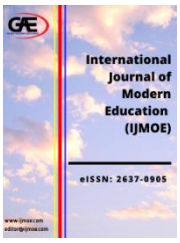
International Journal of Modern Education
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054



INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.ijmoe.com

BIBLIOMETRIC STUDY ON THE APPLICATION OF MATHEMATICS IN STEM EDUCATION

Rasyida A'alaf[1*], Zunainah Abu[2], Badariah Abdollah[3]

[1] Department of Mathematics, Science and Computer, Politeknik Banting Selangor
Email: rasyida@polibanting.edu.my
[2] Department of Mathematics, Science and Computer, Politeknik Banting Selangor
Email: zunainah@polibanting.edu.my
[3] Department of Mathematics, Science and Computer, Politeknik Banting Selangor
Email: badariah@polibanting.edu.my
[*] Corresponding Author

Article Info:

Article history:
Received date: 22.10.2025
Revised date: 11.11.2025
Accepted date: 01.12.2025
Published date: 16.12.2025

To cite this document:

A'alaf, R., Abu, Z., & Abdollah, B. (2025). Bibliometric Study On The Application Of Mathematics In Stem Education. *International Journal of Modern Education, 7* (28), 781-795.

DOI: 10.35631/IJMOE.728054

This work is licensed under CC BY 4.0

Abstract:

The integration of mathematics within STEM education has received increasing scholarly attention, reflecting its essential role in preparing students for interdisciplinary problem-solving and global competitiveness. However, despite its growing significance, limited comprehensive studies have mapped research patterns, influential contributions, and collaboration networks in this domain. This study aims to fill that gap through a bibliometric analysis of publications on the application of mathematics in STEM education. Data were collected from the Scopus database using advanced searching techniques with the keywords "mathematics," "education," and "STEM," covering the period between 2015 and 2025. After applying inclusion and exclusion criteria, a total of 776 articles were retrieved. The dataset was subsequently processed and harmonized using OpenRefine to ensure consistency. Statistical analyses, publication trends, and citation distributions were examined using the Scopus analyzer, while VOSviewer software was employed to visualize keyword co-occurrences, authorship patterns, and international collaboration networks. The findings reveal a steady increase in research output, peaking in 2024–2025, with the United States, Indonesia, and Germany emerging as the most productive countries. Highly cited articles highlight themes such as word problem-solving, interdisciplinary STEM integration, and digital innovations in mathematics education. Keyword analysis identified dominant themes around "mathematics education," "STEM education," "teacher education," and emerging topics such as "computational thinking," "artificial intelligence," and "sustainability," reflecting the field's evolving priorities. Co-authorship network analysis further showed strong international collaboration clustered among developed and emerging economies. Overall, this study contributes to a deeper understanding of the intellectual

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

structure, thematic evolution, and global collaboration trends in mathematics-focused STEM education research, providing valuable insights for educators, policymakers, and future researchers.

Keywords:

Mathematics, Education, STEM

Introduction

The integration of mathematics in STEM (Science, Technology, Engineering, and Mathematics) education is pivotal for developing essential skills such as analytical thinking, problem-solving, and logical reasoning. Mathematics serves as the foundation upon which the other STEM disciplines build, providing the necessary tools and frameworks for understanding complex concepts and solving real-world problems. The application of mathematics in STEM education not only enhances students' comprehension of mathematical theories but also demonstrates its relevance and applicability in various scientific and technological contexts. This paper explores the multifaceted role of mathematics in STEM education, highlighting its importance, the challenges faced in its integration, and the innovative strategies employed to overcome these challenges.

The role of mathematics in STEM education is multifaceted and essential for fostering a comprehensive understanding of the interconnectedness of these disciplines. Mathematics education in STEM studies requires students to practice and apply the methods they learn to ensure accuracy and understanding. The development of high-level mathematical tasks and the use of automatic assessment systems can support this process, providing meaningful feedback and enhancing the learning environment (Horvath et al., 2023). Effective teaching strategies, such as active learning, integration of technology, and problem-based learning, are crucial for engaging students and deepening their understanding of mathematical concepts (Mierluş-Mazilu & Yilmaz, 2024). These strategies enable students to visualize abstract ideas, solve complex problems, and recognize the real-world applications of mathematics in various STEM fields.

University education plays a significant role in preparing future STEM teachers by developing their competencies in mathematics and other STEM subjects. The reciprocal connection between mathematics and STEM is crucial for the development of 21st-century skills, such as critical thinking, collaboration, and creativity (Galabova, 2022). Integrated curriculum approaches that highlight mathematics as a key component of STEM education challenge the notion that mathematics is merely a tool for other disciplines. Instead, they emphasize its contribution to understanding and practicing other STEM subjects (Anderson & Makar, 2024). This integrated approach not only enhances students' mathematical skills but also fosters a deeper engagement with the subject, igniting a passion for learning and innovation (Eshaq, 2024).

The integration of technology in mathematics instruction is another critical aspect of STEM education. Technology tools, such as interactive software, graphing calculators, and data visualization tools, provide dynamic visualizations, simulations, and interactive activities that enable students to explore multiple representations of mathematical ideas (Mierluş-Mazilu &

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

Yilmaz, 2024). These tools support data analysis, graphing, problem-solving, and collaborative learning experiences, making mathematics more accessible and engaging for students. Additionally, technology facilitates real-world connections and applications of mathematics, helping students recognize its relevance in various STEM fields (Mierluş-Mazilu & Yilmaz, 2024).

