribution of output among leading sources.

A different pattern is observed when considering citation impact. Eurasia Journal of Mathematics, Science and Technology Education show the highest total citations (366), followed by Computers and Education (148) and ZDM – Mathematics Education (133). Notably, some sources with fewer publications demonstrate relatively high citation counts, indicating that publication volume and citation impact are not proportionally aligned across sources.

This variation becomes more evident when comparing productivity and citation simultaneously. Sources with high publication output do not always correspond to those with the highest citation impact, while several sources with limited publications contribute disproportionately to total citations. This pattern suggests differences in the visibility and influence of research outputs across publication sources, indicating that research on AI in mathematics learning is not only widely distributed but also selectively concentrated in journals or proceedings that shape its scholarly impact.

### Top Contributing Countries

Based on **Table 1**, publications related to AI in mathematics learning are distributed across multiple countries, with 21.3% international co-authorships. Using bibliometric analysis, the main information regarding country productivity and citation impact is presented in **Table 3**.

**Table 3** 10-Top Contributing Countries

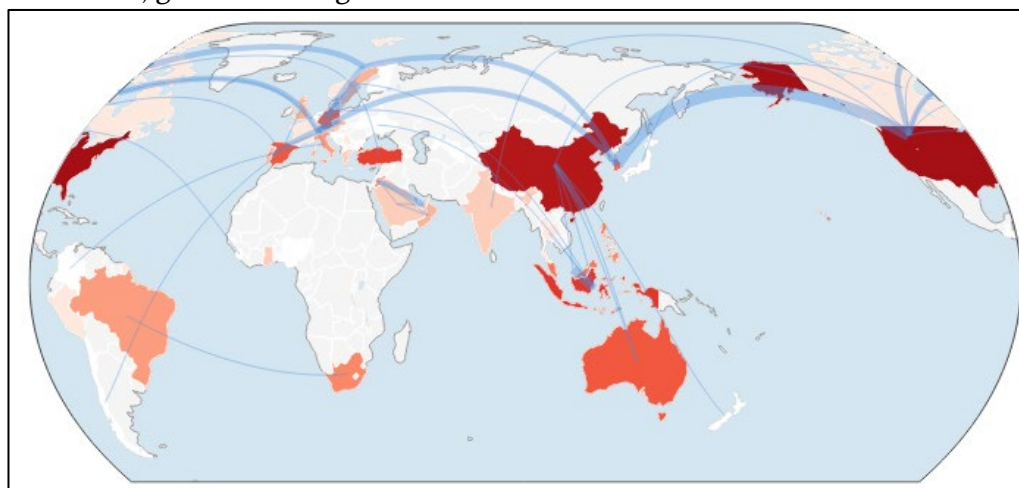
Rank	Country	TP	TC	CPP
1	USA	42	244	0,835417
2	China	35	233	0,714583
3	Indonesia	25	40	0,129167
4	Turkiye	19	63	0,252083
5	Spain	17	46	0,296528
6	Germany	16	48	0,379167
7	Australia	12	74	0,376389
8	Philippines	12	118	0,9625
9	South Korea	12	216	1,793056

10	Malaysia	10	16	0,210417
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*Note: TC (Total Citation), TP (Total Publication), CPP (Citation Per Publication)*

According to **Table 3**, the results show that research on AI in mathematics learning is distributed across multiple countries, with varying levels of productivity and impact. The United States ranks first with 42 publications, followed by China (35) and Indonesia (25), indicating that these countries contribute the largest share of research output within the dataset. Other countries, such as Turkiye, Spain, and Germany, demonstrate moderate levels of productivity, while several countries show lower but still notable contributions. In terms of citation impact, a different pattern emerges, where the United States and China maintain high total citation counts, while South Korea records the highest citation per publication (CPP = 43.2), followed by the Philippines (CPP = 23.6), indicating that countries with fewer publications can achieve relatively higher impact on a per-publication basis.

Furthermore, **Figure 2** illustrates the global collaboration network among researchers, generated using Bibliometrix network visualization.



**Figure 2** Word map collaboration of authors on different countries

*Note: darker tone represents countries with a higher number of publications*

The network visualization shows that research on AI in mathematics learning is concentrated around several central countries with strong collaborative links. The United States and China appear as the most connected nodes, indicating their prominent roles in international collaboration. These countries form multiple connections with other regions, suggesting a higher level of engagement in cross-country research activities. In contrast, several countries with moderate or lower publication output exhibit fewer and weaker connections, indicating more limited collaboration patterns.

### Frequently Cited References

Based on **Table 1**, The bibliometric dataset comprises 1,465 references, reflecting the extensive body of literature that forms the foundation of research on AI in mathematics learning. **Table 4** presents the ten most frequently cited documents in the dataset.

