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A review of STEM education research in BRICS countries: an analysis of research trends

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Research has emphasized the importance of STEM for countries. Many studies have been conducted on STEM education research in countries worldwide. However, there is a lack of research on reviewing the research on STEM education in BRICS countries. Based on this rationale, this paper analyzes research patterns and trends related to STEM education in BRICS countries. The study examined 3,580 journal articles from 2014 to 2023 on STEM education in BRICS countries using the bibliometric analysis method, revealing a significant increase in research. The results showed that the number of published articles increased annually, and 85% were published after 2017. The top three journals publishing STEM studies were the Journal of Engineering Education Transformations, Sustainability, and the International Journal of Emerging Technologies in Learning. China had the highest number of articles on STEM education based on country affiliation, followed by South Africa, India, Brazil, and Russia. The authors' authorship collaborations revealed that China had the most prominent connections compared to other countries. The keywords analysis revealed four research trends: (i) the effects of STEM education on learning outcomes, (ii) the impacts of instructional strategies in engineering education, (iii) gender differences in STEM education, and (iv) the use of artificial intelligence, project-based learning, and active learning. Based on the analyses, researchers suggest recommendations for future research.

KEYWORDS
STEM education, BRICS, bibliometric analysis, research trends, review

Introduction

Research indicates that STEM education has gained worldwide significance since its inception (Hasanah, 2020; Li et al., 2020). In many countries, STEM education remains crucial for cultivating scientific literacy and pursuing a career in related areas (Kelley and Knowles, 2016). STEM education is recognized by countries as necessary for national development, economic growth, and competitiveness with other countries (Irwanto et al., 2022; Kocabas et al., 2019; Pugliese and Santos, 2022). STEM education is crucial for preparing students for future careers and improving learning outcomes in STEM fields (Lian et al., 2021; Thompson et al., 2023; Wahono et al., 2020). In addition, STEM graduates are critical to strengthening countries by meeting the need for a skilled workforce (Newell and Ulrich, 2022). Countries, especially many developed and developing countries, have implemented educational reforms for STEM education and are investing heavily in developing STEM education programs to allow students to pursue careers in STEM fields (El Nagdi and Roehrig, 2020; Jiang et al., 2021). Research has demonstrated that incorporating STEM education into educational programs at various levels, ranging from high school to universities, is crucial for ensuring learning excellence and student development (Mikhaylovsky et al., 2021).

Member countries of the BRICS, including Brazil, China, India, Russia, and South Africa, have been working to improve the quality of STEM education and encourage graduates and students to pursue careers in these fields (Varghese, 2015). The common goal is to promote scientific and technological development in STEM fields and improve their technological developments for economic and technological progress (Loyalka et al., 2021). These countries have created a thriving entrepreneurial ecosystem conducive to innovation and improvement by prioritizing STEM (Loyalka et al., 2021). Furthermore, the interaction between STEM education and economic progress in the BRICS countries emphasizes the importance of education at all levels for developing these nations to contribute to their economic growth and competitiveness in the global arena (Loyalka et al., 2021). Thus, STEM education has gained importance in BRICS countries by imparting technological skills in related fields and pursuing careers in STEM. The countries have hence set themselves the goal of promoting economic and social challenges through STEM education to maintain their competitiveness, enhance their innovation, and achieve sustainable growth in terms of technological developments.

Since the introduction of STEM education, there has been extensive academic literature on the topic. Many countries, including those within the BRICS organizations, have engaged in STEM research to improve the quality of education in related fields. However, no study has yet analyzed and evaluated publications on STEM education, specifically in the BRICS countries. This situation is limited to what researchers know about the use of STEM education in different countries and organizations. Thus, a review of research on STEM education from the perspective of BRICS organizations and countries is needed. Bibliometric analysis is a technique that examines a substantial corpus of literature to obtain significant information about a specific study area or topic over an extended period to explore research trends. Although researchers have frequently used bibliometric analysis to assess research patterns and trends in STEM education (e.g., Cai et al., 2023), no study has examined the patterns and trends in BRICS countries. Thus, there is a need and research gap for specific research to explore research trends of STEM education in BRICS countries. To address this gap in the study, we conducted an overview of STEM education publications in the Scopus database in BRICS countries from the past decade, from 2014 to 2023, to analyze research patterns and trends. The findings could benefit scholars working on STEM education by providing a comprehensive overview of research trends of publications conducted in BRICS countries.