Despite the benefits of integrating mathematics in STEM education, several challenges remain. One significant challenge is the need for a more pronounced role of mathematics in interdisciplinary contexts. Often, mathematics is used as an ancillary discipline in STEM activities, rather than being explicitly integrated within interdisciplinary contexts (Spreitzer et al., 2024). This highlights the need for a more comprehensive approach to incorporating mathematical concepts in STEM education. Furthermore, the preparation of teachers for this integrated approach is crucial. Teachers must be equipped with the necessary skills and knowledge to effectively integrate mathematics into STEM education and to create engaging and meaningful learning experiences for their students (Vaclavikova et al., 2025).

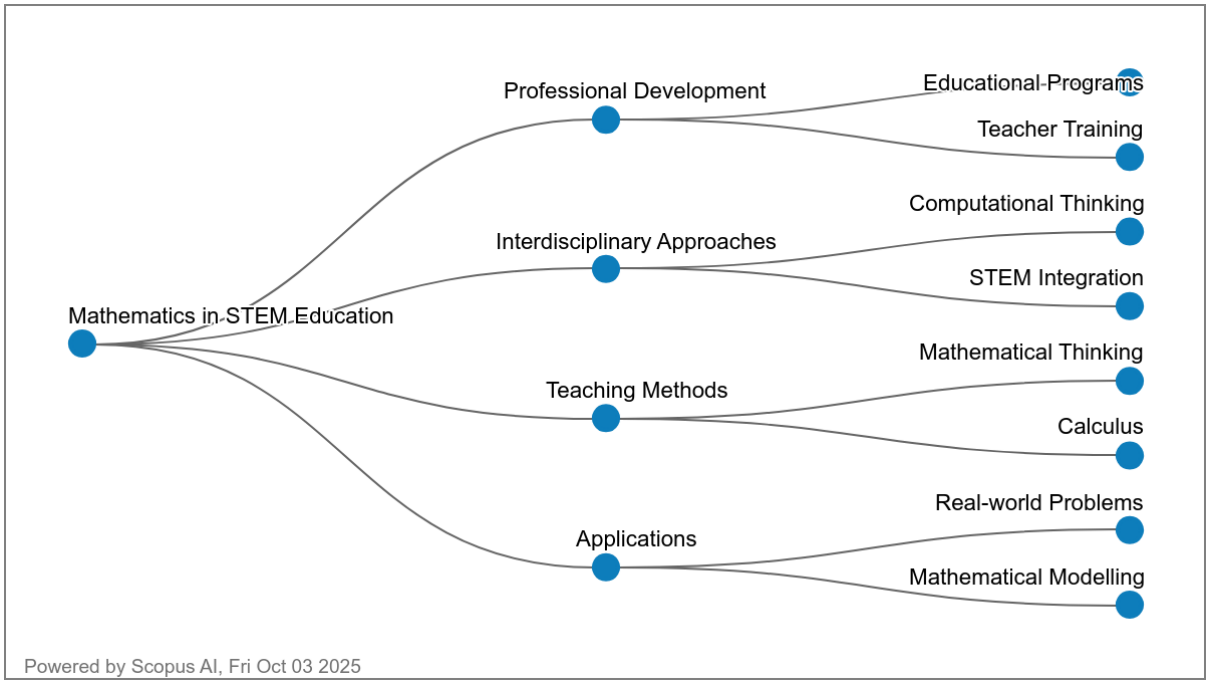


Figure 1: Concept Map of The Application Of Mathematics In STEM Education
Source: (Scopus AI, Fri Oct 03 2025)

Figure 1 illustrates (4) four major clusters are identified, highlighting the diverse roles of mathematics within STEM. First, Professional Development emphasizes the need for educational programs and teacher training that prepare educators to effectively integrate mathematics into STEM curricula. Second, Interdisciplinary Approaches connect mathematics with computational thinking and STEM integration, reflecting the trend of embedding mathematical concepts across disciplines to promote problem-solving and innovation. Third, Teaching Methods focus on cultivating mathematical thinking and strengthening understanding in core areas such as calculus, supporting students' ability to engage critically with abstract concepts. Finally, Applications underscore the practical relevance of mathematics through real-world problems and mathematical modelling, bridging theory and practice to

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

enhance students' analytical skills and readiness for industry demands. Collectively, these clusters reveal that the application of mathematics in STEM contexts is multifaceted, extending beyond content knowledge to include pedagogy, professional capacity building, and authentic problem-solving. This reinforces mathematics as a central pillar in STEM education, crucial for developing 21st-century skills and fostering interdisciplinary collaboration.

In conclusion, the application of mathematics in STEM education is essential for developing the skills and competencies needed for the 21st-century workforce. By employing effective teaching strategies, integrating technology, and preparing future STEM teachers, educators can create a dynamic and engaging learning environment that fosters a deep understanding of mathematical concepts and their applications in various STEM fields. Addressing the challenges of integrating mathematics in interdisciplinary contexts and preparing teachers for this approach will further enhance the effectiveness of STEM education and prepare students for future STEM pursuits.

Research Question

RQ1: What are the research trends in these studies according to the year of publication?
RQ2: What are the top 10 most cited articles?
RQ3: Where are the top 10 countries based on the number of publications?
RQ4: What are the popular keywords related to the study?
RQ5: What is co-authorship by countries' collaboration?

Methodology

Bibliometrics is a systematic approach used to collect, organize, and analyze bibliographic data obtained from scientific publications (Alves et al., 2021; Assyakur & Ros, 2022; Verbeek et al., 2002). While traditional bibliometric studies often emphasize descriptive statistics such as identifying core journals, distribution of publication years, and prolific authors (Wu & Wu, 2017), contemporary approaches extend beyond these basics to incorporate advanced techniques, such as document co-citation analysis, which reveal intellectual structures and emerging research frontiers. Performing a rigorous literature review, therefore, requires an iterative and carefully designed process that involves selecting appropriate keywords, executing comprehensive searches, and performing in-depth analyses. This methodological rigor facilitates the creation of a comprehensive bibliography and enhances the reliability of findings (Fahimnia et al., 2015). Accordingly, the present study focused on high-impact publications, as they provide meaningful insights into the theoretical foundations that underpin the discipline. Scopus was employed as the principal database for data retrieval to secure data accuracy (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). To maintain scholarly rigor, only peer-reviewed journal articles were included, whereas books and lecture notes were deliberately excluded (Gu et al., 2019). Here, the dataset comprised publications indexed in Elsevier's Scopus between 2020 to October 2025, thereby offering a robust foundation for subsequent bibliometric analysis.

