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STEM in Mathematics Teaching and Learning: A Bibliometric Analysis

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***Abstract*:**

STEM education, which integrates science, technology, engineering, and mathematics, has become increasingly important in modern education. This study aims to present a bibliometric analysis of STEM in mathematics teaching and learning topics published in the Scopus database. The data used in this study amounted to 1,787 articles published from 2013 to 2023. This research uses reference management software, namely Publish or Perish for data collection, Microsoft Excel for data analysis, RStudio, and VOSviewer for data visualization. The results showed that STEM in mathematics teaching and learning research increased consistently from 2013 to 2023, with some years experiencing a greater increase than others. A significant increase occurred in 2019–2020. The United States is the most productive country in terms of publications. Yuenyong, C., has the most publications, and Universitas Pendidikan Indonesia is the organization with the most publications. Keywords that are widely used through WordCloud include "students," "STEM education," and "engineering education." Therefore, these findings can serve as a guide for future researchers to conduct relevant research using STEM in mathematics teaching and learning.

Keywords: STEM; Mathematics; Teaching; Learning, Bibliometric.

1. Introduction

STEM education is a pedagogical approach that combines science, technology, engineering, and mathematics in an interdisciplinary manner. This approach promotes an interdisciplinary method of teaching subject matter, in which students acquire the ability to address real-world issues by combining concepts, methods, tools, skills, and values from several domains. (Siritheeratharadol, P., Tuntivivat, S., Intarakamhang, 2023), (Maass et al., 2019).

The curriculum places a strong emphasis on practical implementation, the ability to solve problems, and the development of critical thinking skills. The significance of integrating mathematics with real-world contexts and other STEM disciplines is emphasised by the statement "Teachers can implement the STEM approach in mathematics classrooms by designing activities that integrate mathematical

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concepts with science, technology, and engineering, making mathematics learning more meaningful and enjoyable." This method can be executed using diverse activities and resources. The STEM.org.uk website provides a range of mathematical activities that are integrated with science, technology, and engineering. These activities include counting puzzles, geometric patterns, and resources that explore the mathematical concepts used in science and engineering. In addition, the Science Buddies website provides STEM activities in the field of pure mathematics for children. These activities are designed to stimulate young minds through mathematics-based investigations, with a focus on highlighting the elegance and reasoning behind statistics and equations.

The incorporation of mathematics into STEM education is crucial due to its fundamental significance in these disciplines. STEM education prioritises the pragmatic utilisation of mathematical principles in practical situations, hence cultivating a more profound comprehension of mathematics. Teachers have the ability to utilise a diverse range of resources to aid in the instruction of mathematics within the STEM framework. These resources encompass materials designed for both primary and secondary school. Multiple studies have examined the difficulties and advantages of incorporating STEM education, which includes mathematics, into the curriculum. The results indicate that combining content knowledge from several STEM fields with a critical examination of societal and ethical issues can enhance students' ability to engage in discussion regarding complex global crises, such as climate change. Nevertheless, it is important to note that not all scientific material may or can be instructed through an integrated approach. In addition, while employing an integrated approach, it is crucial to clearly establish the content and relationships. Mathematics should be emphasised to underscore its crucial role in STEM education. Incorporating mathematics into STEM education is crucial in equipping students for the worldwide transition towards science and technology. The subject of STEM (Science, Technology, Engineering, and Mathematics) education research is constantly changing, and bibliometric studies have been used to get insights into the overall advancement and organisation of this study.

Bibliometric analyses have gained significance in STEM education research because to the evolving science and technology landscape, resulting in transformative advancements in human existence. These assessments facilitate staying abreast of the advancements and modifications in the sector, particularly in relation to crucial matters such as the global economic competition, the progress of artificial intelligence, and the demand for sustainable energy sources. Researchers can utilise bibliometric tools to obtain significant insights on the worldwide landscape of STEM education research, the interrelationships among various studies, and the changing patterns and ideas in the area. Various studies have employed bibliometric techniques to chart the terrain of STEM education research, such as analysing co-citations of publications, co-citations of authors, and word frequency. For instance, a bibliometric analysis of STEM in early childhood education unveiled the patterns in the advancement of published research in this domain. (Salah A. M. Ahmed, Wenlan Zhang, Hongliang Ma, 2023).

A different study employed bibliometric analysis to uncover the organisation and evolution of STEM literature, encompassing the geographical, institutional, and temporal distribution of studies in the discipline. (Tas & Bolat, 2022). Bibliometric analysis is an invaluable technique for comprehending

the advancement, organisation, and patterns in STEM education research. It aids researchers in pinpointing crucial study domains and monitoring the development of concepts and methodologies in STEM education. To summarise, bibliometric analyses have demonstrated their worth as valuable instruments for comprehending the advancement, organisation, and patterns in STEM education research. Through the utilisation of these techniques, researchers can acquire a thorough understanding of the discipline, pinpoint crucial areas of study, and monitor the development of ideas and approaches in STEM education.

