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Bibliometric study on research trends in artificial intelligence and mathematics education

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***Abstract*:**
This research analyzes the emerging AI and Mathematics Education nexus from the years 2015 to 2024, aiming to ascertain primary research patterns, significant contributors, and thematic progressions in the specialized bibliometric discourse. By conducting a bibliometric analysis of 840 articles indexed in Scopus, this research uncovers accelerated growth, especially post-2020, in scholarly interest concerning AI applications in mathematics education. The findings emphasize a notable decline in using teaching methods grounded in pedagogy to more sophisticated techniques focused on leveraging machine learning and tutoring systems to maximize educational achievement for students. The United States and China are pointed out as the main players in the mapped research framework. Unlike other studies that vaguely address AI and education, this review stands out in providing a comprehensive assessment of how AI tools are integrated within the teaching of mathematics and tracking the evolution of research in this context. The design seeks to aid educators, policymakers, and even researchers focusing on the intersection of technological advancements and educational reform in mathematics teaching.

Keywords: Artificial Intelligence; Bibliometrics; Mathematics Education; Research Trends.

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Introduction

The use of Artificial Intelligence (AI) today has transformed the entire education sector and has become a major topic of concern for academic discussion the world over.

Digital transformation changes the work and interaction of humans, which needs a different approach to the learning process. In AI application to educational mathematics, innovations range from adaptive learning and intelligent tutoring systems to personalized learning through data-driven learning analytics (Holmes et al., 2019; Zawacki-Richter et al., 2019). The fast-growing dependence on technology to facilitate learning has also brought other challenges to the fore, such as the COVID-19 pandemic, which highlighted the need for scalable, intelligent learning systems applicable to different educational contexts and set many new standards in these frameworks.

A study by Ji et al. (2025) and Dimitriadou and Lanitis (2023) Established that mathematics education is one of the foundational pillars of the education system (Dimitriadou & Lanitis, 2023; Ji et al., 2025). It requires an understanding of concepts, logic, and problems. Because of the complexities of this field, it offers a potential area where AI technologies can be applied to help learners understand abstract ideas more interactively. Regrettably, in many developing nations, limited digital infrastructure, poor teacher readiness, unequal access to technological resources, and the unfair integration of AI into mathematics aid all restrict the ideal use of technology in teaching advanced mathematics. It poses alarming concerns concerning the fairness and pragmatism of integrating AI within varying socioeconomic situations.

AI-assisted instruction can be incorporated into various disciplines with the potential to transform learning for students, especially in fields that require high levels of abstraction. For example, mathematics. As noted by Botelho et al. (2023), newer technologies such as machine learning and natural language processing have created new possibilities for developing context-aware and interactive environments for teaching mathematics (Botelho et al., 2023). As also observed by Papasarantou et al. (2002), the application of AI-based systems has been successful in enhancing problem-solving and motivation skills among learners. Despite these advancements in the teaching of mathematics, most studies focus on experimental implementation; the gap remains as to the effectiveness across diverse educational systems (Papasarantou et al., 2002).

There has been a remarkable increase in publications exploring the intersection of Artificial Intelligence (AI) and mathematics education from 2015 to 2024 (Chen et al., 2020), alongside growing interest in educational technology. However, studies that profile developmental patterns, key contributors, dominant lexicons, collaboration patterns, and holistic, comprehensive analyses within AI and math education parameters are still very few. Such profiling is essential to trace the burgeoning practices, gaps, and trends specific to knowledge development (Donthu et al., 2021). In addition, most available bibliometric studies generalize the application of AI in teaching without considering mathematics as a domain with distinct instructional and cognitive characteristics.

There is some attention paid to the role of AI in education in general education (Durak et al., 2024; Zawacki-Richter et al., 2019), including systematic literature reviews dedicated to AI in teaching and learning (Mustafa et al., 2024). However, studies focusing solely on AI in mathematics education are scarce. Studies adopting bibliometric methods with the intent of identifying publication, key author, and collaboration patterns, along with the conceptual growth in this niche, are even scarcer. It emphasizes the lack of research that analyzes the application and discourse of AI in the context of mathematics learning.

This gap becomes clear when we note that the use of AI in Mathematics education is a relatively new and expanding area. However, there are no comprehensive, empirically based summaries that explain the history of the research, its primary contributors, and the prevailing themes of discussion. One of Talan's recent bibliometric studies (2021) examines AI in general education. However, Talan focused on the broader context of mathematics as a sphere without exploring its distinct pedagogical challenges and dynamic learning processes (Talan, 2021). Unlike Talan's work, this one applies updated bibliometric mapping focused solely on AI in mathematics education over the last decade to uncover previously unexplored new frontiers of research and collaboration patterns.

In this regard, the purpose of this study is to examine the artificial intelligence and mathematics education research trends over the past decade (2015–2024) using bibliometric methods. More specifically, this study attempts to find: (1) changes in publication volume over the years; (2) major sources and contributors; (3) new trends and phrases; and (4) collaboration among the authors within the discipline. It is anticipated that the results of this research will add to existing AI educational research innovations. Furthermore, the results of this study will be valuable for educators, policymakers, and curriculum designers devoted to charting the course for AI applications in mathematics education by determining the primary drivers and relevant approaches to advocate for changes in settings where such innovation is needed.

Research Methods

This study employed a bibliometric approach to analyze the development of research on the topic of Artificial Intelligence (AI) in mathematics education over the period from 2015 to 2024. Bibliometric analysis is a quantitative method used to evaluate and map scientific literature based on publication data, intending to identify research trends, influential authors, collaboration networks, and emerging themes or topics (Aria & Cuccurullo, 2017; Donthu et al., 2021).

Data Source

Bibliographic data were obtained from the Scopus database, selected for its broad coverage of international scientific publications and standardized metadata quality. The search process was conducted in March 2025 using the following search string: TITLE-ABS-KEY ("artificial intelligence" AND "mathematics education") AND (LIMIT-TO (PUBYEAR, 2015-2024)) AND (LIMIT-TO (DOCTYPE, "ar") AND (LIMIT-TO (LANGUAGE, "English").

Inclusion criteria were strictly defined to ensure the relevance and quality of the data analyzed. Only documents categorized as scientific articles were included in this study to ensure that the publications had undergone a peer-review process. Furthermore, only articles published in English were considered, as English is the primary language of international scientific communication. The publication period was limited to January 1, 2015, through December 31, 2024, to provide a representative overview of research developments over the past decade. Lastly, selected articles were required to have a clear thematic connection to the topics of artificial intelligence and mathematics education, as indicated explicitly in their titles, abstracts, or keywords.

Analysis Procedure

The analytical process in this study was conducted systematically to obtain a comprehensive overview of research developments in the field of AI and mathematics education. The first step was data extraction, which involved downloading the metadata from the Scopus database in CSV and BibTeX formats. The metadata included critical information such as article titles, author names, keywords, journal names, publication years, and citation counts.

Subsequently, a descriptive analysis was conducted to identify publication distribution by year, countries of origin, the most productive authors and journals, and the most cited articles during the 2015–2024 period. A bibliometric analysis was then carried out to evaluate the structure and patterns of the scientific literature. It included co-authorship analysis to examine collaboration networks among authors and institutions, co-occurrence analysis to identify frequently co-appearing keywords and uncover dominant themes in the literature, and citation analysis to determine the most influential articles or authors in the field. In addition, bibliographic coupling and co-citation analyses were used to examine relationships between documents or journals based on shared references. The final stage involved data visualization using the latest version of VOSviewer and Bibliometrix through the Biblioshiny interface in R. These tools were used to generate network maps, density maps, and trend graphs that visually and informatively illustrate the dynamics and knowledge structure within AI and mathematics education research.