Literature review

Although many studies (Cai et al., 2023; Ha et al., 2020; Hsu et al., 2023; Irwanto et al., 2022; Jamali et al., 2022; Jemmy et al., 2023; Le Thi Thu et al., 2021; Phuong et al., 2023; Tas and Bolat, 2022; Zhan et al., 2022) have been conducted to review publications on STEM education using bibliometric analysis, none of these publications have examined the status of research on STEM education in BRICS countries to identify research trends. The existing studies in the literature on STEM education research and bibliometric analysis analyzed the publications without focusing on countries' organizations. Only one study analyzed publications in the Southeast Asian Nations region from 2000 to 2019 and found a significant increase in the scientific production of publications between 2017 and 2019 (Ha et al., 2020).

In addition, the results of the existing research show that nearly all of the research has reported a significant increase in publications on STEM education over the last 10 years period (Cai et al., 2023; Ha et al., 2020; Hsu et al., 2023; Irwanto et al., 2022; Jemmy et al., 2023; Le Thi Thu et al., 2021; Phuong et al., 2023; Tas and Bolat, 2022; Zhan et al., 2022). For example, Le Thi Thu et al. (2021) evaluated publications in STEM education at the middle school level from 2000 to 2020 in articles in the Scopus database. They found that publications steadily increased between 2016 and 2020, and researchers in the United States produced the most. Another study by Irwanto et al. (2022) analyzed the research patterns in 336 studies in STEM education between 2011 and 2020. Their research indicates that STEM education garnered increased focus and experienced significant growth between 2011 and 2020. The United States is the most active country.

Furthermore, the researchers, in general, found that the United States contributed the most to STEM education research (Cai et al., 2023; Irwanto et al., 2022; Jamali et al., 2022; Jemmy et al., 2023; Le Thi Thu et al., 2021; Tas and Bolat, 2022; Zhan et al., 2022). For example, the study by Tas and Bolat (2022) conducted a bibliometric review of studies on the use of STEM in education using the Web of Science database. They found that the USA has the most publications. The research also has highlighted the growing collaborative network centered in the US (e.g., Cai et al., 2023; Le Thi Thu et al., 2021).

Moreover, research has reported different clusters, research areas, or trends of STEM education research according to the data analyzed (Cai et al., 2023; Ha et al., 2020; Irwanto et al., 2022; Jamali et al., 2022; Jemmy et al., 2023; Le Thi Thu et al., 2021; Phuong et al., 2023; Zhan et al., 2022). For example, a study by Jemmy et al. (2023) analyzed publications on STEM education in the past two decades in the Scopus. They found increased publications and that Indonesia and the United States contributed the most. They revealed the three main areas: (i) STEM education and teaching, (ii) STEM and engineering education, and (iii) education, technology, and mathematics. In another study, Zhan et al. (2022) examined a review and bibliometric analysis of publications on STEM education in the Web of Science database from 2008 to 2022. They found that STEM education received increased scientific attention, with a growing collaborative network centered in the US that is expanding globally. They concluded that issues of gender and ethnicity were the hot research topics in STEM education. The study of Phuong et al. (2023) performed a bibliometric analysis of 750 studies from 2006 to 2022. Their findings demonstrated a significant and consistent increase in research activity from 2018 to 2022. Their analysis also identified three primary areas of research: (i) STEM education in higher education, (ii) STEM education and STEAM, and (iii) STEM education activities in K12. In a recent research, Cai et al. (2023) conducted a study analyzing 1910 publications from the Web of Science to examine research progress in STEM education. Their study revealed that the USA is the most active country and that STEM, STEM education, self-efficacy, and technology are the primary focus areas in STEM studies. Research by Jamali et al. (2022) evaluated the publications in the SCOPUS database regarding integrated STEM education using a bibliometric analysis.