Data Search Strategy

For the purpose of this study, bibliometric data were obtained from the Scopus database using an advanced search strategy to ensure the precision, relevance, and academic rigor of the dataset. The search string applied was specifically designed to capture research articles focused on the integration of mathematics education with science, technology, engineering, and mathematics (STEM). To enhance the quality of the dataset, several inclusion and exclusion

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

criteria were applied. Only publications written in English were retained, while non-English sources were excluded to maintain consistency and ensure broader accessibility. The timeframe was restricted to 2015– 2025, thereby capturing contemporary and relevant works while excluding older studies published prior to 2015 (refer to Table 2). Furthermore, the subject area was limited to Mathematics, ensuring the dataset remained highly focused on the discipline, and only the document type "article" was included, excluding other forms such as conference papers, book chapters, or reviews. This methodological approach emphasizes both relevance and quality, ensuring that only peer-reviewed scholarly contributions are considered. The search was conducted in October 2025 and yielded a total of 776 articles that met all defined criteria. This carefully curated dataset provides a comprehensive yet focused foundation for bibliometric mapping and analysis, offering significant findings with respect to research trends, thematic developments, and scholarly contributions at the intersection of mathematics education and STEM over the past decade.

Table 1: **The Search String**

Scopus	TITLE (Mathematics AND Education AND (sains OR technology OR engineering OR mathematics)) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "MATH")) AND (LIMIT-TO (DOCTYPE , "ar"))
	Access date: October 2025

Table 2: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2015 – 2025	< 2020
Subject Area	Mathematics	
Document Type	Article	

Data Analysis

VOSviewer, established by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (van Eck & Waltman, 2010, 2017), has established itself as a leading software in the field of bibliometric analysis. Celebrated for its user-friendly design, the tool has become widely adopted for visualizing and interpreting scientific literature. Its core strengths lie in generating intuitive network visualizations, clustering related elements, and constructing density maps that reveal structural patterns within research landscapes. The versatility of VOSviewer allows researchers to explore co-citation, co-authorship, and keyword co-occurrence networks, thereby offering comprehensive insights into scholarly communication and knowledge evolution.

The software's interactive interface, complemented by continuous updates, allows for efficient and dynamic engagement with large and complex datasets. Beyond simple visualization, VOSviewer incorporates advanced capabilities such as metric computation, customizable

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

mapping, and compatibility with a variety of bibliometric data sources. These features collectively position VOSviewer as an invaluable resource for scholars seeking to navigate, interpret, and extract meaningful insights from complex research domains.

A defining feature of VOSviewer is its remarkable ability to convert intricate bibliometric datasets into visually interpretable maps and charts. With an emphasis on network visualization, the software excels at clustering related items, mapping keyword co-occurrence patterns, and generating density visualizations. By providing a balance between methodological rigor and accessibility, VOSviewer serves both novice and expert users, facilitating an efficient exploration of knowledge structures. Its ongoing development ensures that the software remains at the forefront of bibliometric analysis, consistently providing insights through advanced metric computations and flexible visualization techniques. The versatility of VOSviewer in handling various types of bibliometric data—such as co-authorship, co-citation, and citation networks—further highlights its significance as a powerful and indispensable tool for scholarly research.

In this study, datasets containing information such as publication year, title, author names, journal, citations, and keywords in PlainText format were extracted from the Scopus database, covering the period from 2015 to October 2025. These datasets were analyzed using VOSviewer software version 1.6.20, which applied clustering and mapping techniques to generate bibliometric maps. As an alternative to the Multidimensional Scaling (MDS) approach, VOSviewer positions items within low-dimensional spaces, where the distance between any two items represents their degree of relatedness and similarity (van Eck & Waltman, 2010). While this approach bears methodological similarities to MDS (Appio et al., 2014), it diverges in its computational design.

In contrast to MDS, which commonly relies on similarity measures such as cosine and Jaccard indices, VOSviewer utilizes a normalization method that is more appropriate for analyzing co-occurrence data. Specifically, it applies the association strength AS_{ij}, calculated as (Van Eck & Waltman, 2007):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}$$

Here, C_{ij} represents the observed number of co-occurrences between items i and j, whereas $w_i w_j$ denote their respective weights. The association strength is "proportional to the ratio between on the one hand the observed number of co-occurrences of i and j and on the other hand, the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" (Van Eck & Waltman, 2007). By adopting this refined method, VOSviewer enhances the accuracy of bibliometric mapping, ensuring that visualizations more faithfully capture the intellectual and thematic structures underpinning research landscapes.

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

Findings

RQ1: What Are The Research Trends In These Studies According To The Year Of Publication?