Validity and Replicability

To ensure the replicability of this study, all search and analysis procedures were conducted transparently and documented in detail. The keywords and search parameters were aligned with PRISMA standards for systematic reviews. The validity of the bibliometric findings was strengthened by triangulating the results from both VOSviewer and Biblioshiny (Aria & Cuccurullo, 2017).

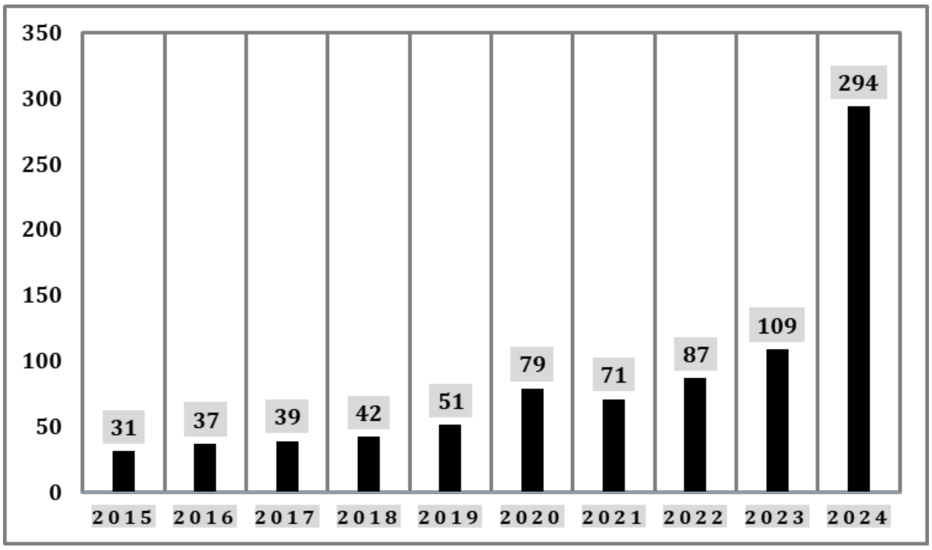
The validity of the findings was reinforced by triangulating the results between VOSviewer and Biblioshiny. Both tools yielded converging visual and quantitative patterns, strengthening internal consistency. As for success indicators, this study considers the following as criteria for successful bibliometric mapping: (a) identification of key research trends over time; (b) detection of the most influential authors and documents; (c) mapping of global collaboration networks; and (d) uncovering of dominant and emerging thematic areas. These outputs are expected to contribute not only to the scholarly understanding of the field but also to guide future research strategies.

Research Result

1. *Publication Trends on Artificial Intelligence and Mathematics Education Research Over the Years*

There has been a notable increase in the AI (Artificial Intelligence) technologies related to Mathematics Education in the past decade. As researched from the Scopus database, there were 840 scientific publications published during the years 2015 to 2024. The distribution of the publications is shown in Picture 1. The first publications in this research area were in 2015 and have been only 31 articles. In subsequent years, there has been a steady growth to 37 articles in 2016, 39 articles in 2017, and finally publishing 42 articles in 2018. The growth has accelerated a little since then, publishing 51 articles in 2019 and 79 articles in 2020, which was an unprecedented surge during the global pandemic throughout 2020. This surge is believed to be a consequence of the pandemic itself, which increased the need for technology-based learning and AI-integrated education systems.

In 2021, the number of publications decreased to 71 but rapidly rose the following year and published 87 articles. In 2023, the number increased to 109 articles, making the growth rate between 2023 and 2024 the largest, with increased publications up to 294, making this the most dramatic increase in publications in a gap of 24 months. It translates into 35% of the total publications of the decade being published during 2024. The remarkable surge over the past five years, especially after 2020, demonstrates the increasing worldwide scholarly attention to the use of artificial intelligence technologies in mathematics education. This information suggests that the issue has advanced from being a nascent topic to a well-developed and vibrant one in the international scientific literature.

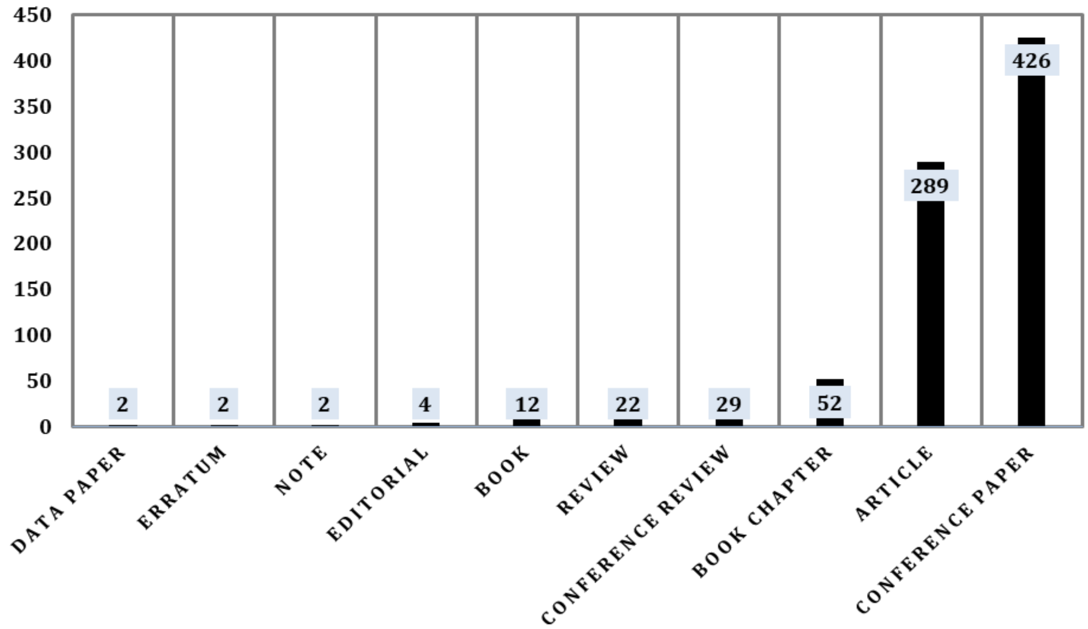


Picture 1. Publication on Artificial Intelligence and Mathematics Education Research According to Years

2. Publications on Artificial Intelligence and Mathematics Education by Document Type

Based on the type of documents published at the intersection of Artificial Intelligence and Mathematics Education, it is clear that the majority of documents, accounting for 426, were published as conference papers. It is indicative of AI and mathematics education being a highly active area of study, developing through academic practices such as seminars and conferences where researchers showcase their findings or the latest results of their work. Scientific journal articles came in second place, with their number reaching 289, which shows that AI and mathematics education have received considerable attention from well-established journals, which typically promote advanced academic discourse, after rigorous peer scrutiny. Also, the number of book chapters published on the topic 52 shows that this field has also attracted interest in more extensive theoretical works.

The data suggests that research on AI in mathematics education is conducted and published through several types of documents. Conference papers, however, seem to be the preferred method of publication. It further suggests that the field is still in development and can be shaped by new information and discussions in various academic forums.



