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Review

Exploring the research trends of mathematics in STEM education: A systematic review using bibliometric analysis

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Abstract: In recent years, the study of science, technology, engineering, and mathematics (STEM) in education has received increasing attention from academics. However, to date, there have been no reports in scientific publications on the development of STEM education studies that explore the dynamics and phenomena related to mathematics knowledge. Therefore, this study aims to present a bibliometric and bibliographic review of mathematics in STEM education studies. A bibliometric analysis was used to conduct this study, thereby using 1296 selected documents from the Scopus database published between 2015 and 2025. Some analyses, such as performance, citation, co-word, and co-authorship, were conducted to analyze the data using VOSviewer. Results of this study revealed that the number of studies on mathematics in STEM education gradually increased, although the progress in citations for these studies was not consistent each year. In addition, the most productive and influential documents, authors, countries, institutions, and sources have contributed to the development of mathematics in STEM education research. Furthermore, educational innovation, student engagement, design thinking, and academic performance are expected to be newly trending research topics in mathematics in STEM education. Consequently, studies on educational innovation, student engagement, design thinking, and academic performance can be directed to further educational studies that focus on mathematics in STEM education.

Keywords: bibliometric analysis, mathematics, scopus, STEM education, systematic review, VOSviewer

1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) education has become a significant research focus in recent years [1]. This approach aims to prepare students for 21st-century challenges by integrating the four disciplines to help students solve real-world problems [2,3]. In the context of education, STEM is considered to improve critical thinking skills, problem solving, and creativity [4]. However, although the implementation of STEM continues to grow, studies that specifically focus on mathematics in STEM education are still relatively limited. Mathematics plays a fundamental role in the STEM approach because it provides a logical foundation to develop concepts in science, technology, and engineering. As one aspect of STEM, mathematics is not only an analytical tool but also a bridge which connects various disciplines [5]. However, previous studies tend to emphasize the integrated application of STEM without thoroughly reviewing the specific contributions of mathematics in this approach. Mathematics in STEM refers to the use of the STEM Embedded approach, as described by Bybee and Robert & Cantu, which integrates science, technology, and engineering as supporting contexts, thus ensuring that mathematical concepts guide problem-solving, reasoning, and real-world applications in interdisciplinary learning. Therefore, this study aims to develop an understanding of mathematics in STEM education through a systematic review supported by a bibliometric analysis.

In recent years, the STEM approach has evolved from simply integrating disciplines to a holistic approach that connects learning with the real world. For example, a study showed that project-based learning models in STEM education can help students apply theoretical concepts to practical situations. In addition, the study emphasized the importance of developing a STEM curriculum that is not only interdisciplinary but also relevant to society's needs [6]. Mathematics has a strategic position in STEM education because it is the foundation to develop competencies in other aspects, such as science, technology, and engineering. In the literature, the integration of mathematics into the STEM approach is often used to improve a student's understanding of abstract mathematical concepts [7]. Additionally, a study highlighted the importance of using digital technologies to connect mathematical concepts to real-life situations in STEM learning [8].

This bibliometric analysis will provide a comprehensive understanding of research developments, publication patterns, influential authors, and key themes that have emerged in the related literature [9]. A bibliometric analysis has become a popular method to evaluate research trends and contributions in various fields, including STEM education [10]. This method allows researchers to map publication patterns, identify prominent authors, and explore the relationships between research themes [11].

Based on the background and literature review described, this study focuses on the following questions:

1. What is the trend of publications on mathematics in STEM education from 2015 to 2025?
2. What are the main themes of research on mathematics in STEM education based on the

bibliometric analysis?

3. What are the opportunities and recommendations for future research in the STEM field, with mathematics as a major aspect?

This study aims to provide a comprehensive overview of the development and contribution of mathematics-based STEM research and identify research directions that require further development.

2. Methods

2.1. Research design

A bibliometric analysis was conducted to describe the overall picture of existing knowledge about mathematics in STEM education. A performance analysis, which is one of the main uses of a bibliometric analysis, can evaluate the publication information of authors and institutions, such as the annual distribution of publications, citations, author rankings, countries, journals, and disciplines. In addition, science mapping, another main use of a bibliometric analysis, develops a structural picture of a scientific field using bibliographic data [9]. Compared with narrative literature reviews, which tend to be influenced by the researcher's subjective biases and are often less rigorous [12], a bibliometric analysis can improve the quality and objectivity of reviews by introducing a systematic, transparent, and reproducible review process. Given that this study focuses on developing a comprehensive understanding of mathematics in STEM education, a bibliometric analysis needs to be conducted to examine the scientific production of mathematics in STEM education.

2.2. Data collection

The second stage of this study involved selecting appropriate databases for the bibliometric analysis and extracting data from the selected databases. One of the most important bibliographic databases is the Scopus database, which was created by Elsevier in November 2004 [13].

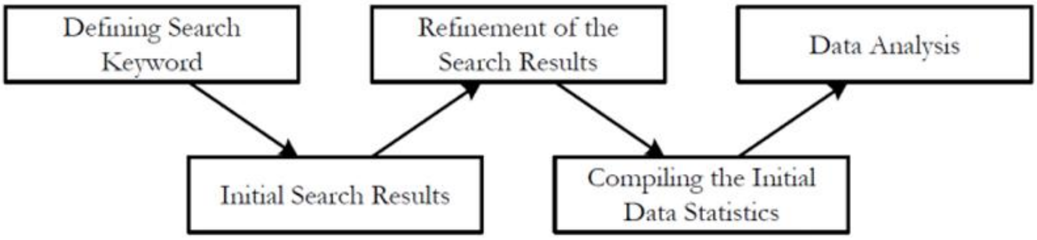

Figure 1. The stages in conducting bibliometric analysis.