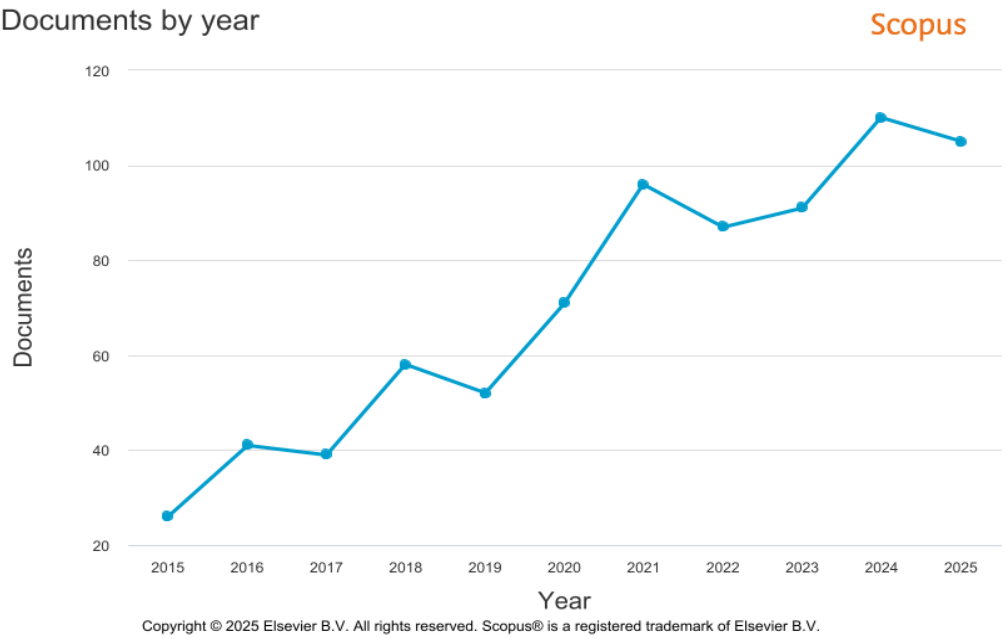


Figure 2: Trends Of Research Based on Year Of Publication.
Source: (Scopus, Fri Oct 03 2025)

The trend of publications on the application of mathematics in STEM education from 2015 to October 2025 shows a steady and significant growth, reflecting the increasing scholarly attention towards this interdisciplinary field. Beginning with just 26 publications in 2015, the number of studies gradually rose over the years, reaching 96 by 2021 and peaking at 110 in 2024, before slightly declining to 105 in 2025. This upward trend reflects an increasing acknowledgment of mathematics as a fundamental component of STEM education and its vital role in shaping curricula, pedagogy, and research. The consistent increase, particularly from 2019 onwards, suggests an expanding research community and a diversification of themes related to mathematics in STEM, possibly driven by global educational reforms, technological advancements, and the integration of digital learning tools.

Several factors may explain this rise in research output. The increasing emphasis on STEM education by governments and education institutions worldwide has positioned mathematics as a cornerstone for cultivating problem-solving, analytical, and critical thinking skills essential for 21st-century careers. The noticeable surge from 2019 to 2024 can also be linked to the global COVID-19 pandemic, which hastened the integration of digital platforms and prompted extensive research into innovative teaching methods, online learning, and technology-enhanced education. Furthermore, funding initiatives and policy frameworks prioritizing STEM education may have encouraged more scholarly contributions. The slight decrease in 2025 compared to the 2024 peak could indicate a natural stabilization after a period of heightened activity, reflecting both the maturation of the field and possible saturation of certain research themes. Overall, the trend highlights mathematics as an indispensable driver of STEM

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

education research, underpinning the development of sustainable and future-ready education practices.

RQ2: What Are The Top 10 Most Cited Articles?

Table 3: Most Cited Author

No.	Authors	Year	Source title	Cited by
1	Verschaffel et al. (2020)	2020	ZDM - International Journal on Mathematics Education	249
2	Maass et al., (2019)	2019	ZDM - International Journal on Mathematics Education	222
3	Gravemeijer et al. (2017)	2017	International Journal of Science and Mathematics Education	205
4	Stahnke et al.,(2016)	2016	ZDM - International Journal on Mathematics Education	204
5	Borba et al., (2016)	2016	ZDM - International Journal on Mathematics Education	189
6	Schukajlow et al., (2017)	2017	ZDM - International Journal on Mathematics Education	138
7	Laurens et al. (2018)	2018	Eurasia Journal of Mathematics, Science and Technology Education	134
8	Sung et al., (2017)	2017	Technology, Knowledge and Learning	123
9	Bakker et al. (2021)	2021	Educational Studies in Mathematics	122
10	Zhong & Xia (2020)	2020	International Journal of Science and Mathematics Education	121

Source: (Scopus, Fri Oct 03 2025)

The citation analysis of the top 10 most influential articles in mathematics education within the STEM context highlights the thematic breadth and evolving priorities of the field. The most cited paper, Verschaffel et al. (2020) with 249 citations, focuses on word problems in mathematics education, reflecting the enduring importance of problem-solving as a central competency in mathematics learning. This is closely followed by Maass et al. (2019) with 222 citations, which emphasizes the function of mathematics in interdisciplinary STEM education—an area gaining global traction as educational systems increasingly align curricula with the needs of a technology-driven society. Other frequently cited works, for instance, Gravemeijer et al. (2017) and Stahnke et al. (2016) with 205 and 204 citations respectively,

International Journal of Modern Education
IJMOE
EISSN: 2637-0905
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

address the broader purpose of mathematics education to equip students for the future and teachers' decision-making processes, showing how both learner-focused and educator-focused perspectives shape the discourse. Collectively, these high-impact works underscore a dual emphasis on fostering student competencies while supporting effective teaching practices in STEM-related mathematics education.

The prominence of journals such as ZDM – International Journal on Mathematics Education and the International Journal of Science and Mathematics Education among these top-cited articles illustrates their role as leading platforms for disseminating high-impact research. Themes such as technology integration (Borba et al., 2016; Sung et al., 2017; Zhong & Xia, 2020) and the affective domain in learning (Schukajlow et al., 2017) highlight the growing recognition of digital transformation and learner motivation as critical dimensions of mathematics education. The inclusion of Bakker et al. (2021), which investigated future research directions during the COVID-19 pandemic, demonstrates how global crises accelerate scholarly reflection and reshape educational priorities. Meanwhile, contributions from regions outside the traditional Western context, such as Laurens et al. (2018) on realistic mathematics education in Indonesia, emphasize the globalization of research and the diversification of perspectives. Overall, these citation patterns reveal a field deeply concerned with balancing traditional pedagogical challenges with contemporary demands of technology, globalization, and interdisciplinarity in mathematics education.