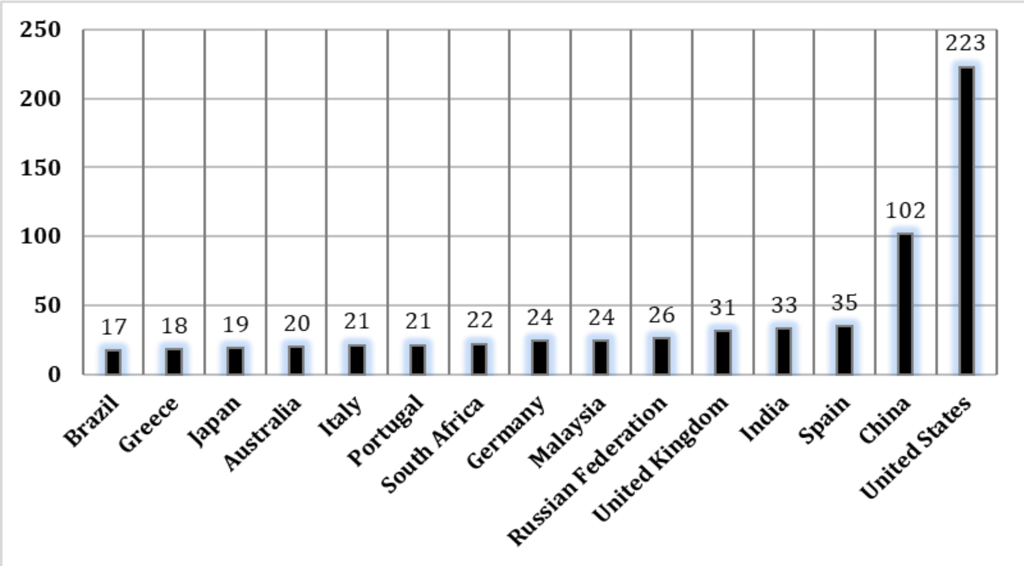
Picture 2. Publication on Artificial Intelligence and Mathematics Education According to Document Type

3. *Publication on Artificial Intelligence and Mathematics Education Research According to Countries*

The provided information shows the top 15 countries that have published the largest amount of documents related to Artificial Intelligence and Mathematics Education. These countries are especially important concerning the growth and access to information in this area.

The United States is in the first position with the largest share of the docs published, which is 223 docs, and China comes second with 102 publications. Both of these countries have always acted as international centers of research, especially in the fields of technology and AI-based pedagogy. Spain occupies third place with 35 publications, followed by India with 33, United Kingdom with 31, which reveals a lot of contribution from the European and South Asian countries into this field. It leads us to make an assumption that high-availability nations and those countries where the digital evolution of education is prioritized are bound to be highly engaged in this topic. Interestingly, a large number of countries from the above list are considered developed, but the presence of India, Malaysia, and South Africa showcases the contribution of emerging nations.

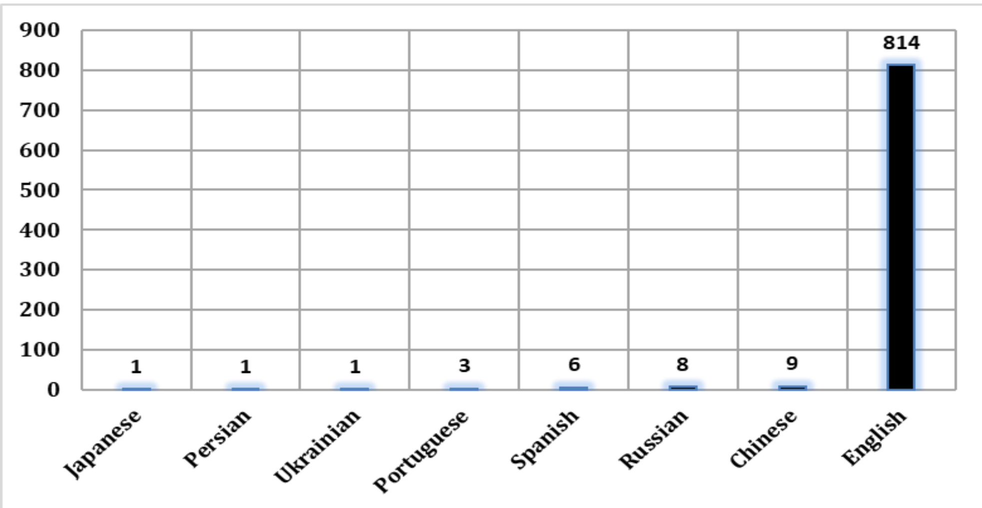
These results can be used as a foundational basis for other countries' researchers and institutions to develop strategies to foster international partnerships and increase research potential concerning AI in mathematics education.



Picture 3. Publication on Artificial Intelligence and Mathematics Education Research According to Countries

4. *Publication on Artificial Intelligence and Mathematics Education Research According to Languages*

In the study of AI paired with mathematics, the language used in educational publications is pivotal to the engagement and impact of scholarly work. The findings of this study showed that English is the predominant language for publishing AI-related research, given that 814 of the documents, which is about 95% of the total data, are in English. It adds to the existing fact that English is the global language of science and academics and the primary teaching language in most reputable journals and high-ranking institutes.



Picture 4. Publication on Artificial Intelligence and Mathematics Education Research According to Languages

From the language distribution, it can be interpreted that although research on AI and mathematics education is available worldwide, the accessibility and the distribution of information are predominantly English-centric. Such conclusions highlight the significance of English language proficiency for researchers who aim to participate and be acknowledged in leading international research discussions.

5. Publication on Artificial Intelligence and Mathematics Education According to Research Areas

Research on Artificial Intelligence (AI) in the context of Mathematics Education reflects a multidisciplinary character, encompassing various fields of study. Data shows that the field with the highest contribution to publications is Computer Science, with a total of 489 publications. This dominance indicates that AI, as a core technology, is closely related to the development of software, algorithms, and intelligent learning systems. Following this, Social Sciences ranks second with 310 publications, highlighting significant attention to pedagogical, social, and educational aspects in the application of AI in mathematics. Engineering also makes a substantial contribution with 273 publications, affirming the role of technology engineering in building and implementing AI solutions for education. Mathematics itself records 189 publications as the primary content area, indicating a focus on the substance of mathematics learning. Decision Sciences and Psychology also emerge as important fields, contributing 62 and 36 publications, respectively; this shows an interest in decision-making processes and cognitive aspects within AI-based learning.

Additionally, several other fields are involved despite having smaller numbers, such as Physics and Astronomy, Medicine, Business, and Environmental Science. Contributions from areas like Multidisciplinary Studies, Arts and Humanities, as well as Health Professions, further illustrate that applying AI in mathematics education is not only technical but also considers ethical, humanistic, and holistic aspects. Overall findings indicate that research on AI and mathematics education is rapidly evolving across various disciplines. Cross-disciplinary collaboration becomes key to developing new approaches and innovations that are more effective in supporting teaching-learning processes in mathematics during the digital era.

Table 1. Publication on artificial intelligence and mathematics education according to research areas

Subject Area	
Computer Science	489
Social Sciences	310
Engineering	273
Mathematics	189
Decision Sciences	62
Physics and Astronomy	49
Energy	37
Psychology	36
Medicine	32
Business, Management and Accounting	23

Subject Area	
Environmental Science	22
Multidisciplinary	20
Health Professions	18
Materials Science	18
Arts and Humanities	16
Earth and Planetary Sciences	14
Chemical Engineering	12
Biochemistry, Genetics and Molecular Biology	11
Economics, Econometrics and Finance	10
Agricultural and Biological Sciences	9
Neuroscience	7
Chemistry	5
Immunology and Microbiology	1
Nursing	1
Pharmacology, Toxicology and Pharmaceutics	1

6. *Publication on Artificial Intelligence and Mathematics Education According to Organizations*

Research on Artificial Intelligence in mathematics education has been conducted by various institutions worldwide. Based on data from the top 20 institutions with the highest number of publications, it is evident that universities from different parts of the world are actively contributing to the development of this topic. The universities with the highest number of publications are the University of Johannesburg and Worcester Polytechnic Institute, each with 9 publications, followed by the University of Georgia with 8 publications. Additionally, several renowned institutions have each contributed 7 publications: Universiti Sains Malaysia, Massachusetts Institute of Technology (MIT), and Carnegie Mellon University. It reflects the involvement of institutions from various regions, including North America, Asia, and Africa, in promoting research at the intersection between AI and mathematics education.