Given this, the present study performed a bibliometric analysis of STEM in mathematics and education to offer insights into research advancements, with the objective of addressing the following inquiries:

1. What is the progress of publications on STEM in mathematics teaching and learning over the past decade?
2. What types of documents are commonly released in relation to STEM in Mathematics teaching and learning?
3. Which country leads in research on STEM in mathematics teaching and learning?
4. The predominant language used in STEM mathematics teaching and learning materials is?
5. Which organisation conducts the highest amount of research on STEM in the field of mathematics education?
6. Which writers are known for regularly publishing studies on mathematics teaching and learning in the field of STEM?
7. Which words are most commonly seen in studies on STEM in mathematics teaching and learning?
8. What are the current areas of focus in mathematics teaching and learning research within the STEM field?
9. What is the distribution of publications on STEM in mathematics teaching and learning shown as a TreeMap?
10. How can research on STEM in mathematics teaching and learning be classified according to topic similarity?
11. The network of links between documents commonly utilized in STEM refers to the interlinking relationships among various papers in the field of mathematics teaching and learning research?

2. Literature Review

STEM education is a pedagogical approach that combines science, technology, engineering, and mathematics in an interdisciplinary manner. An examination of the existing literature on STEM in mathematics education demonstrates that STEM instruction has positive effects on learners by fostering enthusiasm for STEM subjects and enhancing comprehension of essential abilities for the modern day, including problem-solving, critical thinking, communication, and teamwork. The review moreover outlines optimal strategies for STEM education, encompassing fundamental skills, instructional frameworks, and essential implementation of STEM principles. Mathematics educators should ascertain the optimal STEM methodologies to utilize, despite the limited comprehension of efficacious STEM activities and associated difficulties. STEM integration encompasses common characteristics in its design and execution, and it entails students utilizing mathematical and scientific principles they have acquired in a practical context. Integrated STEM programs facilitate the

acquisition of abilities that empower students to understand and utilize their learning in new and unfamiliar scenarios. (Margot & Kettler, 2019), (Kaur et al., 2022), (Siritheeratharadol, P., Tuntivivat, S., Intarakamhang, 2023), (Widya et al., 2019), (Just & Siller, 2022).

The utilization of STEM in the instruction and acquisition of mathematics has been investigated through diverse resources and studies. The objective of these endeavors is to strengthen teachers' comprehension and instructional methods, while also improving students' aptitude for mathematical reasoning and problem-solving. Continued investigation and advancement in this field can result in enhanced and captivating mathematics instruction for students, ultimately cultivating a more robust groundwork for STEM-related careers. The findings from (Li & Schoenfeld, 2019) demonstrate the correlation between mathematics and STEM education, underscoring the significance of mathematics as a fundamental basis for diverse careers, particularly in the fields of science, technology, engineering, and mathematics (STEM). Research repeatedly shows that integrating a STEM perspective into mathematics instruction has a beneficial effect on teaching and learning. (Sevimli & Ünal, 2022) discovered that mathematics teachers hold a favorable perception of STEM tasks, but encounter difficulties when it comes to incorporating them into the curriculum. The studies conducted by (Jawad et al., 2021) and (Kong & Matore, 2022) shown notable enhancements in students' creative thinking and quantitative performance when they were instructed utilizing a STEM methodology. These studies emphasize the significance of including STEM (Science, Technology, Engineering, and Mathematics) into mathematics education in order to improve students' learning outcomes.

The need for study on "Analyzing STEM in mathematics teaching and learning" is pressing in this quickly changing environment. Additional measures are required to thoroughly scrutinize it. Furthermore, the prevailing pattern of incorporating STEM principles into the instruction and acquisition of mathematics. Conducting this type of research is crucial for identifying opportunities, trends, and strategies to optimize the utilization of social media in order to improve learning outcomes, increase student engagement, and enhance the effectiveness of teaching in the field of STEM. By employing a bibliometric approach, this research aims to offer a comprehensive perspective on the impact of STEM on mathematics education, with the goal of informing more effective policies and practices to enhance the quality of learning.

3. Methodology

This study use the bibliometric analysis methodology to examine papers pertaining to STEM in the field of mathematics education. Bibliometrics is a quantitative methodology used to assess and analyze scientific material that has been published. The utilization of bibliometric methodologies, as elucidated by (José de Oliveira et al., 2019), (Oosthuizen & Pretorius, 2020), and (Zupic & Čater, 2015), is highly advantageous for delineating the current status of knowledge, pinpointing areas of study deficiency and emerging patterns, and scrutinizing the cognitive framework of a particular domain. These methodologies, such as citation analysis, co-citation analysis, bibliographical coupling, co-author analysis, and co-word analysis, offer an unbiased and rigorous approach to assessing scientific literature. They serve the purpose of identifying and facilitating the progression of scientific initiatives, ascertaining primary research subjects, and charting research specializations.

This bibliometric analysis utilizes the Scopus database to conduct a search using the terms "STEM", "learning", "teaching", and "mathematics". The specified keywords were used to search for matches

in the titles, abstracts, and keywords of articles. The most often utilized software programs for performing bibliometric analysis include RStudio, VOSviewer, CiteSpace, and Bibliometrix (Colina Vargas et al., 2022). These tools provide a range of functions, including data collecting and analysis. They can be utilized to evaluate the productivity and influence of authors and institutions, as well as to examine collaboration and diversity in authorship (Colina Vargas et al., 2022). However, the selection of a tool should be determined by the unique analysis requirements, as each tool possesses distinct advantages and constraints. (Moral-muñoz et al., 2020).