Their analysis covered publications from 1993 to 2020. The findings indicated that the United States is the most productive. Their findings revealed that STEM education research primarily concentrated on early childhood and environmental education and educational computing. Furthermore, Hsu et al. (2023) analyzed 761 articles on the Web of Science between 2011 and 2020. They found that a growing number of STEM publications were published after 2016. They found that researchers focused on higher education, and many examined students' interdisciplinary STEM learning.

Most of the scholars (e.g., Ha et al., 2020; Jamali et al., 2022; Jemmy et al., 2023; Le Thi Thu et al., 2021; Phuong et al., 2023) used the SCOPUS database to review publications on STEM education research in the bibliometric analysis, while some others used the Web of Science (e.g., Cai et al., 2023; Hsu et al., 2023; Irwanto et al., 2022; Tas and Bolat, 2022).

The research results above show that none of the studies examined trends in STEM education research in BRICS countries. STEM education is also important for BRICS nations (Masalimova et al., 2024). The BRICS countries possess different characteristics in terms of socio-economic contexts and educational policies for STEM education. These characteristics necessitate research to examine and review STEM education research in BRICS countries. Thus, the goal is to analyze research patterns and trends related to STEM education in the BRICS countries.

Method

This quantitative study used a bibliometric approach to capture research patterns and trends related to STEM education in the BRICS countries. We chose the Scopus database to analyze the relevant publications as it is one of the largest databases. We considered publications published between 2014 and 2023. We completed the literature search in March 2024 and did not consider documents published in 2024. Table 1 shows a list of keywords we used during the search. We searched using article titles, abstracts, and keywords for STEM. Regarding the BRICS countries, we choose the "affiliation country" option in the search menu in the database. After the initial search, we filtered the documents using the SCOPUS filter option. When we did conduct the initial search, the results yielded 235,925 documents. Later, we limited our search between 2014–2023, and the results decreased to 165,385 documents. We chose the last 10 years for this bibliometric study to conduct a comprehensive analysis covering a sufficiently long period to capture research trends and developments accurately and to gain a deeper understanding of the evolution of research. After this, we limited the results to social sciences and found 9,300 documents. Another limitation was choosing articles and excluding conference papers, editorials, books, and book chapters. Thus, we found 4,154 articles. Later, we limited the articles to journal articles and found 4,148. Finally, we decided on articles published in English, which yielded 3,580 articles. Of these 3,580 articles, 132 were articles in the press category. The other 3,448 articles were published in the category. Namely, we involved 3,580 articles in the analysis. Our search and analysis did not include conference papers, editorials, books, and book chapters.

TABLE 1 A list of keywords used during the search.

Keywords for STEM education	Keywords for BRICS countries
Biology education	Brazil
Chemistry education	Russia
Engineering education	India
Physics education	China
Mathematics education	Republic of China
Science education	South Africa
STEM education	
STEM	
STEM teaching	

After utilizing the filter options, two researchers individually reviewed the articles' titles and abstracts. They determined that all articles were suitable for analysis. We chose the Scopus database because it is of the highest quality, has the best reputation, and is a good index with the largest curated number (Ghani et al., 2022; Ha et al., 2020; Phuong et al., 2023). In addition, we used the VOSviewer program to analyze the data collected in the database. VOSviewer handles large data sets efficiently and provides diverse and engaging visualizations, analysis, and exploration. We also did not choose any other database because transferring metadata from the different databases was impossible. Regarding data collection, we saved the documents in CSV file format after using all filter options. We downloaded the file, including all the information about the articles we determined to analyze criteria. This file contained detailed information about the article title, author name, affiliation, abstract, keywords, and references in each document. Later, the CSV file was converted into a TAB file format. After we received the TAB file, we uploaded it to the VOSviewer program to analyze the data. We chose VOSviewer because it allows us to understand visualizations and analyze research trends based on parameters. We also used it to analyze and visualize the bibliometric network related to STEM education in BRICS countries to show research trends. It displays the relationships in the metadata and nodes to illustrate the relationships. In addition, it allows researchers to use network analysis to visually display the intensity of the connections between nodes, such as authors, countries, keywords, and publications. In terms of these details, VOSviewer is a valuable tool for conducting different types of bibliometric analysis, such as examining the occurrence of terms together, analyzing the connections between publications, and studying collaborations among authors. It offers researchers valuable insights into current research trends, collaborative efforts, and research clusters (van Eck and Waltman, 2010). Nodes that have strong relationships with each other are close together. The size of these nodes gives an impression of the strength of the relationships in the data. Several nodes classified by different colors form a cluster. In addition, the size of each node in the network is directly proportional to its weight, which can quantify the number of documents and citations.