Other institutions, such as NC State University, New York University, Beijing Normal University, and Michigan State University, also recorded contributions totaling 6 publications each. The presence of institutions like the National Research University, Moscow Power Engineering Institute, and Tecnológico de Monterrey highlights representation from Russia and Latin America. This list also shows that European institutions such as Coimbra Polytechnic - ISEC (Portugal), HSE University (Russia), and the University of Cambridge (UK) play a role in this research area. Furthermore, involvement from The Education University of Hong Kong and the Chinese Academy of Sciences adds an international dimension to collaboration in this field. Overall, the diverse geographical distribution of these institutions indicates that research on applying AI in mathematics education has become a global focus not limited to any single region. It opens up opportunities for cross-country and cross-institutional collaboration to continue developing innovative technology-based learning approaches.

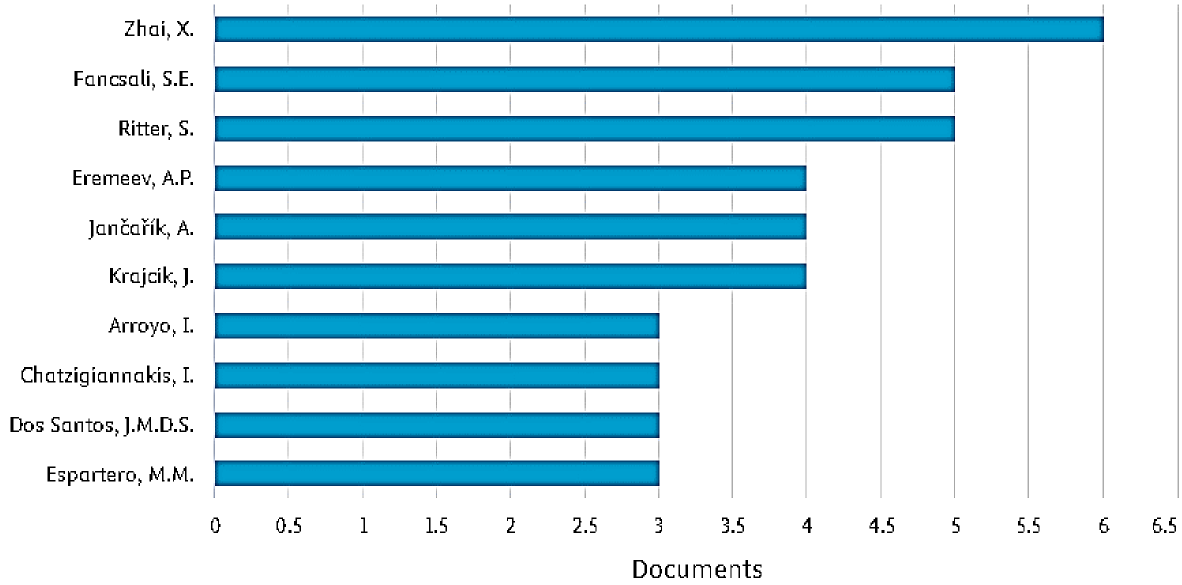
Table 2. Publication on artificial intelligence and mathematics education according to organizations

Affiliation	
University of Johannesburg	9
Worcester Polytechnic Institute	9
University of Georgia	8
Universiti Sains Malaysia	7
Massachusetts Institute of Technology	7
Carnegie Mellon University	7
NC State University	6
National Research University Moscow Power Engineering Institute	6
Tecnológico de Monterrey	6
New York University	6
Beijing Normal University	6
Michigan State University	6
Pontifícia Universidade Católica de São Paulo	5
Norges Teknisk-Naturvitenskapelige Universitet	5
University of Florida	5
The Education University of Hong Kong	5
Chinese Academy of Sciences	5
HSE University	5
Coimbra Polytechnic – ISEC	5
University of Cambridge	5

7. Publication on Artificial Intelligence and Mathematics Education According to Authors

Based on data from the top 10 most productive authors in research related to Artificial Intelligence and Mathematics Education, it is evident that several individuals have consistently contributed to the development of this topic. The author with the highest number of publications is Zhai, X., who has authored 6 publications. It indicates an active role and consistency in research that integrates AI within the context of mathematics education. Next, two authors, Fancsali, S.E. and Ritter, S., each have 5 publications indicating significant involvement in collaborative projects or studies in this field.

Three other authors, Eremeev, A.P., Jančařík, A., and Krajcik, J., each contributed 4 publications, demonstrating a strong contribution to the advancement of this area from both technological and pedagogical perspectives. Meanwhile, four additional authors, Arroyo, I., Chatzigiannakis, I., Dos Santos, J.M.D.S., and Espartero, M.M., each have 3 publications. The presence of these names shows that although their publication count may not be as high as others, they remain active in supporting research at the intersection between artificial intelligence and mathematics education. The diversity among these authors also reflects the involvement of researchers from various parts of the world, creating a collaborative and multidisciplinary research landscape. The contributions of these authors are not only important quantitatively but also impactful regarding future directions and focus for research.



Picture 5. Publication on Artificial Intelligence and Mathematics Education According to Authors

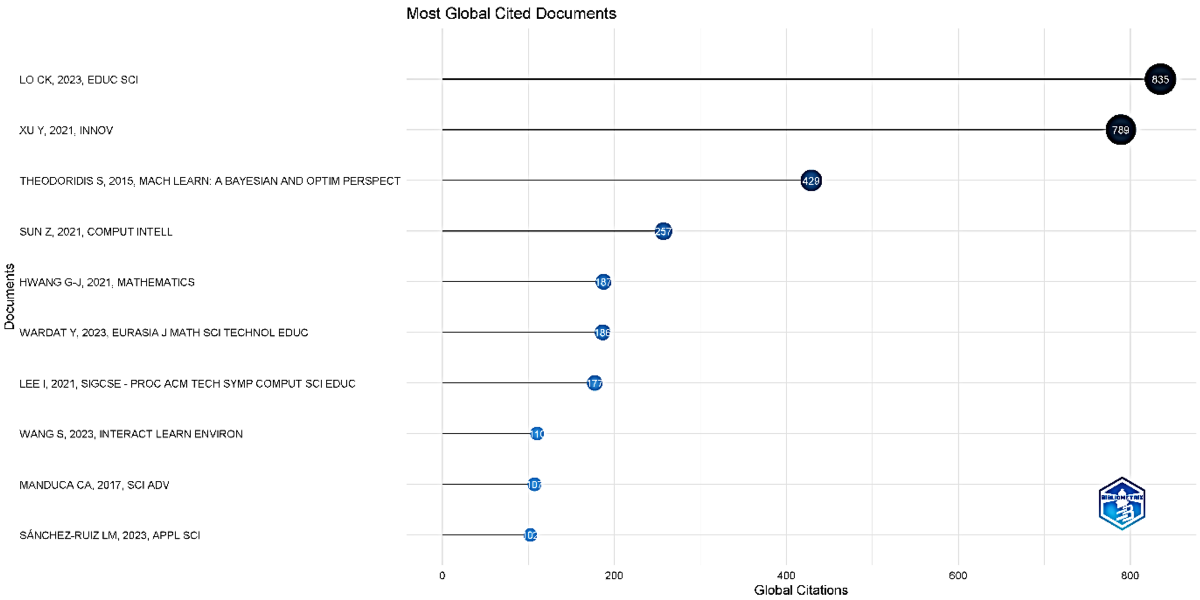
8. Most Global Cited Documents

Most Global Cited Documents present the ten articles with the highest citation counts in the field of Artificial Intelligence (AI) and mathematics education. The article with the highest citations is by (Lo, 2023), published in *Education Sciences*, with 835 citations. This article focuses on the use of AI for personalized learning and is highly influential as it discusses adaptive learning strategies. In second place, Xu (2021) in the journal *Innovation* has garnered 789 citations, highlighting the application of machine learning in real-time educational assessment, making it an important reference for innovations in mathematics learning (Xu et al., 2021).