Bibliometric analysis encompasses several components, including WordCloud, Topic Trends, TreeMap, and Grouping by Coupling. Moreover, bibliometric data is subjected to descriptive analysis, encompassing metrics such as publication count, author count, subject distribution, and keyword frequency. This bibliometric study aims to identify and categorize publications that specifically emphasize the utilization of social media in an educational setting. The analysis considers factors such as the subject matter, publication year, and authorship. Furthermore, a citation network analysis was performed to investigate the correlation between pertinent publications and the study subject being examined.

4. Result

1. Publication on STEM in mathematics teaching and learning according to year

There are a total of 1,787 research data points, and there is a consistent upward trend in the number of articles each year. Figure 1 displays a publication on STEM in mathematics education and learning from recent years. Commencing with a total of 50 articles in 2013, the quantity had a consistent growth and reached its zenith in 2021 with a count of 274 articles. This signifies a substantial increase in the output of articles within that specific time frame. Although there is an overall upward trend, there are variations in specific years. Specifically, there was a decrease in 2022 following a period of growth that reached its highest point in 2021. Exploring this domain further could yield valuable insights into the variables that could impact these oscillations. On the whole, the data indicates a steady upward trend from 2013 to 2023, with certain years experiencing more substantial growth than others. There was a substantial rise in 2019-2020.

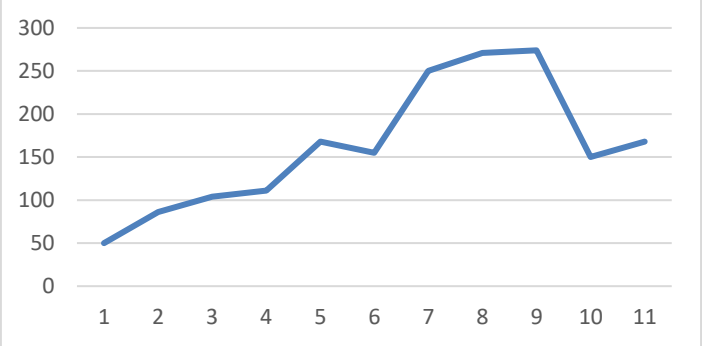

Figure 1: Publication on STEM in mathematics teaching and learning according to year

2. Publication on STEM in mathematics teaching and learning by document type

Figure 2 depicts the representation of STEM in publications related to mathematics teaching and learning, categorized by document type. Conference papers and articles are the most prevalent types of publications, surpassing other types by a wide margin. The category with the greatest count is

Conference Paper, which has a total of 895. It is followed by Article, which has a count of 689. Publication genres such as Book, Conference Review, and Book Chapter have relatively little contributions. The numerals are 30, 25, and 109, in that order. The contributions of Review (33) and Conference Review (25) types are quite restricted compared to other publishing categories. While the quantity of Book Chapters is fewer compared to Conference Papers and Articles, it still makes a substantial contribution with a count of 109. This data provides insights into the extent of collaboration and idea sharing that occurs within a conference or scientific forum, as evidenced by the publication formats such as Conference Paper. Further analysis of this area could provide valuable insights into the collaborative dynamics within the field.

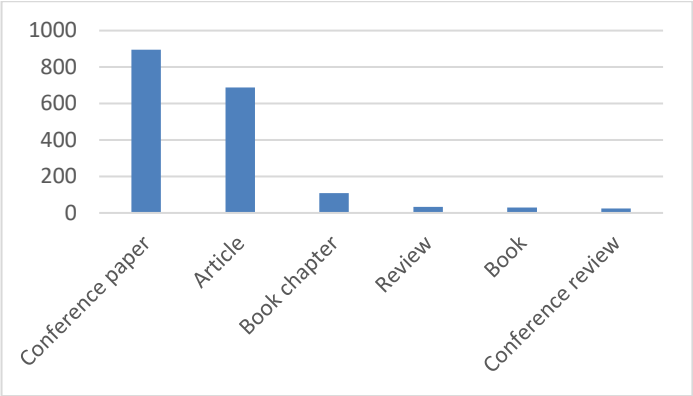

Figure 2: Publication on STEM in mathematics teaching and learning by document type

3. Publication on STEM in mathematics teaching and learning by countries

The study of the obtained data revealed that publications pertaining to STEM in mathematics education encompassed 91 nations. The United States exhibits a substantial contribution in the quantity of publications, amounting to a total of 713. Apart from the United States, Asian countries such as Indonesia (155), Australia (95), Malaysia (74), Thailand (54), Taiwan (41), China (39), Hong Kong (36), and Vietnam (21) also have significant contributions in the number of publications. European countries such as the United Kingdom (68), Spain (64), Germany (50), Italy (43), Ireland (26), and Greece (23) also show strong participation in the production of scientific publications. and other countries consisting of various countries totaling 144 publication.