Every stage of this current bibliometric analysis study is thoroughly presented in the following subsection.

2.2.1. Defining search keywords

The Scopus database was used to search for documents related to technological literacy studies. Keywords and Boolean operators were used to identify scientific papers in the STEM field. "STEM" and "Mathematics" were chosen as keywords. The Boolean operator "AND" was used to combine keywords to achieve more precise results. Therefore, the search equation was TITLE-ABS-KEY

(“Mathematics” AND “STEM Education”). The search strategy is presented in Table 1.

Table 1. Search strategy data.

TYPE	CRITERIA
Database	Scopus
Search String	TITLE-ABS-KEY (“Mathematics” AND “STEM Education”)
Time Span (t)	2015 to 2025
Subject Area	STEM Education, Mathematics
Document Type	Article
Source	Journal
Language	English
Search Date	07/30/2025

2.2.2. Initial search results

An initial search using the keywords mathematics and STEM education found 11,911 documents published between 1960 and 2025. Some documents were still in press, but many documents were published. The obtained documents were written in English, Spanish, Portuguese, Russian, Turkish, Chinese, German, French, Croatian, Bulgarian, Arabic, Serbian, Malay, Korean, Japanese, Czech, Bosnian, and Afrikaans languages. The document sources included journals, conference proceedings, books, book series, and trade journals. The obtained document types were articles, conference papers, book chapters, reviews, books, conference reviews, editorials, notes, short surveys, letters, errata, data papers, retracted papers, and articles in press. Furthermore, most document titles did not contain the keywords mathematics and STEM education.

2.2.3. Refinement of search results

Several inclusion criteria were established to identify relevant documents related to mathematics in STEM education: the title of the documents had to contain the keywords 'mathematics' and 'STEM education'; the publication status of the documents had to be 'published'; the documents had to be written in English; the source type of the documents was limited to journals; the document type was restricted to articles; and the documents had to be published between 2015 and 2025. Furthermore, the four stages to select the documents were as follows: 1) identification, 2) screening, 3) eligibility, and 4) inclusion [14]. The initial results of the search keywords and connectors fielded 11,198 publications. The author filtered using keywords such as mathematics and STEM education, which resulted in 2653 filtered documents. Next, the author selected documents that were already in the final stage of publication, which resulted in 2618 filtered documents. Focusing on English-language documents resulted in 2585 filtered documents. Focusing on journals resulted in 1548 filtered documents. Next, the researcher selected only the article document type, which resulted in 1384 filtered documents. Then, publications from 2015 to 2025 were selected, which resulted in 1296 publications in the last decade. Finally, 1296 journal articles were selected from the Scopus database. The document selection process for this bibliometric analysis is presented in Figure 2.