Theodoridis (2020), through his book *Machine Learning: A Bayesian and Optimization Perspective*, ranks third with 429 citations. Although not specifically about education, this work is frequently referenced in developing AI models across various fields, including mathematics education. Sun et al. (2021) achieved 257 citations in *Computational Intelligence*, discussing AI algorithms for online teaching. Hwang & Tu (2021) received 187 citations in the journal *Mathematics* for addressing adaptive e-learning-based mathematics instruction. An article by (Wardat et al., 2023) published in *EURASIA Journal* occupies sixth place with 186 citations, focusing on intelligent systems to aid students' understanding of mathematical concepts. Lee et al. (2021) discuss integrating AI into computer science and mathematics curricula, earning 177 citations at SIGCSE Proceedings. Following this, (Wang et al., 2023), writing for *Interactive Learning Environments*, reviews user experiences in AI-based mathematics learning and receives 110 citations.

Meanwhile, Manduca et al. (2017)published a paper in *Science Advances* that obtained 107 citations discussing data science-based pedagogical strategies applicable to mathematics education. Finally, Sánchez-Ruiz et al. (2023), publishing in *Applied Sciences*, achieved 102 citations on measuring student competencies using AI and big data analysis. Overall, these articles provide a crucial foundation for understanding how to apply AI to enhance the quality of mathematics education.

These findings indicate that publications integrating modern technological approaches with mathematical pedagogy receive widespread attention and shape research directions within this field.



Picture 6. Most Global Cited Documents

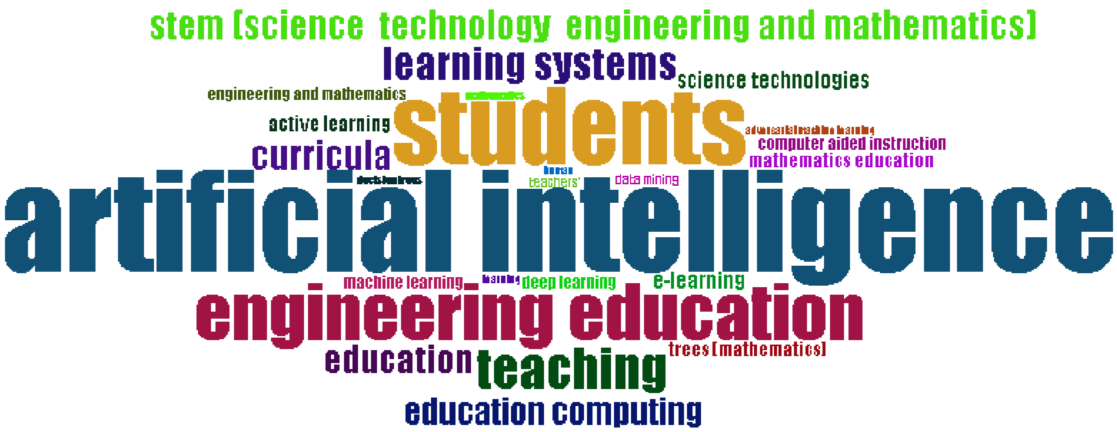
9. Word Cloud Analysis

The word cloud visualization offers a high-level overview of the most frequently occurring terms within the AI and mathematics education literature. Unsurprisingly, the term *artificial intelligence* appears most frequently (401 times), confirming the centrality of this technological paradigm in the analyzed body of literature. The frequent appearance of *students* (304 times) reflects the dominant focus on student-centered research, particularly studies examining how AI applications can enhance students' learning experiences, motivation, and performance in mathematics. It suggests that AI is increasingly being explored not just as a technological tool but as a means to personalize instruction and support diverse learning needs. Many studies, for example, investigate the role of intelligent tutoring systems in facilitating individualized feedback and adaptive learning pathways tailored to students' mathematical competencies.

Terms such as engineering education (221), learning systems (127), and teaching (163) indicate a strong orientation toward technology-mediated pedagogical innovation. These words are closely linked to AI-driven educational systems that employ machine learning algorithms to adjust content delivery based on learner progress and behavior. The prevalence of curricula (116) and STEM (117) suggests that AI is playing an influential role in reshaping the structure and delivery of educational content across disciplines, with mathematics education positioned at the intersection of these reforms.

The words deep learning and machine learning (each 52 times) point to the increasing application of sophisticated AI techniques within educational research. These approaches go beyond rule-based systems to uncover patterns in large datasets, enabling predictive analytics and real-time feedback in mathematics learning environments. For instance, deep learning models are being developed to diagnose student misconceptions, recommend problem-solving strategies, or automate assessment in open-ended math tasks. Interestingly, terms such as computer-aided instruction (55), active learning (62), and e-learning (68) underscore a shift toward more interactive and participatory learning models where students engage with digital tools in dynamic ways. AI is used here to support learning autonomy and engagement, often through gamification, intelligent feedback, or simulations.

The presence of terms like teachers (42) and decision trees (36) reveals that educators remain integral to the AI-mediated learning process. AI is not designed to replace teachers but to augment their instructional capabilities, assist with data-driven decision-making, and facilitate formative assessment practices. Lastly, the appearance of adversarial machine learning (30) hints at emerging concerns related to the ethical and security dimensions of AI integration in education. It includes issues such as data privacy, algorithmic bias, and the transparency of AI-driven recommendations, particularly in high-stakes assessments or personalized learning systems. In sum, the word cloud analysis reveals not only the dominant technical terms in the field but also the pedagogical, psychological, and ethical themes embedded in contemporary AI and mathematics education discourse. These keywords, taken together, portray a research domain that is evolving toward holistic, student-focused, and ethically aware implementations of AI in math classrooms.