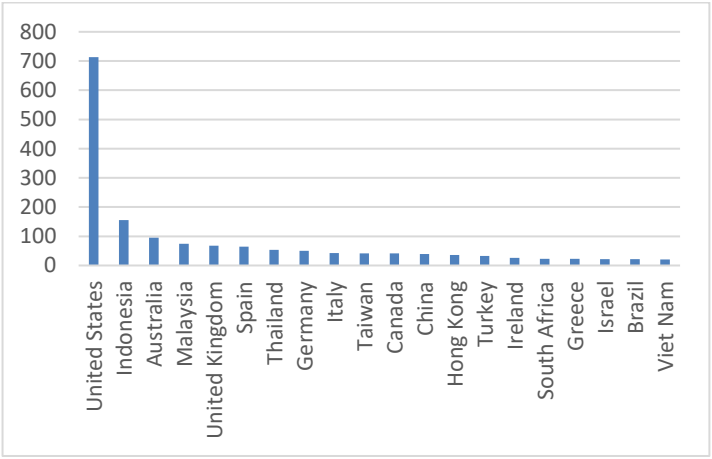

Figure 3. Publications on STEM in mathematics teaching and learning by countries

4. Publication on STEM in mathematics teaching and learning according to language

Figure 4 shows the language used in the publication on STEM in mathematics teaching and learning. English exhibits a pronounced hegemony in terms of publication count, amounting to a total of 1769. This indicates that English is the predominant language utilized in scientific research and worldwide publications. With the exception of English, involvement in other languages is typically restricted. Spanish (6), Chinese (4), and Portuguese (3) make contributions, albeit somewhat smaller in comparison to English. The scarcity of publications in languages other than English poses a constraint on the accessibility of research for groups who utilize these languages. This factor should be taken into account while striving to enhance accessibility and diversity in scientific communication.

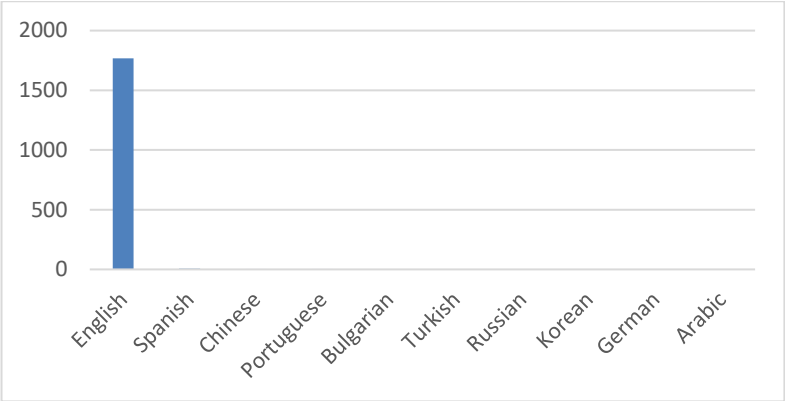

Figure 4. Publication on STEM in mathematics teaching and learning according to language

5. Publication on STEM in mathematics teaching and learning by organization

A total of 160 organizations were found in the data. Figure 6 displays the publishing data regarding STEM in mathematics teaching and learning, categorized by organization. Universitas Pendidikan Indonesia made a noteworthy contribution with a total of 36 publications, establishing itself as the institution with the biggest contribution. Notable American institutions, including Purdue University (34), Texas A&M University (30), Virginia Polytechnic Institute and State University (16), NC State University (15), University of Georgia (12), and others, demonstrated significant contributions. In addition, Universiti Kebangsaan Malaysia (20), Khon Kaen University (19), Universiti Teknologi Malaysia (17), Universitas Lampung (17), Universitas Negeri Malang (14), Universitas Syiah Kuala (11), and Universitas Sebelas Maret (10), among others, demonstrated significant engagement in scientific publications.

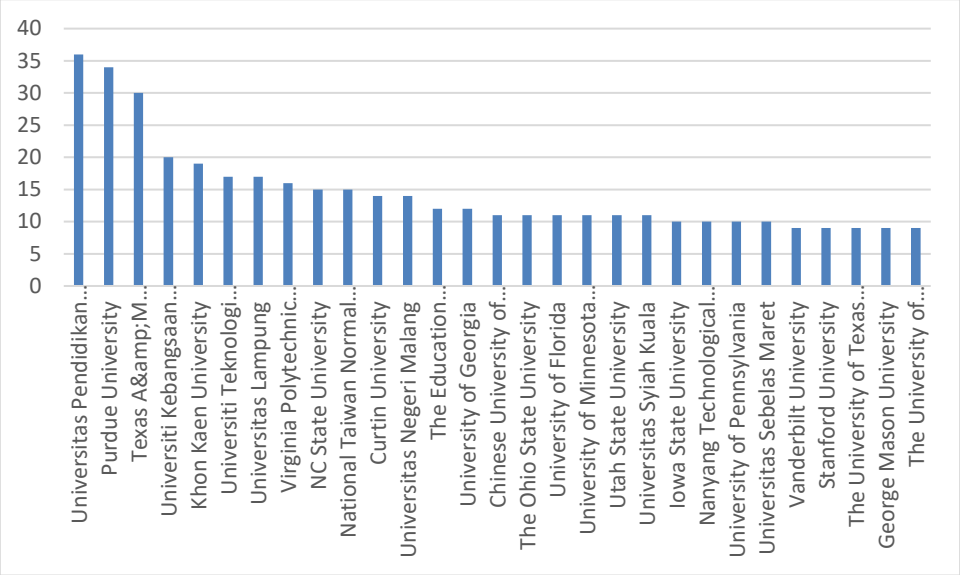

Figure 5. Publication on STEM in mathematics teaching and learning by organization

6. Publication on STEM in mathematics teaching and learning according to the authors

Figure 6 displays publishing data on STEM in mathematics teaching and learning, categorized by author as a collective, with a total of 162 authors. Here are the top 20 authors who have published between 5 and 11 works. Yuenyong, C. has the most number of publications, with a total of 14. The individuals listed in descending order of their rankings are Abdurrahman (11), Capraro, R.M. (10), Capraro, M.M. (10), Muntean, G.M. (8), Lavicza, Z. (8), Ali, M. (8), Suwarma, I.R. (7), So, W.W.M. (6), and Roehrig, G.H. (6). This data can offer a comprehensive perspective of authors who contribute to the field of STEM in research related to mathematics teaching and learning.