RQ3: Where Are The Top 10 Countries Based On The Number Of Publications?

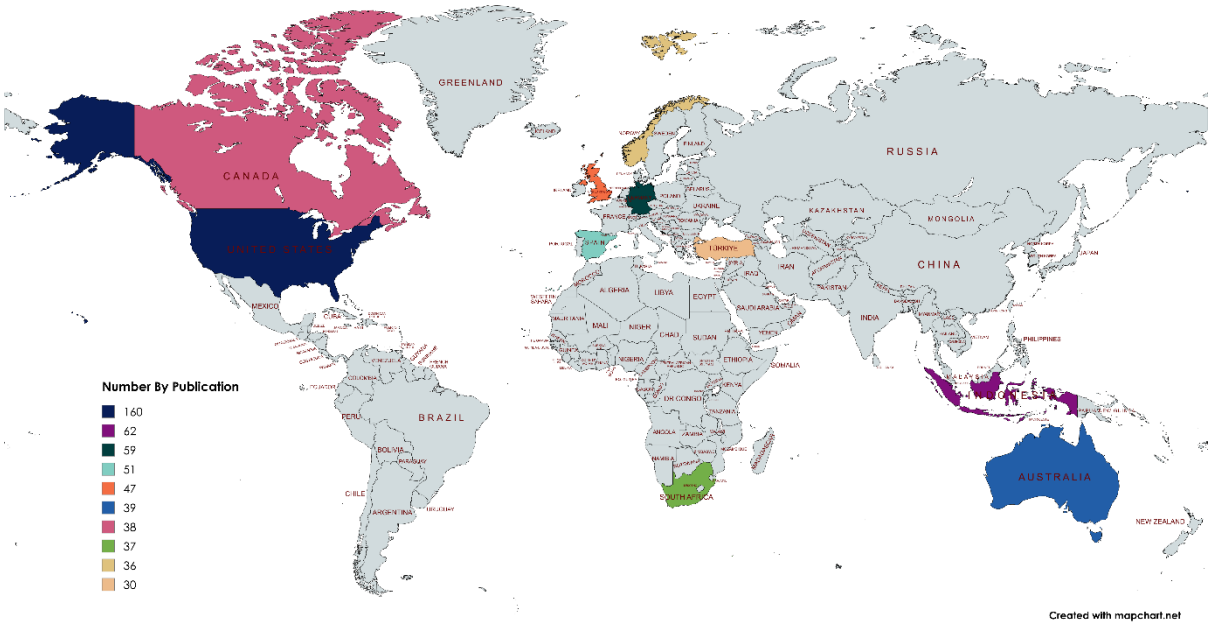


Figure 3: Country Mapping Based On the Number Of Publications
Source: (Scopus, Fri Oct 03 2025)

The distribution of publications by country demonstrates notable geographical disparities, with the United States emerging as the primary contributor, producing 160 documents, far surpassing other nations. This dominance is unsurprising, as the U.S. has long been at the forefront of education research and STEM development, supported by extensive funding, world-class universities, and strong collaborations between academia, industry, and

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

government. Following the U.S., Indonesia (62) and Germany (59) represent significant contributors, indicating the increasing prominence of both Asian and European research communities in advancing mathematics applications in STEM education. Countries such as Spain (51) and the United Kingdom (47) also show substantial outputs, reflecting their well-established academic traditions and commitment to integrating STEM education systems.

The presence of Australia, Canada, South Africa, Norway, and Turkey, each contributing between 30 and 39 publications, highlights a broader global engagement with this field, albeit at varying levels of intensity. For emerging contributors such as Indonesia, the strong output may be attributed to national education reforms, increased government funding in STEM, and a growing academic emphasis on internationalization and collaboration. In contrast, traditional research powerhouses in Europe and North America continue to drive scholarly production due to their established infrastructures and resources. South Africa's inclusion underscores the rising importance of STEM education in developing economies, particularly as a pathway for economic growth and technological advancement. The observed distribution suggests that while advanced economies dominate in terms of volume, emerging regions are progressively investing in research capacity, thereby diversifying the global knowledge landscape in mathematics and STEM education.

RQ4: What Are The Popular Keywords Related To The Study?