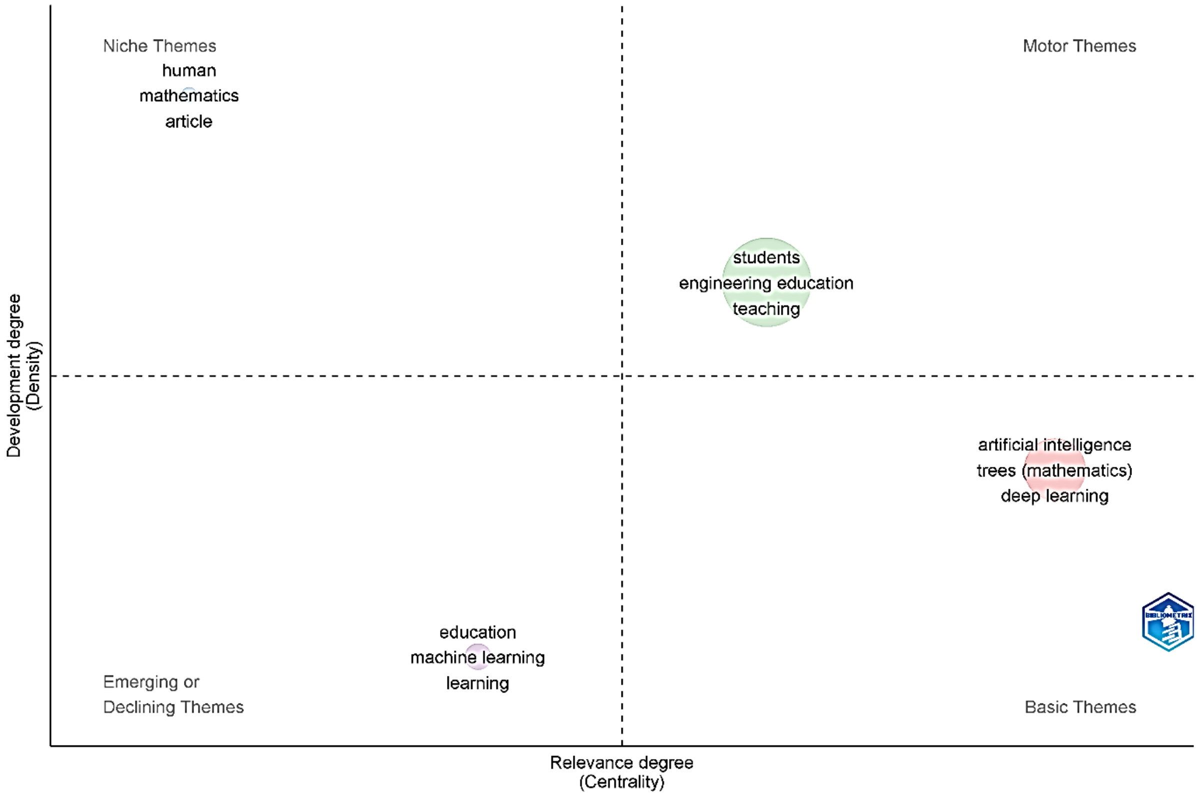
Picture 7. Analysis Word Cloud

10. Thematic Maps

This thematic map analysis divides the main themes into four clusters based on two key indicators: Callon Centrality (measuring the interconnection of themes with other themes) and Callon Density (measuring the internal strength or consistency of a theme). The four identified clusters are artificial intelligence, humans, students, and education. The students cluster occupies a strategic position due to its high centrality value (6.73) and density (28.59), making it the most dominant theme with the highest frequency (2947). It indicates that topics related to students are at the center of attention in research, serving as important motor themes and developing topics. Related keywords in this cluster include engineering education, teaching, and students themselves, with high betweenness centrality and PageRank values indicating their crucial role in connecting other concepts.

The artificial intelligence cluster also holds an important position (centrality: 7.67) and is sufficiently developed internally (density: 24.45). With a frequency of 1082 occurrences, this theme is central to the overall study. Keywords within this cluster, such as deep learning, trees (mathematics), and artificial intelligence itself, reflect a dominance of algorithmic approaches and technology in research related to mathematics education.

Meanwhile, the education cluster has moderate centrality levels (3.47) but low density (13.62), indicating that this theme remains general and requires further development. Important words in this cluster, like machine learning and learning, still have strong connections to main themes but have not yet evolved into mature subthemes. Finally, the human cluster exhibits the highest density value (38.62) but low centrality (2.46), suggesting that while this theme is quite developed internally, it has not connected much with other themes. With a low-frequency count of 197 occurrences, this topic likely represents a niche area or more specific subject matter, such as studies on ethics or human interaction with technology.



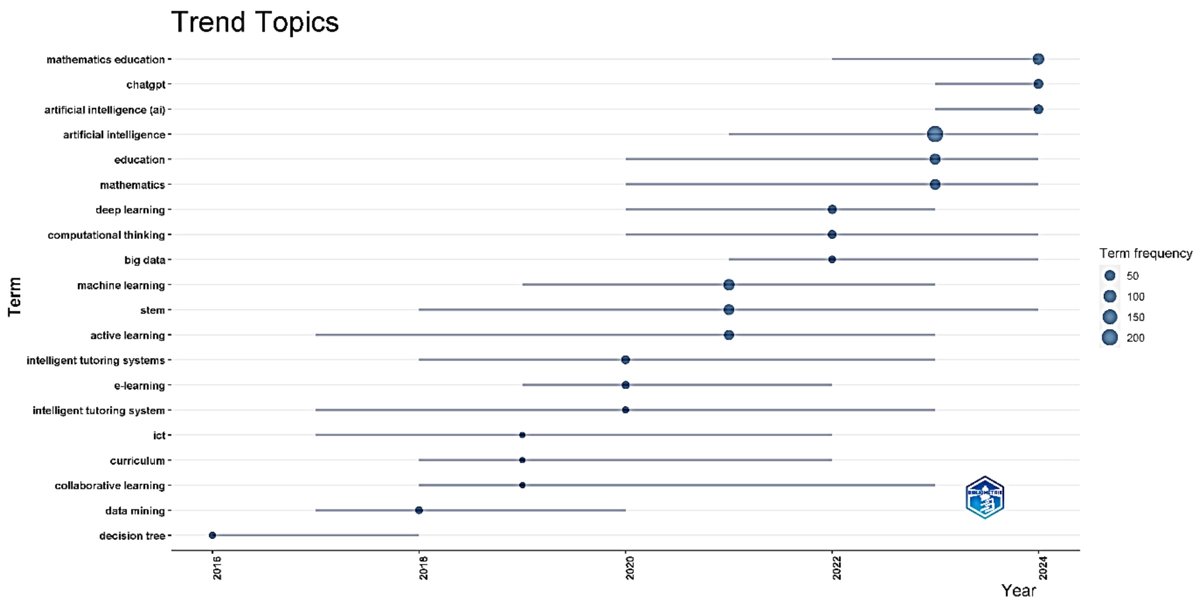
Picture 8. Thematic Map

11. Trend topics

Based on the analysis of topic trend data, there has been a significant development in research focus within the field of artificial intelligence and mathematics education over recent years. Several topics, such as decision trees and data mining, began to emerge around 2016–2017, laying the foundational groundwork for applying data analysis technology in education. Topics like collaborative learning, curriculum, and ICT also started to gain traction around 2018–2019, indicating an interest in collaborative learning approaches and the integration of information technology into educational curricula.

Entering the period from 2019 to 2021, trends began to shift towards more complex and advanced technologies. Topics such as e-learning, intelligent tutoring systems, and machine learning became primary areas of focus. It aligns with the increasing demand for online-based learning systems and personalized education supported by artificial intelligence technology. STEM topics and active learning also gained popularity during this time frame, reflecting a growing interest in exploration-based learning approaches and 21st-century skills.

From 2022 to 2024, there was a surge of attention towards topics such as deep learning, computational thinking, big data, and most notably artificial intelligence (AI), mathematics, and mathematics education. These three have become central themes in current research that demonstrate a deep integration between AI technology and mathematics instruction. The most recent development is the emergence of topics related to ChatGPT and artificial intelligence since 2023, with peak visibility expected in 2024. It indicates that generative AI technologies like ChatGPT have become focal points for innovation in educational research today. Overall, these trends reflect an evolution from basic technical approaches toward cutting-edge applications of AI while emphasizing the importance of utilizing technology to enhance teaching effectiveness—particularly within mathematics education.



Picture 9. Trend Topics

12. Co-citation Network

Based on the Co-citation Network analysis, nine major clusters were identified from references that are frequently cited together in the literature. These clusters represent key thematic areas that are interconnected within the broader scope of research, particularly focusing on education, technology, and artificial intelligence.

Cluster 1 emerged as the most dominant and central network, with Chen L. (2020) serving as the key node, exhibiting the highest betweenness centrality (26) and the highest PageRank score (0.1157). It indicates that Chen's work plays a pivotal role in bridging references across diverse topics. This cluster also includes significant references such as Chassignol (2018) and the foundational educational document Principles and Standards for School Mathematics (2000), reflecting a strong emphasis on the integration of AI in mathematics education.

Cluster 2 is composed of key figures such as Baker (2019) and Roll & Wylie (2016), who address issues related to learning analytics and adaptive learning systems. Their contributions significantly shape the understanding of measurement and evaluation in technology-enhanced learning.

Cluster 3, led by Wardat (2023), contains contemporary literature exploring recent applications of AI in education. This cluster includes recent studies by Mohamed (2022) and Higgins (2019), which illustrate the rapid integration of AI technologies into instructional settings. Collectively, these works indicate a clear shift in research interest from conceptual discussions toward modern, practice-oriented AI implementations in classrooms.

Cluster 4 highlights theoretical foundations in education, marked by the presence of influential thinkers such as Vygotsky (1978) and VanLehn (2011). These foundational works contribute significantly to understanding cognitive development, social interaction, and scaffolding in learning process concepts that are crucial when considering how AI tools support human learning. The inclusion of such references reflects the importance of aligning AI integration with established educational psychology frameworks.