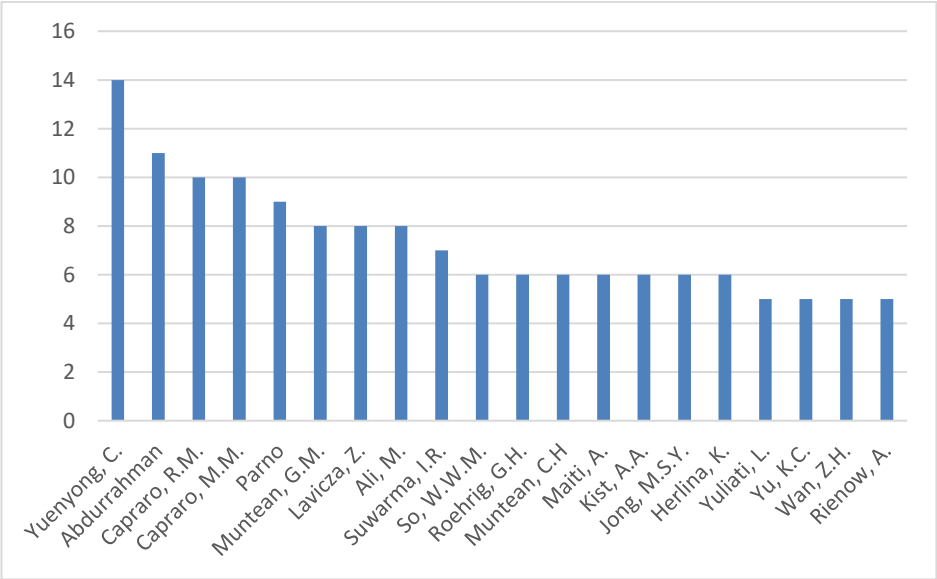

Figure 6. Publication on STEM in mathematics teaching and learning according to the authors

7. WordCloud analysis

A WordCloud offers a potent depiction of the most prominent or pertinent keywords. Figure 7 displays a WordCloud that illustrates the most frequently utilized keywords in research related to teaching and

learning mathematics in the STEM field. The term "students" is the keyword that appears most frequently. Additional terms include "STEM (Science, Technology, Engineering, and Mathematics)" and "Engineering Education," "Teaching," "Education," "Curricula," and "STEM Education," "Computing Education," and "E-learning."

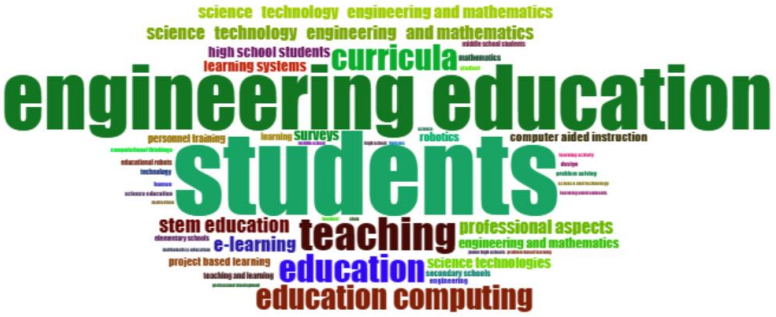

Figure 7: WordCloud

8. Trend Topics

The number of research utilizing specific keywords has been steadily rising over the years, as depicted in Figure 8. The terms "Postsecondary Education," "Constructionism," "Experiments," and "Standards" have exhibited a rising trend between 2013 and 2017. The terms "Standards" and "Mathematical Techniques" exhibit a steady and continuous increase from 2014 to 2017. This could indicate the emphasis on creating and executing standards in mathematics education. In addition, there has been a growing body of study and interest in the fields of STEM teaching and math education between 2016 and 2021, as seen by the increased use of terms such as "Teaching," "Education," "Engineering Education," and "STEM Education." The fields of Science, Technology, Engineering, and Mathematics (STEM) and its derivatives demonstrate a notable and consistent increase in growth between the years 2015 and 2020. From 2018 to 2023, there was an upward tendency in topics such as "Social Networking (Online)," "Augmented Reality," "Learning Systems," and "Machine-Learning." This indicates a growing desire to include technology into the process of studying mathematics. Subsequently, in 2021, the emergence of topics like "Science Technologies" and "Science Curriculum" indicates the possibility of new research directions.