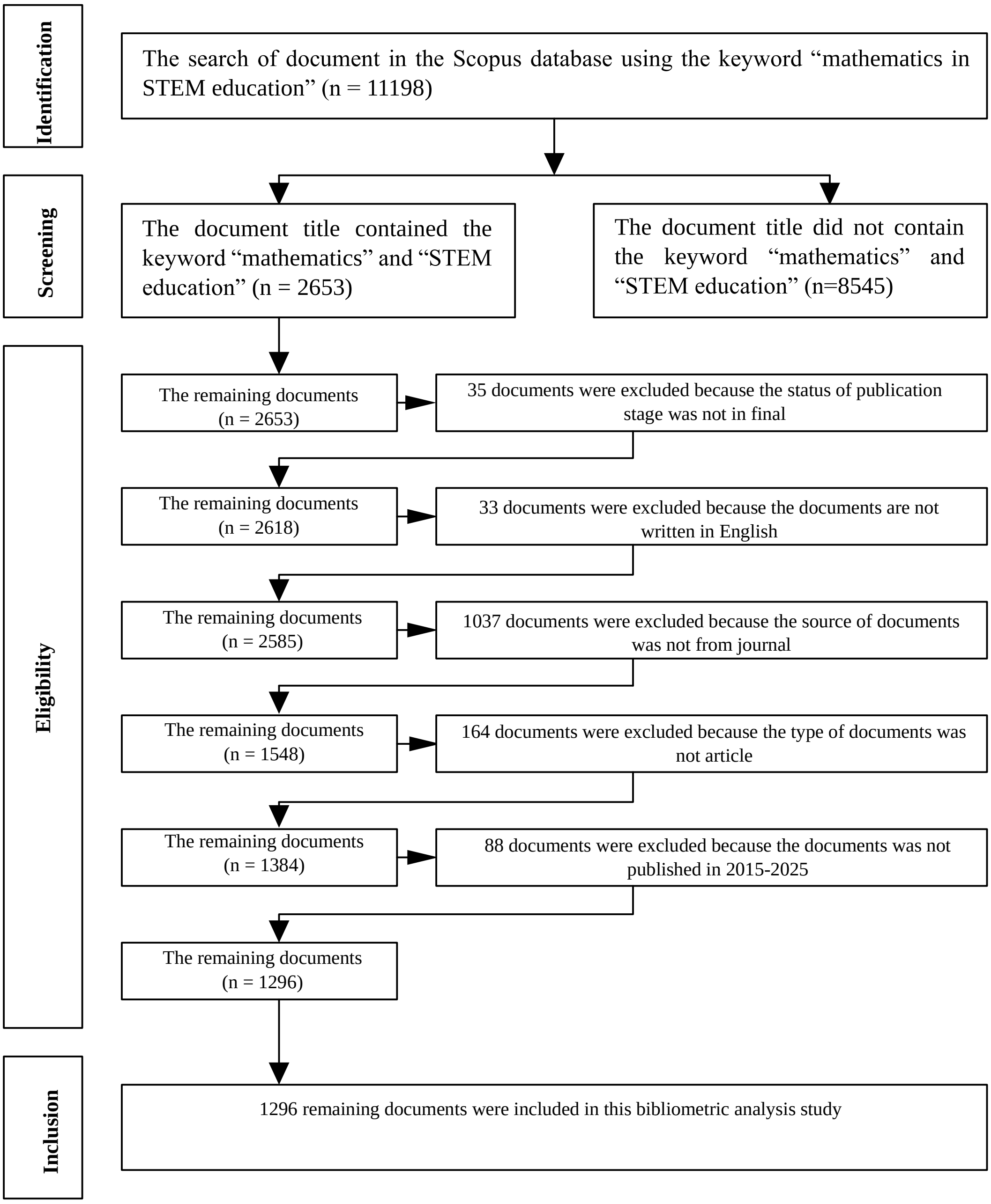

Figure 2. The stages of document selection

After the documents were identified from the Scopus database, the records of the 1296 documents were exported in the comma-separated value (CSV) format with their authors' bibliographic information. Next, the relevance and eligibility of the articles were further verified. As a result, all publications had the complete author information and could be selected for the analysis. Therefore, 1296 documents were included in the bibliometric analysis. The process described above is shown in Figure 2.

2.2.4. Compiling the initial data statistics

The included documents were downloaded from the Scopus database in the CSV format, which included bibliometric information, bibliographic information, abstracts, and keywords. In the Publish or Perish (PoP) software, some initial statistical data, such as document title, document type, citation, author, publication year, publisher, and source, was observed. Moreover, the software provided a summary of descriptive analyses, such as total citation (TC), total publication (TP), number of authors per publication (NAP), number of citations per publication (NCP), number of citations per year (NCY), g-index, m-index, and h-index [13].

2.2.5. Data analysis

A performance analysis presented the publication and citation trends related to mathematics in STEM education [9]. The PoP software was used to support the performance analysis [15]. Meanwhile, some science mapping analyses, such as citation, co-word, and co-authorship, were employed to examine the relationships among research constituents [9]. In detail, a citation analysis was used to present the most productive and influential documents, authors, countries, affiliations, and sources related to technological literacy studies. In contrast, a co-word analysis was used to show the most frequently emerging keywords in technological literacy studies and present the distribution of the most frequently appearing keywords in 2023–2024. On the other hand, a co-authorship analysis was used to show the social interactions among the authors and countries related to technological literacy studies. In addition, to enrich the science mapping analysis, a network analysis consisting of network & overlay visualization and hierarchical clustering was performed [11,15]. The VOSviewer software supported the science mapping and network analyses [11].

3. Results

3.1. Performance analysis

A performance analysis was used to present the development of publications and citations related to mathematics in STEM education studies from 2015–2025 (see Figures 3 and 4).

Figure 3 shows that the development of publications related to mathematics in STEM education studies relatively increased from 2015 to 2025. In detail, of the 1296 documents published during the time period, there were 50 documents published in 2015 and 2016, followed by 72 documents in 2017, 94 documents in 2018, 119 documents in 2019, 142 documents in 2020, 149 documents in 2021, 158 documents in 2022, 160 documents in 2023, 169 documents in 2024, and 133 documents in the first few months of 2025 until July 30, 2025. These show that the number of publications on mathematics in STEM education studies was the same in 2015 and 2016, but there was an increase from 2016 to 2024. In 2025, which is only a few months old, we cannot yet conclude whether it will decrease or increase, but the number of publications is already more than three-quarters of the citations in 2024.

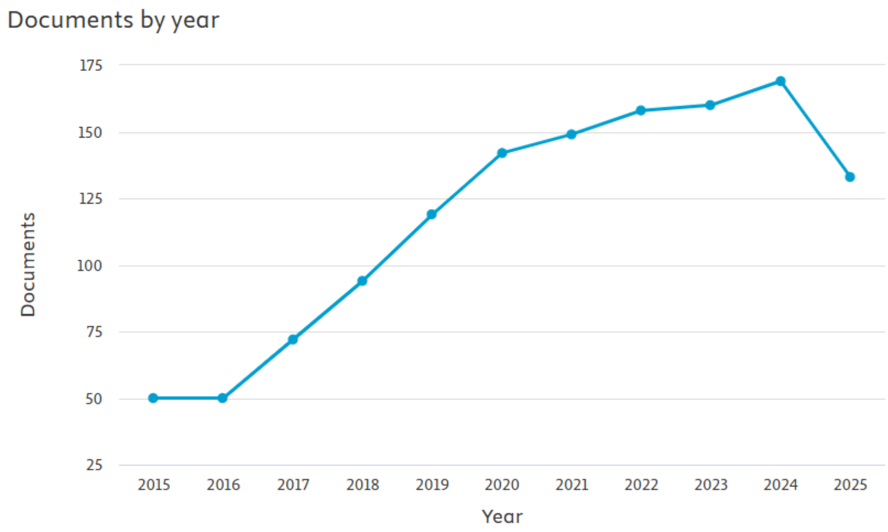

Figure 3. The development of publications regarding mathematics in STEM education studies.