Results

Over 10 years, we found 3,580 publications regarding STEM education conducted in BRICS countries from 2014 to 2023. The number of publications is shown in Figure 1. Between 2014 and 2017, the number of publications stagnated, but there was a significant increase after 2017. This increase appeared from 2017 to 2023. This

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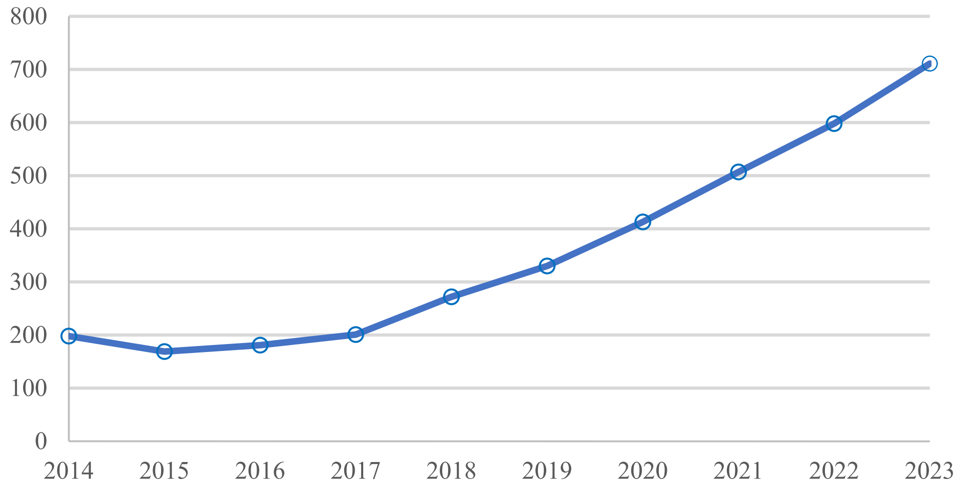

FIGURE 1
Number of publications on STEM education in BRICS countries (2014–2023).

result shows an increasing tendency of research and researchers on STEM education in BRICS countries. We found that almost 85% of all articles were published after 2017. This result shows a constant rise in the number of articles after 2017.

The top three journals publishing studies on STEM education in BRICS countries are the Journal of Engineering Education Transformations, Sustainability, and the International Journal of Emerging Technologies in Learning (Figure 2). The results show that these three journals published over 100 STEM articles. The other following journals are Computer Applications in Engineering Education, International Journal of Engineering Education, Acta Scientiae, Eurasia Journal of Mathematics Science and Technology Education, Journal of Baltic Science Education, World Transactions on Engineering and Technology Education, and International Journal of Science Education. We found that 160 different journals published 3,580 articles.

Figure 3 shows that countries published more articles on STEM among BRICS countries. China has the highest number of articles on this topic based on the country of affiliation. South Africa, India, Brazil, and Russia follow. This result shows that researchers from China have paid special attention to STEM. Interestingly, our results show that researchers from Russia published 16 articles on STEM education in the last 10 years.