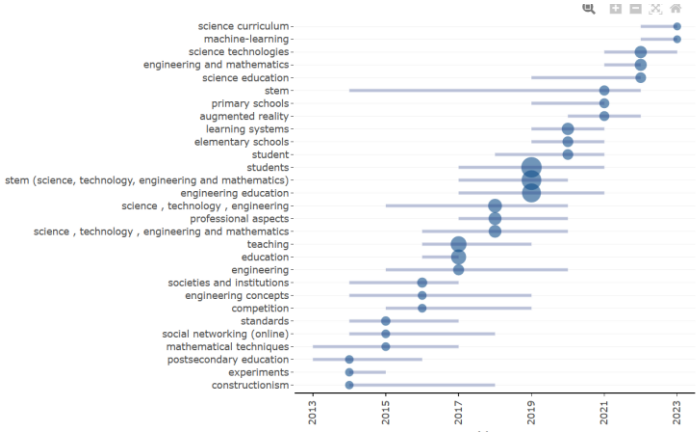

Figure 8: Trend Topics

9. Tree Map

A TreeMap is a type of data visualization that presents data in the form of rectangles. The largest rectangles represent the terms that occur most frequently in the research. Figure 10 displays the data pertaining to often encountered phrases in the field of STEM in research on mathematics teaching and learning. Based on the data analysis, the terms "students", "STEM (Science, Technology, Engineering, and Mathematics)", and "Engineering Education" have the largest impact on the number of publications. The titles "Teaching" and "Education" suggest a strong focus on instructing and educating within the STEM setting. The terms "Science, Technology, Engineering, and Mathematics" (STEM), "Science Technologies," and "Learning Systems" reflect a strong enthusiasm for using technology into STEM education. This signifies a transition towards a learning strategy that is increasingly centered around technology.

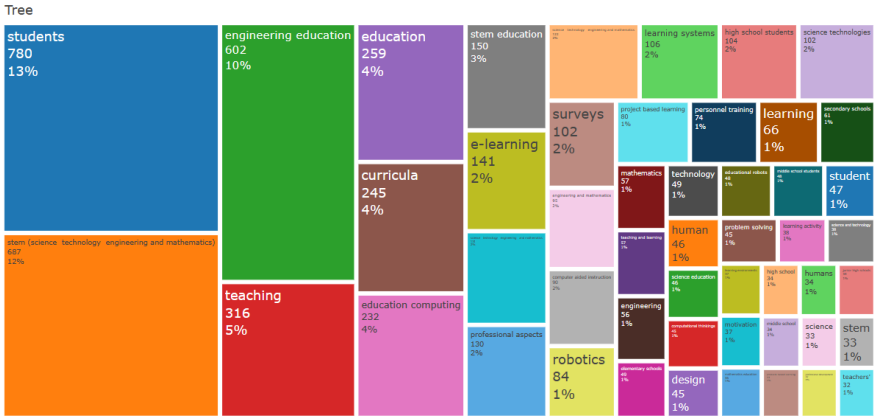

Figure 9: TreeMap

10. Clustering by Coupling

This analysis presents data regarding the distribution of frequencies, measures of centrality, the influence of variables, and the visual representation of information within the research groups. Group comparisons facilitate the comprehension of the respective contributions of each group to the research network and its influence within a certain setting. Figure 10 depicts the categorization of data according to various pertinent keywords related to the investigation. Group 1, which represents STEM (Science, Technology, Engineering, and Mathematics), exhibits the highest frequency (62) and a relatively high centrality (0.310934247). This suggests that Group 1 is the most influential and interconnected within the network. Group 1 and Group 4 demonstrate the substantial impact of STEM and engineering education in establishing connections with other groups. The influence of STEM on Group 3 is substantial, suggesting a robust correlation between STEM and computing education. Group 6, which specifically targeted "adolescents" with a low frequency of 17, exhibited a notable level of centrality and an exceptionally high impact of 6.532537237. These findings indicate that studies on teenagers have a significant impact, particularly in the fields of science, technology, engineering, and mathematics (STEM), as well as among university students. Despite its relatively high frequency, Group 5 has a comparatively low impact (2.520936469) in relation to the other groups. This suggests that the themes within this group are more narrow and have a more restricted influence.