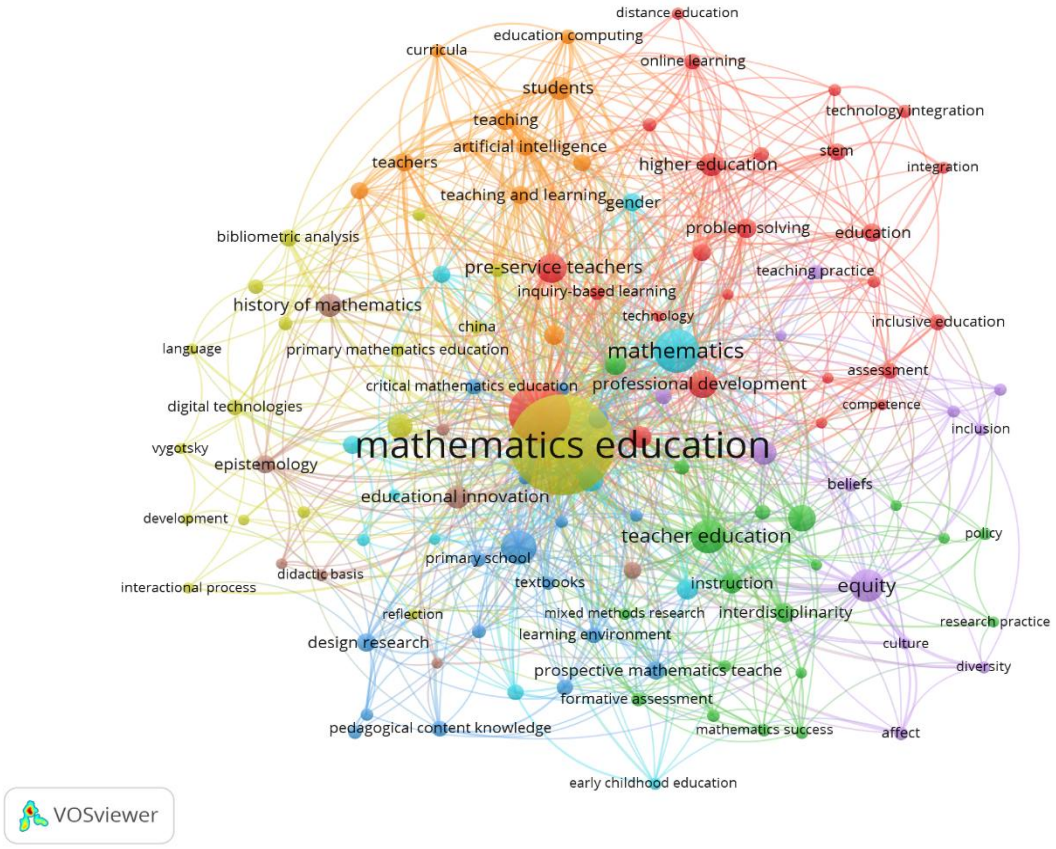


Figure 4: Network Visualization Map Of Keywords' Co-Occurrence
Source: (Sopus, Fri Oct 03 2025)

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

Co-occurrence analysis with respect to author keywords in VOSviewer identifies how frequently keywords appear together in the same publications, thus mapping relationships and thematic structures within a research field. In this study, the settings applied included the full counting method, with a minimum threshold of 5 occurrences. From a total of 1,574 keywords, 120 met this threshold, and applying a minimum cluster size of 5 resulted in the formation of 8 clusters. Each cluster is represented by a distinct color, with node size corresponding to the frequency of keyword usage. For instance, larger nodes like *mathematics education* (258 occurrences) and *mathematics learning* (100 occurrences) indicate central themes, while smaller nodes, such as *critical thinking* or *curriculum reform,* represent more specialized areas. This visualization allows researchers to see both dominant and emerging trends in mathematics education research.

The clustering reveals meaningful thematic groupings in the field. For example, clusters may capture themes such as mathematics learning processes, teacher education, equity in education, integration of technology, sustainability, and specialized approaches like realistic mathematics education or computational thinking. The color-coded clusters suggest that the research body is not monolithic but consists of interconnected subfields, each contributing distinct insights. These findings enrich the body of knowledge by highlighting research hotspots, gaps, and interdisciplinary intersections—for example, the integration of mathematics education with climate change, sustainability, and artificial intelligence. Such insights guide future research directions, policymaking, and curriculum development, ensuring that mathematics education evolves in response to contemporary educational and societal challenges.

RQ5: What Are Co-Authorship By Countries' Collaboration?

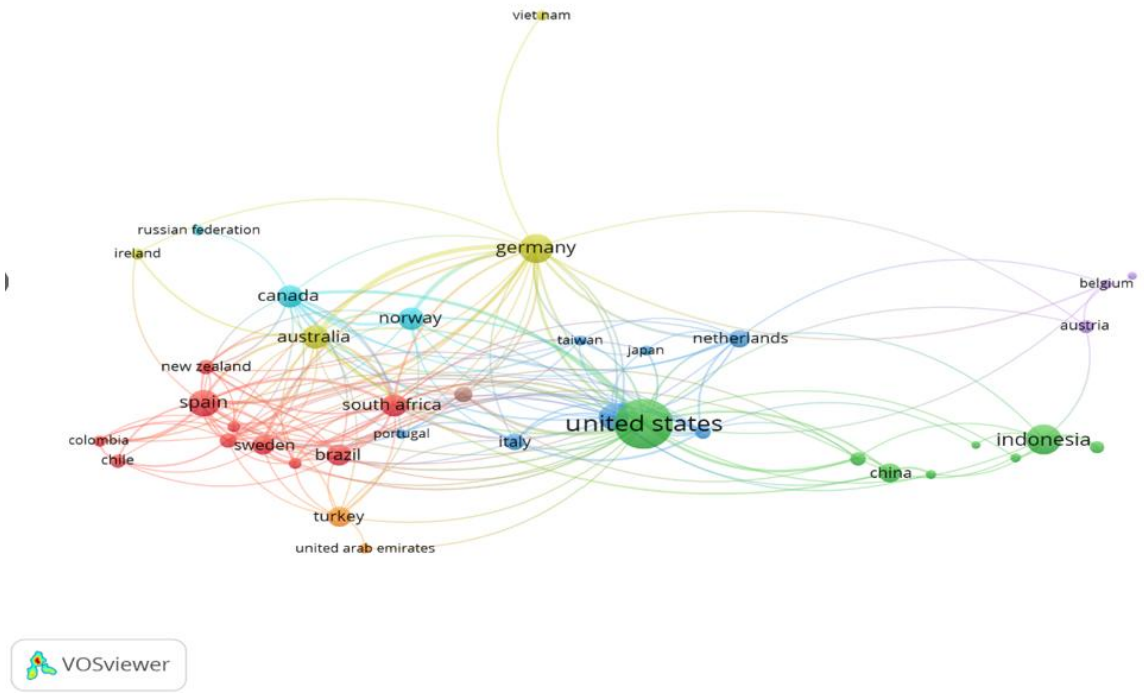


Figure 5: Network Visualization Map Of Co-Authorship By Countries
Source: (VOSviewer, Fri Oct 03 2025)