Figure 4 shows the authors' authorship collaborations among countries. We chose countries with more than 10 published articles. The size of nodes in the networks shows connections and collaborations among authors from different countries. China has the most prominent node size, while South Africa, Brazil, India, and the United States follow China. This result shows that while China has the most noteworthy number of connections (collaborates with more countries), it also has the most robust connections compared to other countries. The results yielded six clusters regarding researchers' publication collaborations among countries. The first cluster (red color) includes 14 countries, including Australia, Chile, Colombia, Finland, France, Germany, Israel, Japan, Mexico, Spain, Sweden, Taiwan, Thailand, and Turkey. The second cluster (green color) includes 10 countries: China, Denmark, India, Indonesia, Ireland, Malaysia, Pakistan, Russia, Saudi Arabia, and South Korea. The third cluster (blue color) includes 9 countries: Belgium, Italy, Kenya, Netherlands, Nigeria, Norway, South Africa, United Kingdom, and Zimbabwe. The fourth cluster (yellow color) comprises Canada, Hong Kong, Macao, and Singapore. The fifth cluster (purple color) contains Brazil and Portugal, while the sixth cluster (turquoise color) includes the only United States. The results from this cluster reveal that Chinese authors collaborate the most with many researchers from diverse countries. Brazilian authors collaborate the most with many researchers from Portugal. Finally, Indian authors have authorships from China, Denmark, Indonesia, Ireland, Malaysia, Pakistan, Russia, Saudi Arabia, and South Korea. In addition, the results revealed that Russian authors had collaborated with researchers in many countries, such as China, Denmark, India, Indonesia, Ireland, Malaysia, Pakistan, Saudi Arabia, and South Korea.

Figure 5 shows the authors' affiliations with more articles on STEM in BRICS countries. Accordingly, authors from South Africa, China, and Brazil have published more on STEM in other countries. The first affiliations stem from the University of Johannesburg ($n = 108$), Beijing Normal University ($n = 106$), and the University of Pretoria ($n = 89$). The other following affiliations come from the University of the Witwatersrand, Universidade de São Paulo, University of Cape Town, University of KwaZulu-Natal, East China Normal University University of South Africa, and Chinese Academy of Sciences.

Regarding the authors' coauthorship analysis, we examined the connections among their organizations. We searched for collaborations among the authors' organizations and involved institutions with more than five articles. Accordingly, the VOsViewer program yielded 46 institutions among the authors' organizations. However, the collaborations among the institutions were very few, and VOSviewer revealed 19 links for collaborations among the institutions among the BRICS countries. The collaborations of authors' organizations with five or more articles are shown in Figure 6. This result shows that many institutions did not have connections for STEM education research in BRICS countries. The results yielded five clusters for institutions. In these clusters, the universities in Figure 5

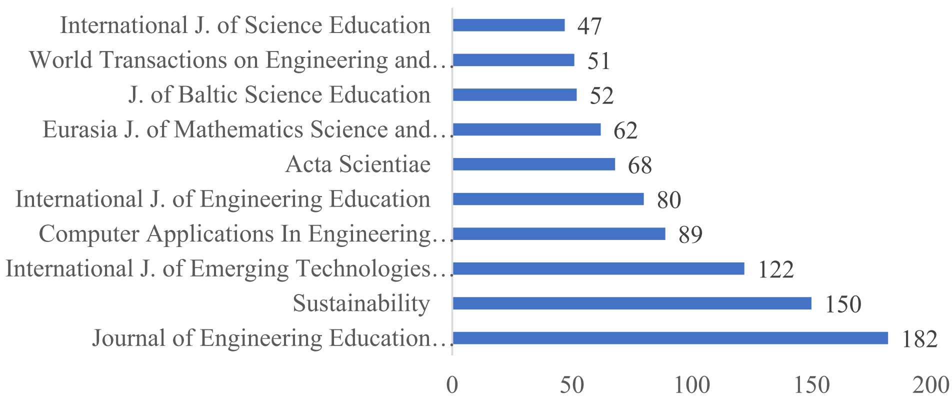

FIGURE 2
Journals that published most articles.