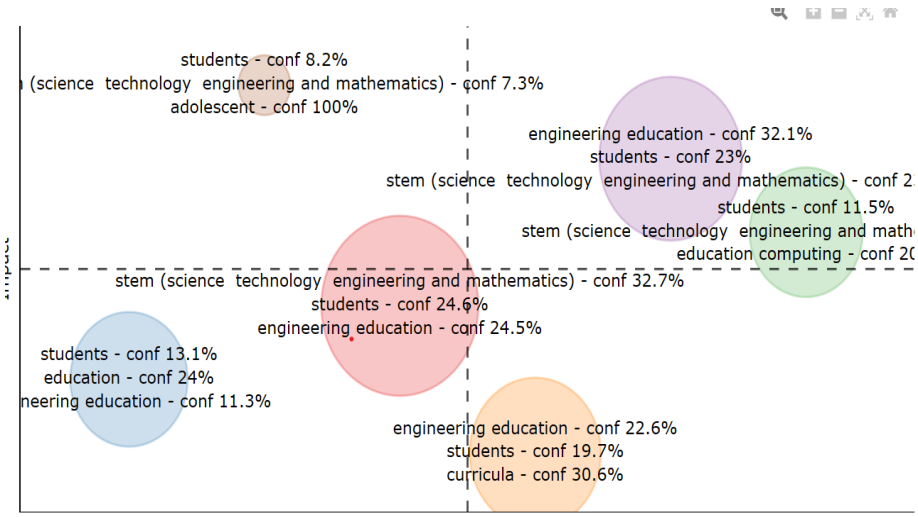

Figure 10: Clustering by Coupling

11. Co-citation Network

Presenting data via co-citation networks offers distinct perspectives on the connections between various subjects or concepts in scientific literature. Co-citation is a method used to identify multiple papers that are regularly mentioned together, indicating a potential relationship or relevance between them. A co-citation network enables the identification of linkages and interrelationships between themes or concepts in the literature. The network's nodes correspond to documents or scientific articles, while the edges connecting the nodes show co-citation links. Presenting co-citation network data enables the discovery of commonly co-cited theme groups or research clusters. These thematic groups may indicate prevailing research patterns or central focuses within a specific discipline or field. Documents or scientific articles with high centrality in the co-citation network suggest that the work is regularly linked to several other concepts or topics. Identifying unexpected clusters or papers lacking evident ties may suggest the detection of novel concepts or developing research trends.

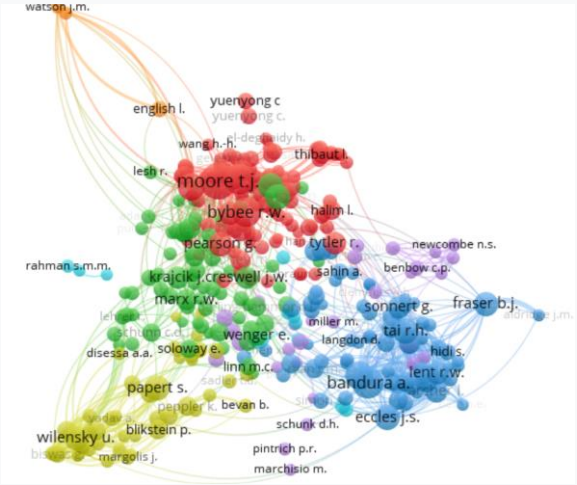

Figure 11: Co-Citation Network

5. Discussion

The data indicates a consistent upward trend in the number of articles from 2013 to 2023. This is highlighted by the fact that the quantity of articles started at 50 in 2013 and reached its highest point

in 2021 with 274 articles. Despite the overall upward trend, there are variations in specific years. Notably, there was a decrease in 2022 after a period of growth. This suggests that while the general trajectory is positive, there are fluctuations that need examination. The years 2019-2020 stand out as a period of substantial growth, indicating a noteworthy increase in the output of articles during that timeframe. The mention of 2021 as the year with the highest count (274 articles) is significant. It signifies a peak in productivity, and understanding the factors contributing to this spike could provide valuable insights. The overall conclusion drawn from the data is that there is a steady upward trend over the specified period. However, the nuanced analysis acknowledges the importance of understanding variations in specific years for a comprehensive understanding of the data.

The consistent rise in the publication of STEM in mathematics teaching and learning indicates a growing interest in STEM education over time. This phenomenon can be ascribed to various factors: (a) Growing important of STEM education: The worldwide acknowledgment of the escalating significance of STEM education has resulted in a pressing requirement to bolster research and academic pursuits in this domain (Li et al., 2020); (b) Increased funding and support: Governments, educational institutions, and commercial entities have displayed optimism in their efforts to advance STEM education among children in grades K-12, resulting in a surge of funding and support for STEM initiatives; (c) Adoption of digital technology: The adoption of digital technology in mathematics education has grown increasingly widespread, enabling teachers to enhance the learning experience and tailor it to the specific needs of students; (d) The establishment of national and international standards for STEM education has played a crucial role in ensuring uniformity and excellence in the execution of STEM programs; and (e) The incorporation of STEM into curricula has experienced a growing prevalence, as elementary schools progressively integrate STEM to foster the development of problem-solving and experiential learning abilities among students.

Ultimately, the rise in the number of STEM publications in mathematics education signifies the increasing significance of STEM education, amplified financial resources and assistance, the embrace of digital technology, the establishment of national and global benchmarks, and the incorporation of STEM into educational curricula. These considerations have led to a growing fascination with STEM education over time.

The research findings demonstrate a substantial presence of STEM in publications pertaining to the teaching and learning of mathematics, with conference papers and articles being the most common forms of publication. This is demonstrated by the significant numbers of 895 for conference papers and 689 for articles, exceeding other types by a considerable margin. Although genres like book, conference review, and book chapter have fewer contributions, they still offer useful insights about the level of collaboration and exchange of ideas within the area.

The frequency of conference papers and articles in your research findings corresponds with the wider scholarly focus and growing enthusiasm for STEM education, as demonstrated by various bibliometric analyses. An extensive examination and bibliometric analysis of the literature in STEM education conducted over the last 15 years demonstrated that there has been a growing scholarly interest in STEM education. Additionally, it has been observed that STEM education is evolving through collaborations across different domains and regions. Furthermore, a bibliometric analysis conducted on STEM education articles using the Web of Science Core database has brought attention to the advancements

made in STEM education research. This analysis has underscored the importance of doing up-to-date bibliometric studies in this particular field (Zhan et al., 2022).

The prevalence of conference papers and articles in your research results highlights the importance of scientific forums and scholarly publications as means of sharing research and promoting collaboration within the STEM education community. This implies that researchers and educators are actively enriching the existing body of knowledge and participating in the exchange of ideas through these publication options.