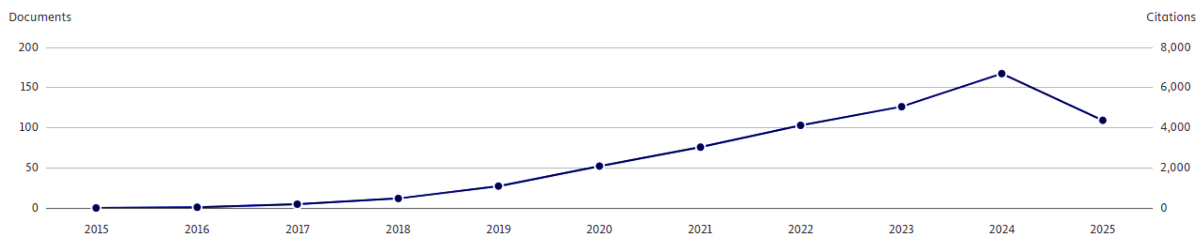

Figure 4. The development of citations regarding mathematics in STEM education studies.

Figure 4 shows that the development of citations related to mathematics in STEM education studies has relatively increased from 2015 to 2025. A total of 27,136 citations were recorded in the Scopus database, with 1 citation in 2015, followed by 36 citations in 2016, 186 citations in 2017, 474 citations in 2018, 1090 citations in 2019, 2086 citations in 2020, 3026 citations in 2021, 4113 citations in 2022, 5047 citations in 2023, 6696 citations in 2024, and 4369 citations in the first few months of 2025 until July 30, 2025. These figures indicate that citations on mathematics in STEM education studies have consistently increased from 2015 to 2024. Since 2025 is only a few months old, we cannot yet determine whether the number of citations will decrease or increase, but it is already more than half of the citations in 2024.

3.2. Science mapping and network analysis

3.2.1. Citation analysis

The citation analysis presented the most productive and influential documents, authors, countries, institutions, and sources related to mathematics in STEM education studies. The total publication (TP) was used to establish the most productive authors, countries, institutions, and sources. In contrast, the total citation (TC) was employed to determine the most influential documents, authors, countries, institutions, and sources [13]. An analysis of every unit is partially explained in the subsection. First, the most influential documents related to technological literacy studies were presented in the top five documents with the highest citation (see Table 2). Table 2 shows that the document titled “Defining Computational Thinking for Mathematics and Science Classrooms” was the most influential document regarding mathematics in STEM education studies. The document, written by Weintrop, was published by the Journal of Science Education and Technology in 2016. From 2016 until July 2025, the document was 1086 times by other relevant documents.

Table 2. Top Five documents with the highest citation.

Document Tittle	**Authors**	**Source**	**TC**	**Year**
Defining computational thinking for mathematics and science classrooms	Weintrop, D.	Journal of Science Education and Technology	1086	2016
The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education	Stoet, G.	Psychological Science	676	2018
Augmented reality for STEM learning: A systematic review	Ibanez, M.	Computers and Education	669	2018
Improving underrepresented minority student persistence in STEM	Estrada, M.	CBE Life Sciences Education	492	2016
A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers	Estrada, M.	CBE Life Sciences Education	323	2018

Second, the top five authors with the highest publications were the most productive authors, while the top five presented the most influential authors with the highest citations (see Table 3).

Table 3. Top Five authors with the highest publication and citation.

The Five Productive Authors		**The Five Influential Authors**	
Author	**TP**	**Author**	**TC**
Ladachart, L.	12	Weintrop, D.	1086
JR	9	Freeman, S.	935
Roehrig, GH.	9	Pickett, SB.	893
Chiang, F-K	6	Estrada, M.	892
Lavicza, Z	6	Theobald, EJ.	886

Table 3 shows that Ladacart was the most productive author, having published 12 documents related to mathematics in STEM education studies. Meanwhile, Weintrop was the most influential author, with his document on mathematics in STEM education studies being cited 1086 times.

Table 4. Top five countries with the highest publication and citation.

The Five Productive Countries		**The Five Influential Countries**	
Author	**TP**	**Author**	**TC**
USA	256	USA	16189
China	244	Spain	1399
Malaysia	191	United Kingdom	1189
Spain	158	China	1013
Australia	154	Australia	764

Third, the top five countries with the highest number of publications were the most productive countries, while the top five countries with the most citations were the most influential (see Table 4). Table 4 shows that the United States was the most productive country, thereby publishing 256 documents related to mathematics in STEM education studies. Moreover, the United States was the most influential, with documents on mathematics in STEM education studies cited as many as 16,189 times by other relevant documents. Fourth, the top five institutions with the highest publication counts were presented as the most productive (See Table 5).

Table 5. Top Five institutions with the highest publication.

The Five Productive Institutions	
Author	**TP**
Vanderbilt University	73
University of California	68
University of Washington	51
San Francisco State University	47
Stanford University	41

Table 5 shows that Vanderbilt University was the most productive institution, thereby publishing 73 documents related to mathematics in STEM education studies. The top five sources with the highest number of publications are listed in Table 6.

Table 6. Top five sources with the highest publication.

The Five Productive Sources	
Author	**TP**
CBE Life Sciences Education	98
Education Sciences	46
PLOS One	42
Sustainability (Switzerland)	29
Eurasia Journal of Mathematics, Science and Technology Education	27

Table 6 shows that the CBE Life Sciences Education Journal was the most productive source, which published 98 documents related to mathematics in STEM education.