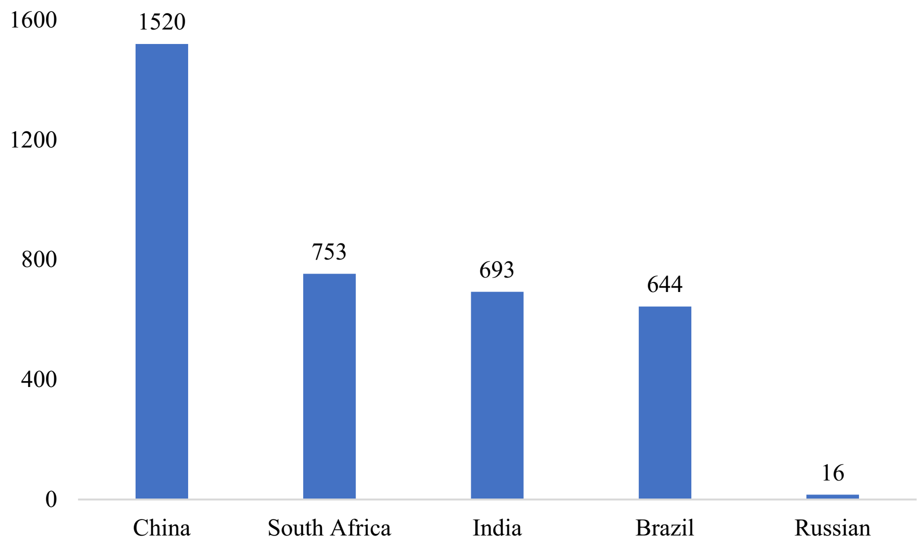

FIGURE 3
Countries published more articles.

with the most articles are central. University of Johannesburg, Beijing Normal University, and the University of Pretoria are central in these clusters.

Figure 7 shows keywords used in STEM research conducted in BRICS countries. We examined the keywords used more than 30 times. The results in Table 2 yielded four clusters and 52 keywords in total. The articles in the first cluster (red in Figure 7) included 26 keywords. These emerging keywords illustrate that research in this cluster has mainly focused on examining the effects of STEM education on sustainable development (e.g., Chen et al., 2022; Sigahi et al., 2023; Zhang and Liu, 2024), sustainability (e.g., Zanitt et al., 2022), decision-making (e.g., Sun et al., 2023), online learning, academic performance (e.g., Geng, 2023), and design skills (e.g., Baligar et al., 2022). In addition, higher education, mathematics, and science education have dense links with other keywords in this cluster. This result suggests that more research has been conducted on these areas in STEM education. Furthermore, other keywords emerging from this cluster are "China," "South Africa," "India," and "Brazil," revealing the origin of STEM education studies in this cluster.

The second cluster (green color) contains 12 keywords (see Table 2). These emerging keywords in this cluster illustrate that researchers have mainly focused on engineering education and explored understanding the impact of instructional strategies such as learning systems, educational computing, computer-assisted instruction, e-learning, personnel training, and virtual reality. These studies include the implementation and use of e-learning (e.g., Kalkhambkar and Gaikwad, 2023; Pramod et al., 2021), virtual reality learning (e.g., Lin et al., 2022; Wang et al., 2022; Zhang et al., 2023), computer-aided instruction (e.g., Lei et al., 2021), educational computing (e.g., Elgrably and Oliveira, 2022; Zhu et al., 2021) in engineering education. In addition, the frequent occurrence of "engineering education" and its connection to "students," "teaching," and "surveys" keywords suggest the use of focus of studies in engineering education.