**Table 4** Frequently Cited References

Title of Document	Author	DOI	TC	TC per Year
ChatGPT: A revolutionary tool...	Wardat et al. (2023)	10.29333/ejmste/13272	308	3,208333
When adaptive learning is effective...	Wang et al. (2020)	10.1080/10494820.2020.1808794	191	47.75
Developing an AI-based chatbot...	Lee & Yeo (2022)	10.1016/j.compedu.2022.104646	146	1,222222
Enhancing Computational Thinking Skills Through Artificial...	Huang & Qiao (2024)	10.1007/s11191-022-00392-6	81	1,125
Artificial intelligence, computational thinking...	Gadanidis (2017)	10.1108/IJILT-09-2016-0048	76	0,333333
Coping with math anxiety...	Inoferio et al. (2024)	10.54517/esp.v9i5.2228	65	0,921528
Recent developments ...	Engelbrecht & Borba (2024)	10.1007/s11858-023-01530-2	57	0,791667
The Impact of Artificial Intelligence-Based...	Qawaqneh (2023)	10.3991/ijet.v18i14.39873	46	0,493056
Examining the Effects of Artificial...	Hwang (2022)	10.3390/su142013185	46	0,388889
Exploring the Integration of Artificial...	Egara (2024)	10.3390/educsci14070742	43	0,60625

Table 4 indicates that [Wardat et al. \(2023\)](#) has the strongest influence, with the highest citation count and citation-per-year rate. This indicates the rapid scholarly attention toward generative AI technologies, particularly ChatGPT, in mathematics learning contexts. Similarly, the high citation count of [Wang et al. \(2023\)](#) highlights the continuing importance of adaptive learning systems in AI-supported instructional environments.

A comparison of total citations and citation-per-year values reveals variation in citation patterns across documents. Some publications with high total citations also maintain high citation rates per year, indicating consistent citation accumulation over time. In contrast, several more recent publications demonstrate relatively high citation-per-year values despite lower total citations, suggesting rapid citation growth within a shorter time span.

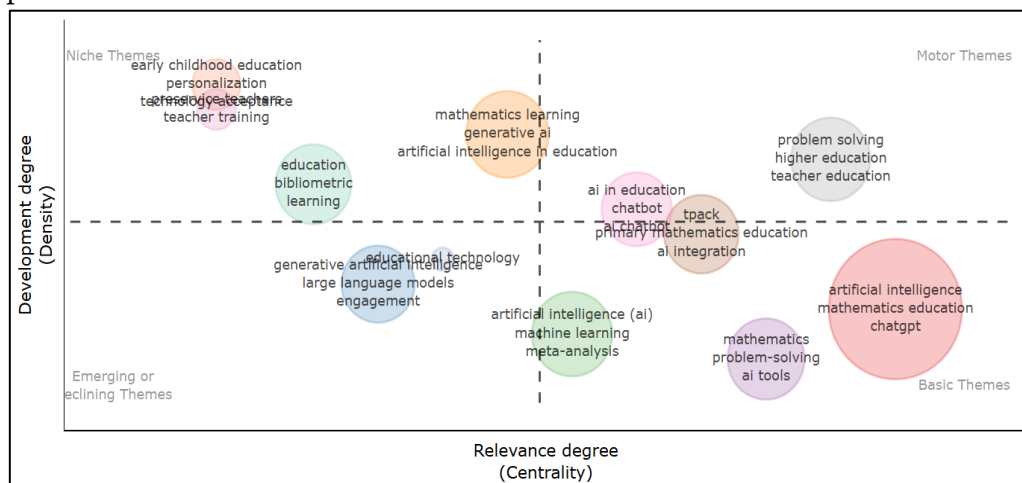
### Keyword Co-occurrence

The dataset in Tabel 1 contains 509 author keywords, reflecting the thematic diversity of research on AI in mathematics learning. To identify the most prominent research directions, the top 50 keywords with the highest co-occurrence were analyzed. **Figure 3** summarizes these keywords along with their frequency.



## Thematic Evolution

Lastly, the thematic map displayed in **Figure 5** presents the structural organization of research themes related to AI in mathematics learning over the period 2015–2026.



**Figure 5** Thematic evolution map of AI in mathematics learning

The results show that research themes are distributed across four themes: motor, basic, niche, and emerging or declining. Each category reflects a different position in terms of relevance and development within the overall research structure.

Motor themes, located in the upper-right quadrant, include topics such as problem solving, higher education, and teacher education, characterized by high centrality and density, indicating strong connectivity and development within research on AI in mathematics learning. In contrast, basic themes, positioned in the lower-right quadrant, such as artificial intelligence, mathematics education, and ChatGPT, show high centrality but lower density, indicating broad connections but relatively lower internal development. Niche themes, found in the upper-left quadrant, including early childhood education, personalization, and teacher training, exhibit high density but lower centrality, reflecting well-developed but more specialized and less connected topics. Meanwhile, emerging or declining themes in the lower-left quadrant, such as generative artificial intelligence, large language models, and engagement, display both low centrality and density, indicating limited development and weaker integration within the research network.