3.2.2. Co-word analysis

The co-word analysis involved the use of network and overlay visualizations, which were further enhanced by a hierarchical clustering analysis [14]. Network visualization supported by a hierarchical clustering analysis was performed to present the most emerging keywords related to mathematics in STEM education. The smallest number of occurrences of a keyword was selected, with as many as ten occurrences, which resulted in 28 inter-connected keywords (see Figure 5).

Figure 5 shows that 28 interconnected keywords were divided into five clusters. The red cluster contains 9 keywords, followed by the green cluster with 7 keywords, the blue cluster with 5 keywords, the yellow cluster with 4 keywords, and the purple cluster with 3 keywords. The hierarchical clustering analysis supported grouping the themes of the emerging keywords (see Table 7).

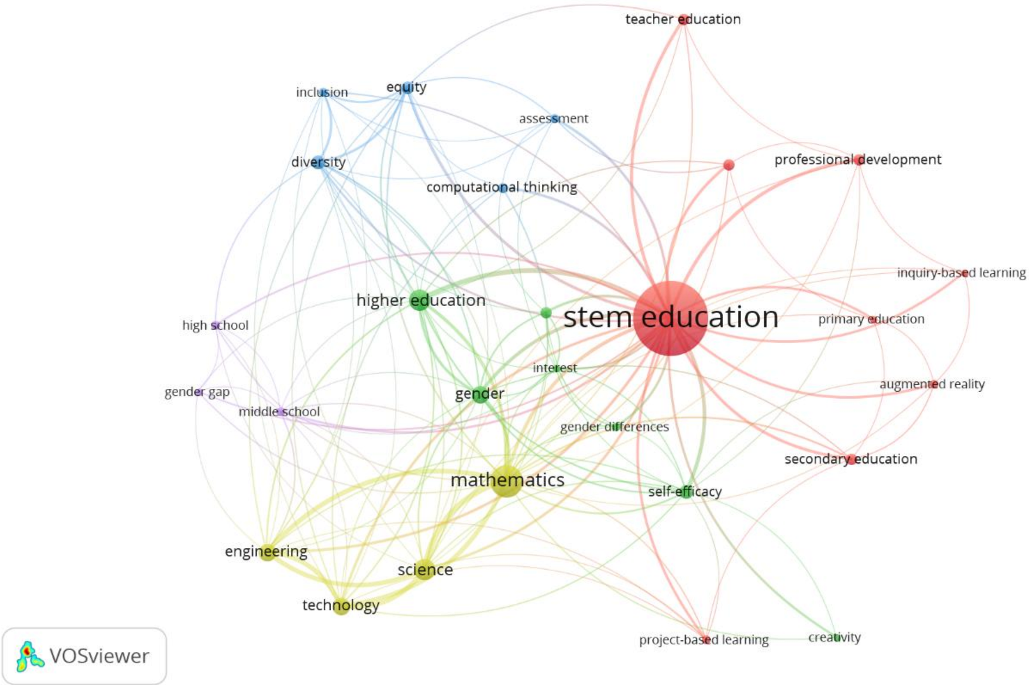

Figure 5. The emerging keywords related to mathematics in STEM education.

Table 7. The results of hierarchical clustering analysis of the emerging keywords.

No	Keyword	Cluster (Color)	Occurrence	Total Link Strength
1	stem education	Red	764	306
2	teacher education	Red	17	21
3	professional development	Red	20	23
4	primary education	Red	10	13
5	secondary education	Red	17	24
6	inquiry-based learning	Red	10	13
7	augmented reality	Red	13	16
8	project-based learning	Red	13	17
9	active learning	Red	19	20
10	mathematics	Yellow	144	194
11	science	Yellow	63	141
12	technology	Yellow	41	118
13	engineering	Yellow	45	122
14	higher education	Green	60	88
15	Gender	Green	44	59
16	interest	Green	10	20
17	gender differences	Green	12	15
18	self-efficacy	Green	29	46
19	creativity	Green	10	11

20	motivation	Green	19	22
21	Equity	Blue	25	45
22	diversity	Blue	26	38
23	inclusion	Blue	12	24
24	assessment	Blue	12	18
25	computational thinking	Blue	16	19
26	high school	Purple	12	13
27	middle school	Purple	11	20
28	gender gap	Purple	10	10

Table 7 shows that the most prominent keyword in the red cluster was "STEM education," followed by "mathematics" in the yellow cluster, "higher education" in the green cluster, "diversity" in the blue cluster, and "high school" in the purple cluster. Additionally, overlay visualization supported by a hierarchical clustering analysis was conducted to display the distribution of the most prominent keywords related to mathematics in STEM education between 2022 and 2023. The keyword with the fewest occurrences was selected, with as many as five occurrences, which resulted in 126 interconnected keywords (see Figure 6).