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

Co-authorship analysis by countries in VOSviewer maps international collaboration patterns by identifying how often authors from different countries publish together. It reflects the strength of research partnerships and the global interconnectedness of scientific production. In this case, the analysis used the full counting method, with a minimum threshold of 5 publications. Out of 88 countries, 39 met the threshold, and with a minimum cluster size of 5, eight clusters were generated. These clusters reveal groups of countries that collaborate more frequently with each other, while node size indicates publication volume, and links shows co-authorship ties. For example, the United States (158 publications, 2619 citations) dominates the network, connecting with multiple countries, while Germany (59 publications, 1644 citations) and Indonesia (61 publications, 638 citations) also play significant roles in building regional and global collaboration networks.

The findings add to the literature by highlighting both research powerhouses and emerging contributors in global collaboration on mathematics education and related fields. Countries like the United States, Germany, and Australia lead as central hubs of research cooperation, while nations such as Indonesia, South Africa, and Spain demonstrate strong regional partnerships that expand the inclusivity of knowledge production. The clustering of countries into eight groups shows the importance of international collaboration in advancing research impact, as countries working together often achieve higher visibility and citation counts. These insights emphasize the need for fostering cross-border partnerships, supporting developing countries' research capacity, and strengthening networks that integrate diverse perspectives, which in turn enrich the global knowledge base and drive innovation in education research.

Conclusion

This study aimed to examine the application of mathematics in STEM education through a bibliometric lens, with the objective of mapping publication trends, identifying influential works, highlighting leading countries, analyzing keyword distributions, and exploring international research collaborations. The analysis sought to answer key questions regarding the growth of research output, the most cited contributions, geographical research productivity, prominent thematic areas, and global authorship patterns.

The findings revealed a consistent upward trajectory of publications between 2015 and 2025, demonstrating the increasing significance of mathematics as a core element in STEM education. Highly cited articles emphasized problem-solving, interdisciplinary integration, and the role of digital tools in transforming mathematics pedagogy. The United States emerged as the most productive country, followed by Indonesia and Germany, reflecting both established research leadership and the growing contributions of emerging regions. Keyword analysis highlighted mathematics education, STEM education, and teacher education as central themes, with newer topics such as computational thinking, artificial intelligence, and sustainability indicating evolving research priorities. Co-authorship analysis confirmed strong global collaborations, with networks clustered across both advanced and developing economies.

The study adds to the field by providing a comprehensive overview of intellectual structures, thematic developments, and global research networks, thereby providing a reference point for future investigations. These insights may inform the design of curricula, teaching practices, and policy initiatives aimed at strengthening mathematics education within STEM contexts. Limitations of this analysis include reliance on a single database and a focus restricted to articles, which may not include related literature like conference proceedings and book

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

chapters. Future research could broaden the scope by integrating multiple databases, applying advanced bibliometric techniques, and exploring thematic evolutions across broader timeframes.

Overall, this study underscores the value of bibliometric analysis in clarifying knowledge structures and tracking the evolution of research in mathematics-focused STEM education. Mapping global trends and collaborations, it provides a foundation for informed decision-making by educators, policymakers, and researchers, while highlighting the necessity of sustained international cooperation to advance the field.

Acknowledgements
The authors would like to extend their heartfelt gratitude to Politeknik Banting Selangor for its continuous support and encouragement throughout the completion of this paper, and to Ts. Dr. Wan Azani for his kind guidance and assistance during the writing of this article.

References

Al-Khoury, A., Hussein, S. A., Abdulwhab, M., Aljuboori, Z. M., Haddad, H., Ali, M. A., Abed, I. A., & Flayyih, H. H. (2022). Intellectual Capital History and Trends: A Bibliometric Analysis Using Scopus Database. *Sustainability (Switzerland)*, *14*(18). https://doi.org/10.3390/su141811615

Alves, J. L., Borges, I. B., & De Nadae, J. (2021). Sustainability in complex projects of civil construction: Bibliometric and bibliographic review. *Gestao e Producao*, *28*(4). https://doi.org/10.1590/1806-9649-2020v28e5389

Anderson, J., & Makar, K. (2024). The Contribution of Mathematics to School STEM Education: Current Understandings. In *The Contribution of Mathematics to School STEM Education: Current Understandings*. Springer Nature. https://doi.org/10.1007/978-981-97-2728-5

Appio, F. P., Cesaroni, F., & Di Minin, A. (2014). Visualizing the structure and bridges of the intellectual property management and strategy literature: a document co-citation analysis. *Scientometrics*, *101*(1), 623–661. https://doi.org/10.1007/s11192-014-1329-0

Assyakur, D. S., & Rosa, E. M. (2022). Spiritual Leadership in Healthcare: A Bibliometric Analysis. *Jurnal Aisyah : Jurnal Ilmu Kesehatan*, *7*(2). https://doi.org/10.30604/jika.v7i2.914

Bakker, A., Cai, J., & Zenger, L. (2021). Future themes of mathematics education research: an international survey before and during the pandemic. *Educational Studies in Mathematics*, *107*(1). https://doi.org/10.1007/s10649-021-10049-w

Borba, M. C., Aşkar, P., Engelbrecht, J., Gadanidis, G., Llinares, S., & Aguilar, M. S. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM - International Journal on Mathematics Education*, *48*(5), 589–610. https://doi.org/10.1007/s11858-016-0798-4

di Stefano, G., Peteraf, M., & Veronay, G. (2010). Dynamic capabilities deconstructed: A bibliographic investigation into the origins, development, and future directions of the research domain. *Industrial and Corporate Change*, *19*(4), 1187–1204. https://doi.org/10.1093/icc/dtq027