Cluster 5, which includes Bryman (2016) and Field (2013), focuses on methodological rigor, particularly emphasizing the role of quantitative and statistical analysis in educational technology research. These references serve as a basis for the design, validation, and interpretation of AI-enhanced learning interventions. Their prominence in the co-citation network underscores the necessity for robust data analysis in the evaluation of AI tools used in mathematics education.

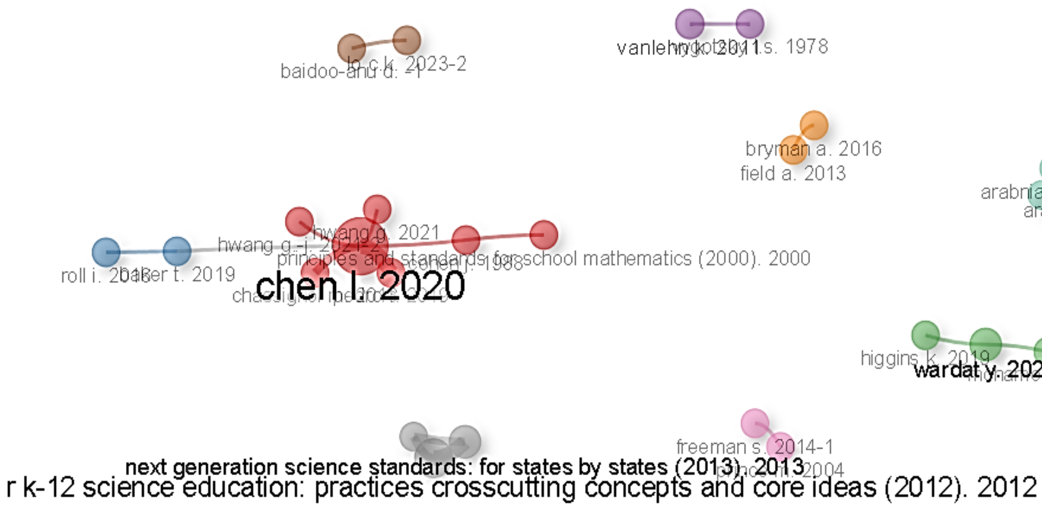
Cluster 6 is centered on exploratory studies and localized case-based implementations, represented by contributors such as Lo C.K. (2023) and Baidoo-Anu. These studies often investigate the feasibility and outcomes of AI adoption in specific cultural or institutional contexts. This cluster demonstrates the importance of understanding how local factors influence the success of AI integration in diverse educational environments.

Cluster 7 emphasizes active learning approaches, with key references to Freeman (2014) and Prince (2004), both of whom are considered pioneers in the design of student-centered and participatory learning models. The inclusion of these works suggests that AI in education is increasingly being applied to promote engagement and interaction, aligning with constructivist pedagogical frameworks. This cluster bridges the gap between technology use and effective teaching strategies.

Cluster 8 includes major educational policy documents such as the Next Generation Science Standards (2013) and A Framework for K–12 Science Education (2012), which are frequently cited in discussions about curriculum reform and STEM education policy. These sources indicate that the implementation of AI is not only a technological advancement but also a policy-driven movement aimed at transforming science and mathematics education at the system level.

Finally, Cluster 9 showcases the sustained contributions of Arabnia across multiple publications (2007, 2008, 2012). Although more technical in scope, these works remain relevant due to their early emphasis on AI systems and computational modeling. Their consistent presence in the co-citation network highlights the lasting influence of foundational computational research in shaping current AI applications in education.

Overall, the network identifies Chen L. (2020) as a central node connecting various approaches and schools of thought in education and technology. The diversity of clusters reflects the interdisciplinary nature of this research area, highlighting strong connections among educational theory, policy, methodology, and emerging technological applications such as artificial intelligence.



Picture 10. Co-citation Network

Discussion

The significant increase in publications on Artificial Intelligence (AI) in Mathematics Education over the past decade reflects the growing global concern with integrating technology into education. The sharp surge since 2020 is likely influenced by the COVID-19 pandemic, which forced a massive shift to online learning and the use of digital technologies. According to Zawacki-Richter et al. (2019), the rapid adoption of online learning technologies during crises has accelerated the integration of innovative educational practices, indicating that emergencies can accelerate the adoption of new technologies in education. The increase in the number of publications from 31 articles in 2015 to 294 articles in 2024 demonstrates that this topic has evolved from an emerging theme into a mature and dynamic field of study. It aligns with the perspective of (Baker et al., 2016), who stated that "the growing interest in educational data mining and learning analytics reflects a broader trend towards data-driven decision-making in education. Thus, the academic attention to AI in mathematics education not only reflects technological development but also a need to understand and optimize teaching and learning processes through data analysis.

This finding strengthens the report by Zawacki-Richter et al. (2019) but contrasts with the earlier findings by (Levis, 2024), who argued that AI integration was still limited to theoretical research. The significant increase since 2020 suggests a shift from theoretical studies to practical applications in AI and mathematics education. Overall, this publication trend indicates that research on AI in Mathematics Education is gaining significant recognition in the international scientific literature. It also opens opportunities for interdisciplinary collaboration to explore innovations aimed at enhancing the effectiveness of teaching and learning in today's digital era.

An analysis of document types reveals that the majority of publications on Artificial Intelligence and Mathematics Education are conference papers, with a total of 426 documents. It indicates that the field is still highly dynamic and developing through academic forums such as seminars and conferences, where researchers tend to present preliminary findings or the latest research outcomes. According to (Sarabipour, 2020), conferences provide an ideal platform for researchers to share new ideas and receive direct feedback from peers. Furthermore, journal articles published in reputable journals also make a significant contribution, with a total of 289 documents. It demonstrates a strong effort to deepen scholarly discourse through rigorous peer-review processes. Active involvement in conference-based publications can be seen as an indicator of the academic vitality of a field. As Specht & Crowston (2022) explain, participation in conferences not only increases research visibility but also fosters interdisciplinary collaboration. These findings indicate that although many initial studies are presented at conferences, there is also a strong push to publish the results in leading journals after undergoing the peer-review process.

The data shows the top 15 countries with the highest number of publications in research on Artificial Intelligence and Mathematics Education. These countries are key players in the development and dissemination of knowledge in the field. The United States ranks first with the highest number of publications, totaling 223 documents, followed by China with 102 publications. These two countries have consistently been global research hubs, particularly in the fields of technology and AI-based education. Previous studies have also shown that countries with strong research infrastructure tend to produce higher research output (Melaas & Zhang, 2016). It aligns with the finding that the United States and China not only have substantial financial resources but also extensive collaborative networks among academic institutions, industries, and governments (Qiao et al., 2016).

Spain holds the third position with 35 publications, followed by India (33 publications) and the United Kingdom (31 publications), reflecting the significant roles played by European and South Asian countries in this field. These findings suggest that although much of the contribution comes from developed countries such as the US and the UK, the active participation of developing nations such as India reflects increasing attention to digital transformation in education in those regions. The involvement of various countries in AI research for mathematics education opens opportunities for international collaboration and knowledge exchange, which can strengthen research capacity globally. As Jung (2022) stated, cross-border collaboration can improve research quality through the exchange of innovative ideas and best practices among countries.

However, despite the increasing global attention and research output in this field, the implementation of AI in mathematics education faces several critical challenges, particularly in developing countries. Infrastructure limitations, such as insufficient internet access, lack of digital devices, and unstable electricity, pose significant barriers to the effective use of AI-based educational tools. Additionally, the technological gap between developed and developing nations results in unequal access to AI innovations, further widening educational disparities.