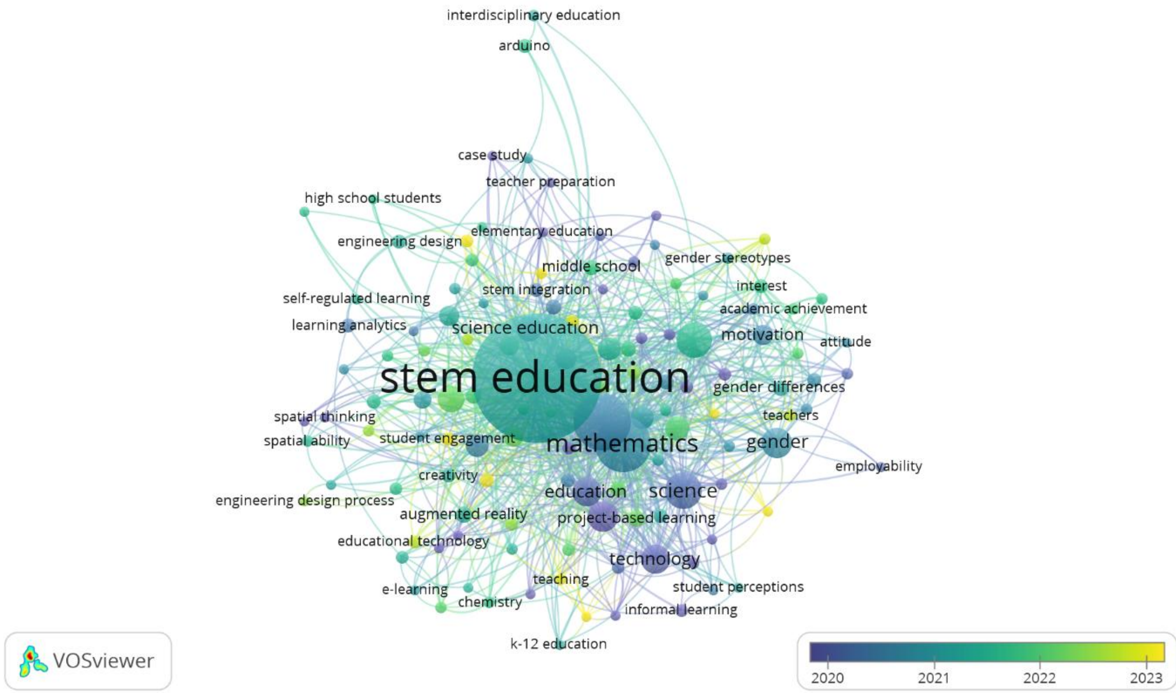

Figure 6. The distribution of emerging keywords regarding mathematics in STEM education in the recent period.

Figure 6 shows that there were some emerging keywords from 2022 to 2023, such as “inquiry-based learning”, “inclusivity”, “educational technology”, “teachers”, “teaching”, “design thinking”, “academic performance”, “educational innovation”, and “student engagement”. These findings indicate that these emerging keywords have become trending topics in research on mathematics in STEM education.

3.2.3. Co-author analysis

This study's co-authorship analysis included the author and country units. The co-authorship analysis at the author level was used to show social relationships among authors related to mathematics in STEM education. The minimum number of documents for an author was set to one, which included a document that involved 16 commonly connected authors (see Figure 7).

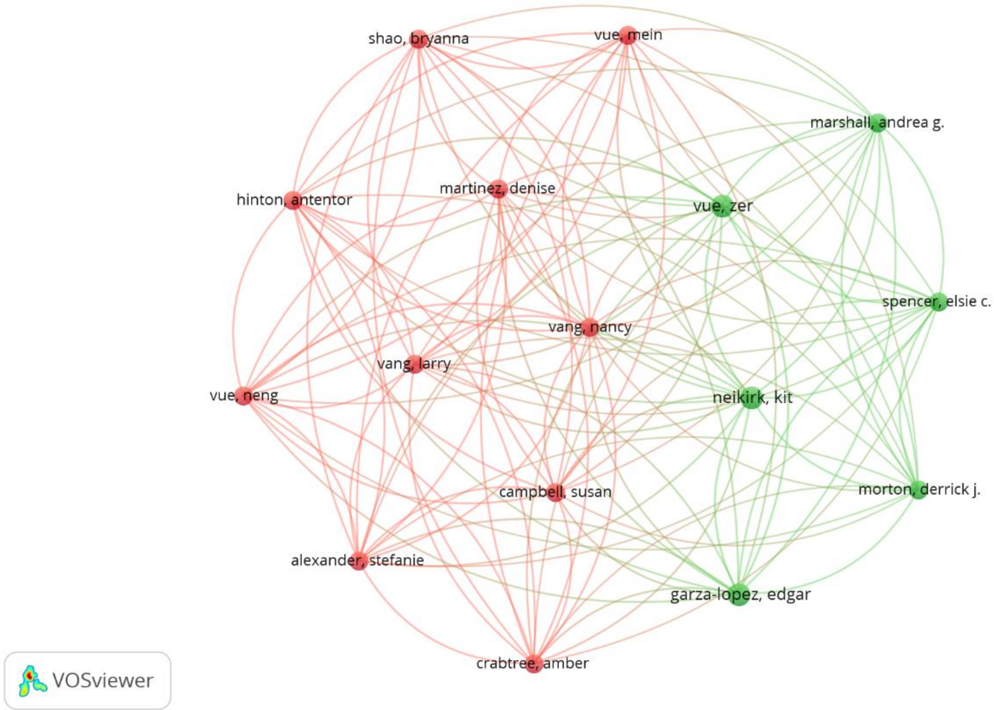

Figure 7. The social interactions among authors related to mathematics in STEM education studies.

Figure 7 shows two distinct co-author clusters, represented by red and green nodes. Each cluster indicates a group of authors who were commonly interconnected through co-authorship in the field of mathematics in STEM education. The red cluster consisted of the following 10 authors: Alexander, Stefanie; Campbell, Susan; Crabtree, Amber; Hinton, Antentor; Martinez, Denise; Shao, Bryanna; Vang, Larry; Vang, Nancy; Vue, Meng; and Vue, Mein. The green cluster included the following 6 authors: Garza-Lopez, Edgar; Marshall, Andrea G.; Neikirk, Kit; Spencer, Elsie C.; Morton, Derrick J.; and Vue, Zer.