To summarize, this research findings indicate that conference papers and articles have a significant presence in publications related to mathematics teaching and learning, highlighting the growing scholarly focus and collaborative nature of STEM education. These findings align with wider bibliometric assessments in the field, emphasizing the increasing significance and worldwide dissemination of STEM education research. The research on the publication of STEM in mathematics teaching and learning by countries yields significant insights into the worldwide panorama of STEM education research. The significant contributions from multiple nations, including the United States, various Asian countries (such as Indonesia, Australia, Malaysia, Thailand, Taiwan, China, Hong Kong, and Vietnam), and several European countries (such as the United Kingdom, Spain, Germany, Italy, Ireland, and Greece), highlight the extensive interest and active involvement in promoting STEM education.

The geographical spread of research on STEM education is a subject that is receiving more and more attention from scholars. This is evident from a thorough study and bibliometric analysis of the literature on STEM education conducted over the last 15 years. The analysis indicates that there is a growing scholarly interest in STEM education, and it is evolving through collaborations across different domains and regions. The collaborative network centered around the USA is progressively expanding to encompass a worldwide scale, emphasizing the interdependence of research endeavors in STEM education (Zhan et al., 2022).

Moreover, the focus on STEM education is not restricted to particular regions, as seen by the significant contributions made by countries across various global locations. Specifically, a comprehensive analysis of STEM education research in the Gulf Cooperation Council (GCC) countries emphasized the growing significance of STEM education in these countries and the necessity to tackle deficiencies and obstacles in STEM education research. Furthermore, the examination of the progress and characteristics of STEM education in various global locations offers valuable insights for academics and policymakers to advance the promotion of STEM education worldwide (Li et al., 2020).

Overall, your research findings on the publication of STEM in mathematics teaching and learning by countries are consistent with the larger patterns observed in the global distribution of STEM education research. The significant contributions from a wide range of countries highlight the interdependent and cooperative nature of research endeavors in promoting STEM education worldwide. These findings add to the expanding collection of literature that aims to comprehend and advance STEM education in many areas and countries (Cai et al., 2023). The findings of this bibliometric analysis offer significant insights into the worldwide panorama, research emphases, and developing patterns within the domain of STEM in mathematics education. The significant contributions from multiple nations, organizations, and writers highlight the extensive interest and involvement in promoting STEM education. The prevalence of English as the predominant language in STEM education publications

underscores the possible limitations on the availability of research for communities that rely on languages other than English. This highlights the significance of improving accessibility and diversity in scientific communication to guarantee the widespread availability and inclusivity of research findings.

The changing patterns in research subjects, including the rising focus on standards, the integration of technology, and the expanding interest in specific areas of STEM education, offer significant insight into the dynamic character of research and academic work in STEM education. This indicates the changing priorities and specific areas of concentration within the field. The clustering analysis offers a thorough view of how frequencies are distributed, measures of centrality are calculated, and variables influence the research groups. It emphasizes the interconnections between themes and the significant influence of STEM and engineering education on the research network. This highlights the significant and interrelated nature of research topics in the field of STEM education.

Co-citation network analysis provides unique insights into the interactions between different subjects or concepts in scientific literature, allowing for the identification of connections and interdependencies between themes or concepts in the literature. This offers significant insights into the current research patterns or main foci within the subject of STEM education, as well as the identification of new concepts or emerging research trends. The WordCloud and TreeMap analyses underscore the predominant themes and priorities in the realm of STEM education, emphasizing the significant emphasis on students, STEM education, engineering education, and the growing incorporation of technology into STEM education. This indicates a shift towards an educational approach that is progressively focused on technology.

In summary, the findings of this bibliometric analysis add to the expanding corpus of research that aims to comprehend and advance STEM education worldwide. The findings offer useful insights into the worldwide panorama, research goals, and changing patterns within the domain of STEM in mathematics education. These observations could guide future investigations and policy efforts focused on enhancing STEM education and fostering inclusive and accessible scientific communication.

6. Conclusion

Ultimately, we have performed a bibliometric examination of articles pertaining to STEM in the realm of mathematics education and acquisition. There are a total of 1,787 research data points, indicating a steady growth in the number of papers from 2013 to 2023. The zenith was reached in 2021 with a total of 274 articles, however, there was a subsequent decrease in 2022. The general pattern indicates substantial expansion, but with variations in certain years. We conducted a more detailed analysis of the Scopus data from this study in order to identify the organizations that are actively engaged in conducting the highest amount of research in mathematics education within the STEM field. Based on the analysis results, Universitas Pendidikan Indonesia is the leading institution in performing research on STEM in mathematics education. The authors publish Conference papers and essays. Regarding publication productivity and international collaboration, the United States is the most productive country, with significant contributions from Indonesia and Australia in conducting this study. The predominant languages employed by authors are English. Yuenyong, C. has authored the highest number of publications on STEM themes specifically related to mathematics education. This discovery

can function as a blueprint for future researchers to carry out pertinent investigations utilizing STEM. The word cloud displays the term "student" as the most commonly occurring term, followed by "STEM", "engineering education", "education", and "teaching". Hence, it is advisable for future researchers to take into account this keyword trend as a factor when undertaking mathematics education research with the STEM approach.

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