In many low-resource contexts, educators may lack sufficient training in AI-integrated pedagogy, while schools may not have the technical support needed to maintain or deploy intelligent learning systems. These conditions hinder the scalability of AI initiatives and require collaborative efforts involving policymakers, private sectors, and international stakeholders to build equitable digital learning environments. As AI becomes increasingly embedded in educational strategies worldwide, addressing these challenges becomes essential to ensure the inclusive and sustainable adoption of AI in mathematics instruction. It aligns with Wang and Chen's study from 2020 but clashes with Johnson et al. from 2018, who argued that developing countries had not significantly advanced AI and education research. India, along with some other nations, seems to be shifting this narrative, which shows that there is growing potential from developing countries. These gaps in the literature imply that while countries like the US and UK dominate the figure in the contribution, the emerging involvement of India indicates attention toward changes in educational technology in these regions.

Research on Artificial Intelligence (AI) in the context of Mathematics Education demonstrates a multidisciplinary nature involving various fields of study. The data shows that the academic discipline with the highest number of publications is Computer Science, with 489 publications. This dominance indicates that AI, as a core technology, is closely related to the development of software, algorithms, and intelligent learning systems that support educational processes. The involvement of the Social Sciences in second place with 310 publications highlights the importance of pedagogical and social aspects in the application of AI in mathematics education. It supports the view that technological integration requires not only technical understanding but also an understanding of how students learn and interact with the technology (Howland et al., 2013).

The research of Luckin & Holmes (2016) emphasizes the importance of interdisciplinary collaboration. However, there is still limited research exploring how the field of psychology can mediate the use of AI in mathematics learning, a gap that warrants further study. Furthermore, the contribution of Engineering, with 273 publications, underscores the role of engineering in building AI-based solutions for education. Research by Luckin et al. (2016) emphasizes that collaboration between engineering and pedagogy is crucial to developing effective tools to support learning. Although the primary focus remains on Computer Science, the presence of contributions from other fields, such as Mathematics (189 publications), as well as disciplines like Decision Sciences, Psychology, and even sectors like healthcare, demonstrates the complexity of applying AI in mathematics education, which involves not only technical aspects but also cognitive, ethical, and humanistic considerations. Overall, these findings illustrate how research on AI in Mathematics Education is rapidly expanding across various disciplines, encouraging cross-field collaboration as a key to developing more effective innovations to support teaching and learning in the current digital era.

The Most Global Cited Documents list highlights the ten articles with the highest citation counts in the field of Artificial Intelligence and Mathematics Education. The most cited article is by Lo (2023), published in Education Sciences, with 835 citations. This article focuses on the use of AI for personalized learning and has had a strong impact due to its discussion of adaptive learning strategies that can significantly enhance students' learning experiences. The popularity of this article reflects a global trend toward implementing AI technologies in education, where the emphasis on personalized learning is increasingly important. According to Hwang et al. (2020), AI has the potential to revolutionize the way we educate students through more individualized approaches (Hwang, G.J., & Chen, C.H.). It aligns with Lo's findings that adaptive strategies can help meet the unique needs of each student, thus improving the effectiveness of teaching and learning.

Moreover, the other articles on the list also reveal key themes, such as the development of AI-based teaching tools and the use of big data analytics to understand students' learning patterns. Research by Chen et al. (2019) emphasizes that "big data analytics enables educators to identify gaps *in students' understanding and design more targeted interventions"* (Chen, L., & Wang, Y., 2019). Overall, these most cited documents not only offer insights into the latest trends in AI research in mathematics education but also highlight the importance of integrating technology and pedagogy to create more effective learning environments.

The results of the WordCloud analysis indicate that the term "artificial intelligence" is the most frequently occurring keyword in the publications, appearing 401 times. It affirms that the central theme of this review focuses on the application of artificial intelligence (AI) in the field of education. The word "students" appears 304 times, suggesting that a significant portion of the research is centered around the impact of AI on students' learning experiences and outcomes. As a concrete example, several studies highlight how AI can be used to personalize learning for students. According to Luckin et al. (2016), AI has the potential to transform education by providing personalized learning experiences that adapt to individual student needs. In addition, research by Jonassen et al. (2019) states that the integration of AI in educational settings can enhance problem-solving skills among students through tailored instructional strategies. These quotations underscore the importance of leveraging AI technologies to improve the quality of education and provide enhanced learning experiences for students.

The thematic map analysis categorizes the main themes into four clusters based on two key indicators: Callon Centrality, which measures the degree of interaction with other themes, and Callon Density, which assesses the internal coherence or strength of each theme. The four identified clusters are *artificial* intelligence, humans, students, and education. The student cluster occupies a strategic position with a centrality score of 6.73 and a density score of 28.59. It indicates that student-related topics are highly interconnected with various aspects of AI research in education and demonstrate strong thematic consistency in academic discussions. This finding aligns with earlier observations that many studies focus on the influence of AI on student learning experiences (Luckin et al., 2016).

On the other hand, the artificial intelligence cluster also shows a high centrality value, reflecting its importance as the core of these academic investigations. This cluster serves as a primary driver of educational innovation through the application of intelligent algorithms and adaptive learning systems (Jonassen et al., 2019). The human cluster illustrates the interaction between humans, both teachers and students, in the context of AI usage in education. It highlights that despite the emphasis on technology, the human element remains crucial for the effective implementation of AI-based solutions. Lastly, the education cluster encompasses educational policies and teaching methodologies influenced by advances in AI technologies. With the increasing integration of artificial intelligence into mathematics education curricula, educators need to understand how these emerging tools can be utilized to enhance overall learning outcomes. Collectively, the thematic map analysis offers a comprehensive overview of how various elements interact within the context of artificial intelligence and mathematics education while also identifying key areas for future research.

Based on the topic trend analysis, there has been a noticeable shift and development in the research focus on AI and mathematics education over recent years. Topics such as decision trees and data mining began to emerge around 2016–2017, laying the groundwork for the application of data analytics technologies in education.

Over time, themes like collaborative learning, curriculum, and ICT have also gained prominence as critical areas of investigation. It aligns with the assertion made by Chen et al. (2020), who noted that the application of AI in education is not limited to data processing but also includes pedagogical aspects such as student collaboration and technology-driven curriculum development (Chen, Y., & Huang, R.H., 2020). With the growing interest in AI integration in classrooms, researchers have increasingly explored how technology can more effectively support students' learning experiences. For instance, the use of machine learning algorithms to analyze student interactions can provide valuable insights for educators to refine and enhance their instructional methods.

Conclusion

This study aimed to map and analyze research trends in Artificial Intelligence (AI) and Mathematics Education from 2015 to 2024 through a bibliometric approach. In addressing the formulated research questions, the findings provide clear and data-driven answers. First, the trend analysis reveals a substantial growth in publications, especially post-2020, demonstrating increasing scholarly attention to AI as a transformative force in mathematics education. Second, the identification of influential authors, countries, and institutions highlights the central role of technologically advanced nations such as the United States and China while also showing emerging contributions from developing regions like India and Malaysia. Third, keyword co-occurrence and thematic mapping show a growing emphasis on personalized learning, student engagement, and AI-driven instructional strategies. Clusters such as students, education, and artificial intelligence suggest that research is shifting toward human-centered applications of AI. Finally, collaboration network analyses uncover the structure of knowledge production in this field, emphasizing the need for stronger interdisciplinary and cross-country partnerships.

Theoretically, this study contributes by offering a structured overview of how AI is being conceptualized and studied within mathematics education, which can serve as a foundation for future conceptual models. Practically, it provides guidance for educators, policymakers, and developers to align AI innovations with student needs and pedagogical goals. Despite these insights, challenges such as infrastructure limitations and technological disparities between countries must be addressed to ensure equitable AI integration. Moving forward, future research should include longitudinal studies on the long-term effectiveness of AI in improving mathematical understanding, especially in under-resourced settings. Further bibliometric mapping with a focus on ethical, psychological, and cross-cultural dimensions of AI implementation is also recommended to expand the current knowledge base.

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