The co-authorship analysis in the country unit was used to present the social interactions among countries regarding mathematics in STEM education. The smallest number of documents of an author was set to one document, which resulted in four commonly interconnected authors (see Figure 8).

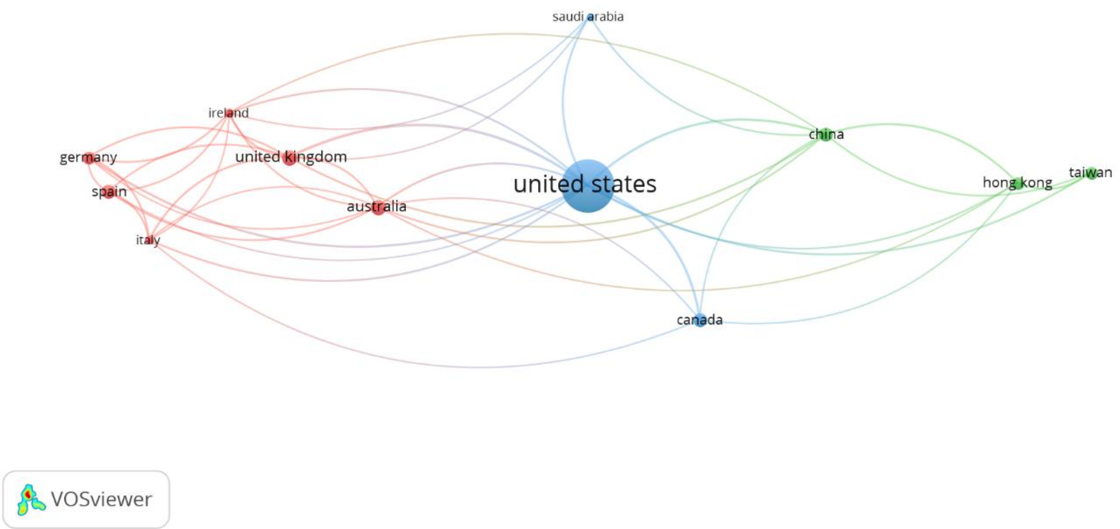

Figure 8. The social interactions among countries regarding the mathematics in STEM education studies.

Figure 8 shows that the United States played a central role in international collaboration related to mathematics in STEM education, thereby establishing co-authorship links with various countries such as Canada, China, Saudi Arabia, the United Kingdom, Australia, Germany, and others. This central position indicates that the United States has extensive international networks and plays a leading role in this field of research. Moreover, China demonstrated regional collaborations with Hong Kong and Taiwan, thus forming an East Asian cluster that is actively engaged in mathematics in STEM education. Simultaneously, European countries, such as Germany, Spain, Italy, Ireland, and the United Kingdom, were strongly interconnected, thus reflecting active intra-European partnerships and collaborations with countries such as Australia and the United States. Australia appeared to function as a bridging country that linked European and American collaborators. Similarly, Saudi Arabia has formed partnerships with both Western and Asian countries, thus indicating its growing involvement in this research domain.

4. Discussion

4.1. Publication and citation trends of mathematics in STEM education studies

The development of publications related to mathematics in STEM education studies showed a consistent increase over the decade from 2015 to 2025. This growth reflects the increasing attention given by scholars, policymakers, and educators to the integration of mathematics into interdisciplinary STEM learning. As seen in previous bibliometric studies on STEM-related fields [1,10], the number of publications tends to increase annually in response to technological progress and the urgent need for mathematical competence in scientific and technological advancements. The upward trend is clearly illustrated in 2015–2016, where the number of publications was still modest, and then rapidly escalated, thus reaching its peak in 2024. Although the data from 2025 only include the first seven months, the number of publications has already surpassed three-quarters of those from 2024, thus indicating sustained research interest in the field.

The citation trend also reflects a steady rise. Starting with just a few citations in 2015 and 2016, the number of citations rapidly increased, thus indicating a growing influence of mathematics in STEM education literature. This trend aligns with the increasing global emphasis on 21st-century skills, where mathematics serves as the core of computational thinking, problem solving, and innovation within the broader STEM framework [16,17]. Thus, both publication and citation trends highlight the strategic importance of mathematics in STEM education over the last decade.

4.2. The most productive and influential documents, authors, countries, institutions, and sources regarding mathematics in STEM education studies

The most influential documents in mathematics in STEM education tend to highlight the integration of mathematics with computational thinking, gender equity in STEM, and the use of augmented reality in learning environments. For example, Weintrop's highly cited article on computational thinking in mathematics and science classrooms emphaszized the central role of mathematics in developing cognitive and technological skills. Similarly, Estrada's works focused on diversity and persistence in STEM careers, thereby connecting mathematics education to inclusive STEM learning pathways [18].

Productive authors such as Ladachart and Roehrig have significantly contributed to topics ranging from teacher education to STEM curriculum integration [19,20]. On the other hand, Weintrop and Freeman emerged as influential voices with high citation counts, thus indicating the relevance and applicability of their research across STEM domains [21–23].

At the national level, the United States is the most productive and influential country, with the highest number of publications and citations. This dominance aligns with global bibliometric trends, where the United States often acts as a central hub of educational innovation and collaboration [24–26]. Additionally, China, Malaysia, and Australia play prominent roles in reflecting regional investments in STEM reforms and mathematics curriculum innovation.