Eshaq, H. A. (2024). The effect of using STEM education on students' mathematics achievement. *Journal of Pedagogical Research*, *8*(1), 75–82. https://doi.org/10.33902/JPR.202423476

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054
Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. In *International Journal of Production Economics* (Vol. 162, pp. 101–114). https://doi.org/10.1016/j.ijpe.2015.01.003

Galabova, D. (2022). DEVELOPING STEM COMPETENCE IN FUTURE TEACHERS IN MATHEMATICS IN THE TREND OF STEM EDUCATION. *Mathematics and Education in Mathematics*, *51*, 124–136. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85153357936&partnerID=40&md5=5b1aa8a7a34a95f4fb208cc81a3cf69f

Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L., & Ohtani, M. (2017). What Mathematics Education May Prepare Students for the Society of the Future? *International Journal of Science and Mathematics Education*, *15*, 105–123. https://doi.org/10.1007/s10763-017-9814-6

Gu, D., Li, T., Wang, X., Yang, X., & Yu, Z. (2019). Visualizing the intellectual structure and evolution of electronic health and telemedicine research. *International Journal of Medical Informatics*, *130*. https://doi.org/10.1016/j.ijmedinf.2019.08.007

Horvath, C., Körner, A., & Međo, L. (2023). A framework for developing mathematical tasks for automatic formative assessment in higher education. *International Conference on Higher Education Advances*, 567–575. https://doi.org/10.4995/HEAd23.2023.16293

Khiste, G. P., & Paithankar, R. R. (2017). Analysis of Bibliometric term in Scopus. *International Research Journal*, *01*(32), 78–83.

Laurens, T., Batlolona, F. A., Batlolona, J. R., & Leasa, M. (2018). How does realistic mathematics education (RME) improve students' mathematics cognitive achievement? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 569–578. https://doi.org/10.12973/ejmste/76959

Maass, K., Geiger, V., Romero Ariza, M. R., & Goos, M. (2019). The Role of Mathematics in interdisciplinary STEM education. *ZDM - International Journal on Mathematics Education*, *51*(6), 869–884. https://doi.org/10.1007/s11858-019-01100-5

Mierluș-Mazilu, I., & Yilmaz, F. (2024). Teaching Mathematics in STEM Education. In G. M. V., Y. F., Q.-D. A., M.-V. J., R. D.M.L.D., & M.-M. I. (Eds.), *Springer Proceedings in Mathematics and Statistics* (Vol. 439, pp. 147–170). Springer. https://doi.org/10.1007/978-3-031-49218-1_11

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2017). Emotions and motivation in mathematics education: theoretical considerations and empirical contributions. *ZDM - International Journal on Mathematics Education*, *49*(3), 307–322. https://doi.org/10.1007/s11858-017-0864-6

Spreitzer, C., Kaar, V., Kollosche, D., & Krainer, K. (2024). THE ROLE OF MATHEMATICS AND INSTRUCTIONAL PRACTICES IN INTEGRATED STEM EDUCATION. In E. T., M. O., H. J., L. G., & J. J. (Eds.), *Proceedings of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 121–128). Psychology of Mathematics Education (PME). https://www.scopus.com/inward/record.uri?eid=2-s2.0-85199602254&partnerID=40&md5=5eead0566b2317d123233a50257b93f9

Stahnke, R., Schueler, S., & Roesken-Winter, B. (2016). Teachers' perception, interpretation, and decision-making: a systematic review of empirical mathematics education research. *ZDM - International Journal on Mathematics Education*, *48*(1–2), 1–27. https://doi.org/10.1007/s11858-016-0775-y

Sung, W., Ahn, J., & Black, J. B. (2017). Introducing Computational Thinking to Young Learners: Practicing Computational Perspectives Through Embodiment in Mathematics

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 28 (December 2025) PP. 781-795
DOI: 10.35631/IJMOE.728054

Education. *Technology, Knowledge and Learning*, *22*(3), 443–463. https://doi.org/10.1007/s10758-017-9328-x

Vaclavikova, Z., Marsalek, R., & Trckova, K. (2025). Mathematics in the Background of a Virtual Escape Game. In G. M., H. J., S. I., & V. M. (Eds.), *Journal of Physics: Conference Series* (Vol. 3037, Issue 1). Institute of Physics. https://doi.org/10.1088/1742-6596/3037/1/012005

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, *111*(2), 1053–1070. https://doi.org/10.1007/s11192-017-2300-7

Van Eck, N. J., & Waltman, L. (2007). Bibliometric mapping of the computational intelligence field. *International Journal of Uncertainty, Fuzziness and Knowldege-Based Systems*, *15*(5), 625–645. https://doi.org/10.1142/S0218488507004911

Verbeek, A., Debackere, K., Luwel, M., & Zimmermann, E. (2002). Measuring progress and evolution in science and technology - I: The multiple uses of bibliometric indicators. *International Journal of Management Reviews*, *4*(2), 179–211. https://doi.org/10.1111/1468-2370.00083

Verschaffel, L., Schukajlow, S., Star, J., & van Dooren, W. (2020). Word problems in mathematics education: a survey. *ZDM - International Journal on Mathematics Education*, *52*(1), 1–16. https://doi.org/10.1007/s11858-020-01130-4

Wu, Y. C. J., & Wu, T. (2017). A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice. In *Management Decision* (Vol. 55, Issue 7, pp. 1333–1350). https://doi.org/10.1108/MD-05-2017-0518

Zhong, B., & Xia, L. (2020). A Systematic Review on Exploring the Potential of Educational Robotics in Mathematics Education. *International Journal of Science and Mathematics Education*, *18*(1), 79–101. https://doi.org/10.1007/s10763-018-09939-y