## DISCUSSION

This study addresses the limited understanding of how research on AI in mathematics learning has evolved by providing a large-scale bibliometric mapping of publication patterns, intellectual structure, and thematic development using Scopus data analyzed through Bibliometrix and VOSviewer.

The observed publication trends reveal a substantial increase in research output, particularly in the period 2024–2025. This pattern supports the assumption outlined in the introduction that AI in mathematics learning is an expanding research domain. The sharp rise in recent years can be interpreted in relation to broader technological developments, especially the increased accessibility of generative AI tools following the release of ChatGPT in late 2022. While earlier studies primarily focused on intelligent tutoring systems and adaptive learning (bin Mohamed et al., 2022; Son, 2024), the current findings suggest a shift toward more interactive and generative approaches, supporting recent arguments that AI is becoming more integrated into real-time learning processes (Wardat et al., 2023; Liu et al., 2025).

Moreover, the distribution of publication sources and citation patterns further indicates that influence within this field is not solely determined by the number of publications. This finding extends previous bibliometric observations that emphasize the role of high-impact journals in shaping research directions. In this study, several sources with fewer publications demonstrate higher citation impact, suggesting that research visibility is influenced by both source quality and the relevance of the research topics. This highlights the importance of not only increasing publication output but also strengthening the quality and positioning of research contributions.

From a geographical perspective, the findings reveal both global participation and uneven research influence. Indonesia's position as the third most productive country reflects strong national engagement in research on AI in mathematics learning. However, the relatively low citation per publication (CPP) indicates a gap between productivity and global impact. This finding provides an important point of reflection within the national context. While the quantity of research has increased, challenges remain in enhancing international visibility, research quality, and collaboration. Compared to countries with higher CPP values, which tend to produce fewer but more influential studies, the results suggest that increasing international collaboration and publishing in higher-impact journals may improve research influence.

The analysis of keyword co-occurrence and thematic evolution further supports the argument that the field is undergoing a transition from general technological exploration to more specialized and pedagogically oriented applications (Nguyen & Pham, 2025). While foundational concepts such as artificial intelligence and mathematics education remain central, emerging topics such as generative AI, chatbots, and personalization indicate increasing diversification. Similar patterns have been observed in recent studies on AI in education, which report that generative AI technologies are increasingly shaping research directions and pedagogical experimentation in digital learning environments (Semmour et al., 2026).

The implications of these findings are both theoretical and practical. Theoretically, this study contributes to a clearer understanding of the intellectual structure and evolution of AI research in mathematics learning. Practically, the results highlight the need for educators to integrate AI tools to support personalized and adaptive learning in mathematics, while policymakers are encouraged to develop pedagogical guidelines, improve teacher readiness, and ensure ethical AI implementation.

However, this study is still limited by its reliance on a single database, the use of predefined search keywords, and the nature of bibliometric analysis, which does not assess classroom effectiveness. Future research should therefore incorporate multiple data sources and combine bibliometric and empirical approaches, particularly to examine the impact of AI tools on students' learning outcomes, engagement, and problem-solving in real educational contexts, as well as to address issues related to ethics, teacher readiness, and long-term implementation.

## CONCLUSION

This study provides a bibliometric overview of the evolution of Artificial Intelligence (AI) research in mathematics learning from 2015 to 2026. The findings reveal a rapid growth of publications, particularly after 2021, alongside a clear shift from general technological exploration toward more pedagogically oriented applications, especially in personalized learning, chatbots, and generative AI. While research output is concentrated in a few leading countries, variations in citation impact indicate differing levels of influence.

These trends suggest several practical implications. For mathematics teachers, AI can be used to support personalized learning through adaptive content, real-time feedback, and step-by-step problem-solving assistance. Chatbot-based tools can serve as interactive assistants to guide students, answer questions instantly, and support independent learning. For policymakers, these developments highlight the need to strengthen teacher training in AI literacy, integrate AI into curriculum frameworks, and ensure ethical standards such as data privacy and responsible use.

However, this study is limited by its reliance on a single database and predefined keywords, which may restrict the coverage of relevant literature, as well as by the nature of bibliometric analysis that does not assess classroom effectiveness. Future research should integrate multiple data sources and combine bibliometric with empirical approaches. In particular, collaborative studies between education researchers and industry developers are needed to bridge the gap between technological innovation and pedagogy, alongside empirical investigations on the effectiveness of AI tools in diverse mathematics learning contexts.

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## CONFLICT OF INTEREST

The author hereby declares that this research is free from conflicts of interest with any party.

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