Among institutions, Vanderbilt University, the University of California, and the University of Washington lead the contributions, thus showing how elite institutions have become focal points for STEM education research. Similarly, journals such as *CBE Life Sciences Education*, *Education Sciences*, and *PLOS One* are key sources where mathematics in STEM education studies are disseminated, thus highlighting the interdisciplinary nature of this field.

4.3. The most emerging keywords regarding mathematics in STEM education and their distribution in the recent period

The co-word analysis identified 28 interconnected keywords, which were classified into five dominant clusters:

1. **Red Cluster** (9 keywords): The most dominant centered around "STEM education" as the primary keyword. Other associated terms include "project-based learning," "inquiry-based learning," "professional development," and "teacher education." This shows that mathematics in STEM is strongly linked with pedagogical strategies and educational practices.
2. **Yellow Cluster** (4 keywords): Featuring "mathematics", "science", "technology", and "engineering", this cluster highlights the four pillars of STEM with mathematics as the

foundation. The prominence of "mathematics" as a keyword reflects its central role in STEM integration and the necessity of cross-disciplinary competence.

3. **Green Cluster** (7 keywords): This cluster includes affective and psychological constructs such as "motivation", "self-efficacy", "gender", and "creativity". The appearance of these terms reveals the increasing emphasis on a student's interest, equity, and identity in mathematics within STEM learning environments.
4. **Blue Cluster** (5 keywords): Keywords such as "diversity", "equity", "assessment", and "computational thinking" dominate this cluster, thus underscoring the importance of inclusivity and evaluation in modern STEM pedagogies.
5. **Purple Cluster** (3 keywords): Comprising "high school", "middle school", and "gender gap", this cluster focuses on demographic and schooling levels, thus indicating where most interventions and studies are situated.

The overlay analysis (Figure 6) suggests a recent shift in research themes between 2022 and 2023. Emerging keywords such as "educational innovation," "student engagement," "design thinking," and "academic performance" reflect new directions in STEM education research, particularly the role of technology and active learning models in enhancing mathematical thinking [4,27].

4.4. The social interaction among authors and countries regarding mathematics in STEM education studies

The co-authorship analysis revealed two distinct author clusters (red and green), thus representing research collaboration networks in mathematics in STEM education. The red cluster, with ten authors, includes prolific contributors such as Alexander, Campbell, Crabtree, and Martinez. These authors tend to collaborate on projects that emphasize mathematics learning in interdisciplinary STEM settings. The green cluster includes six authors, such as Garza-Lopez, Spencer, and Neikirk, thus showing another group of active researchers with a distinct collaborative network.

Meanwhile, the country-level analysis showed that the United States is the central hub of international research collaboration. The United States maintains strong co-authorship ties with countries such as Canada, China, United Kingdom, Saudi Arabia, and Australia, indicating its leadership role in the global STEM education discourse. China, along with Hong Kong and Taiwan, formed a distinct East Asian collaborative group, whereas European countries such as Germany, Spain, Italy, and Ireland showed strong intra-continental cooperation. Australia acted as a bridge between European and North American collaboration. These patterns highlight the global scope of mathematics in STEM education and the value of international cooperation in advancing this field [7,22].

4.5. Limitation of the study

Despite its broad scope, this bibliometric analysis has some limitations. First, it exclusively used the Scopus database, thereby excluding relevant studies indexed in other databases such as Web of Science, ERIC, or Google Scholar, which may provide a broader coverage. Second, the analysis of emerging keywords was solely based on the co-word analysis. Incorporating bibliographic coupling or co-citations could yield deeper insights into the intellectual structure and research fronts. Third, the visualization was solely conducted using VOSviewer. Employing additional tools, such as Gephi or Bibliometrix R, could offer more advanced and dynamic visualizations of network structures among keywords, authors, and institutions.

5. Conclusions

This bibliometric analysis provided a comprehensive overview of research trends in *mathematics in STEM education* from 2015 to 2025. The data revealed a consistent upward trajectory in publication output, with a particularly notable increase beginning in 2020 and a peak in 2024. Although data from 2025 are still incomplete, they already indicate ongoing interest and activity in this research area. The trend in citations showed a similar pattern, thus indicating that the field is increasing in both volume and academic influence. A thematic analysis using co-occurrence mapping identified five main research clusters. Among these, the red cluster, centered on “STEM education,” emerged as the most dominant, thus reflecting mathematics as a unifying force in diverse STEM educational practices. A collaborative network analysis showed that the United States is the most active and influential country in terms of publication and international collaboration, with strong connections to countries such as China, Australia, and the United Kingdom. The co-authorship patterns indicated the existence of closely linked research communities, although the number of authors connected internationally remains relatively small. These findings suggest opportunities to expand international collaborations, especially those that involve underrepresented regions. The results highlight several opportunities for future research, including a deeper exploration of how mathematics can drive innovation within STEM, particularly through the integration of educational innovation, student engagement, design thinking, and academic performance. These insights can help guide future studies and policy directions that aim to elevate the role of mathematics within interdisciplinary STEM education.

Author contributions

The conception or design of the work: Agus Maqruf; The acquisition, analysis, or interpretation of data for the work: Agus Maqruf, Tatang Herman, William Ko-Wai Tang; Drafting the work or revising it critically for important intellectual content: Elah Nurlaelah, Irma Rahma Suwarma; Checking and correcting grammar is Agus Maqruf and William Ko-Wai Tang.

Use of Generative-AI tools declaration

The authors declare that we did not use Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors confirm that they have no conflicts of interest, whether financial or personal, that could have potentially influenced the findings presented in this paper.

Ethics declaration

The author declared that no ethics approval is required for the study.

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