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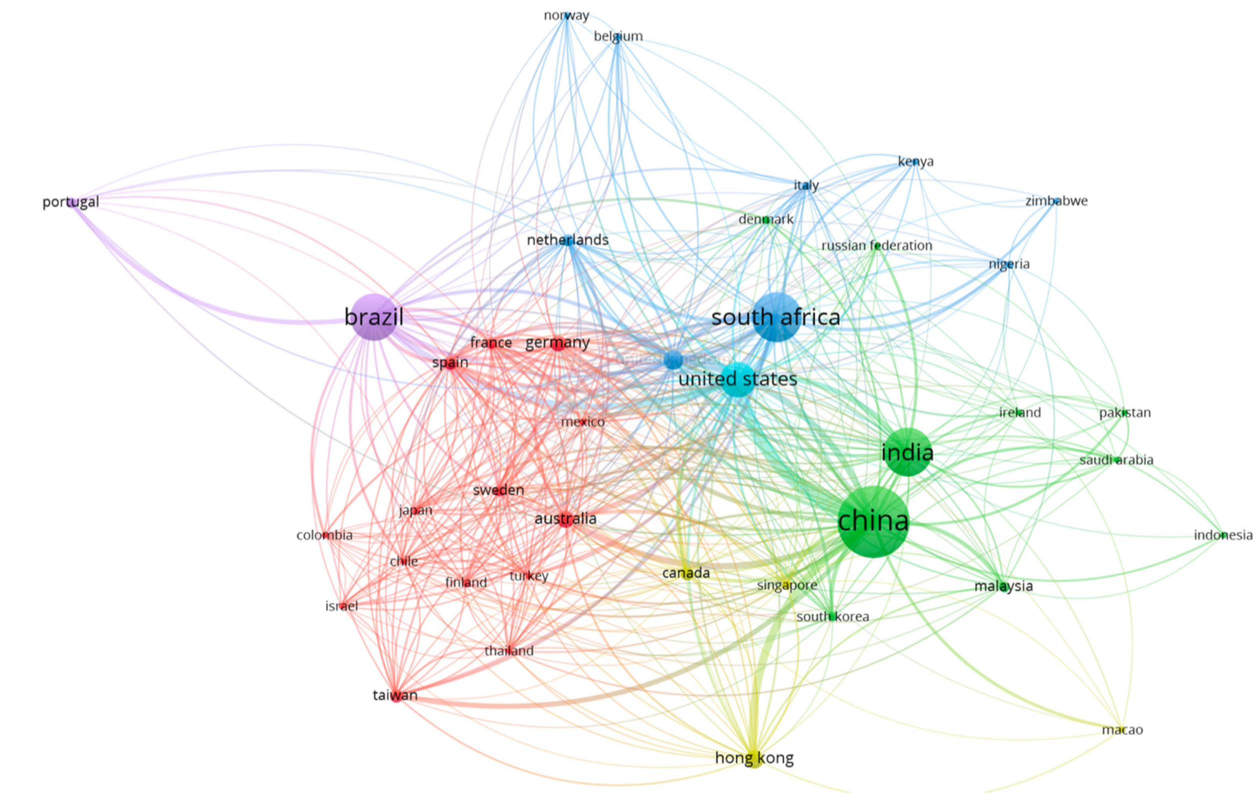

FIGURE 4
Authorship collaboration among countries.

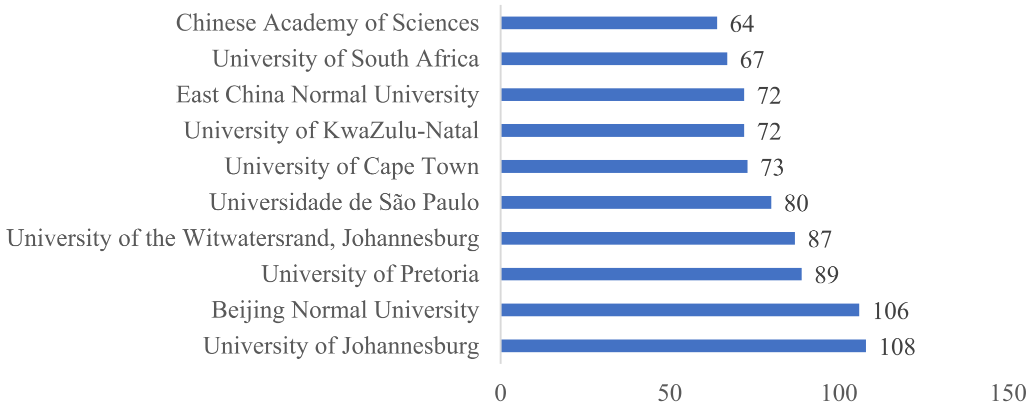

FIGURE 5
The affiliations with more articles.

FIGURE 6
Collaborations of authors' organizations with five or more articles.

The third cluster (blue, see Figure 7) contains eight keywords. These keywords reveal that research has mainly focused on gender differences in STEM education. For example, research by Gupta (2023) explored the status of women in STEM and the gender-related challenges they encountered. In another study, Sahoo and Klasen (2021) investigated the gender differences in STEM education in India

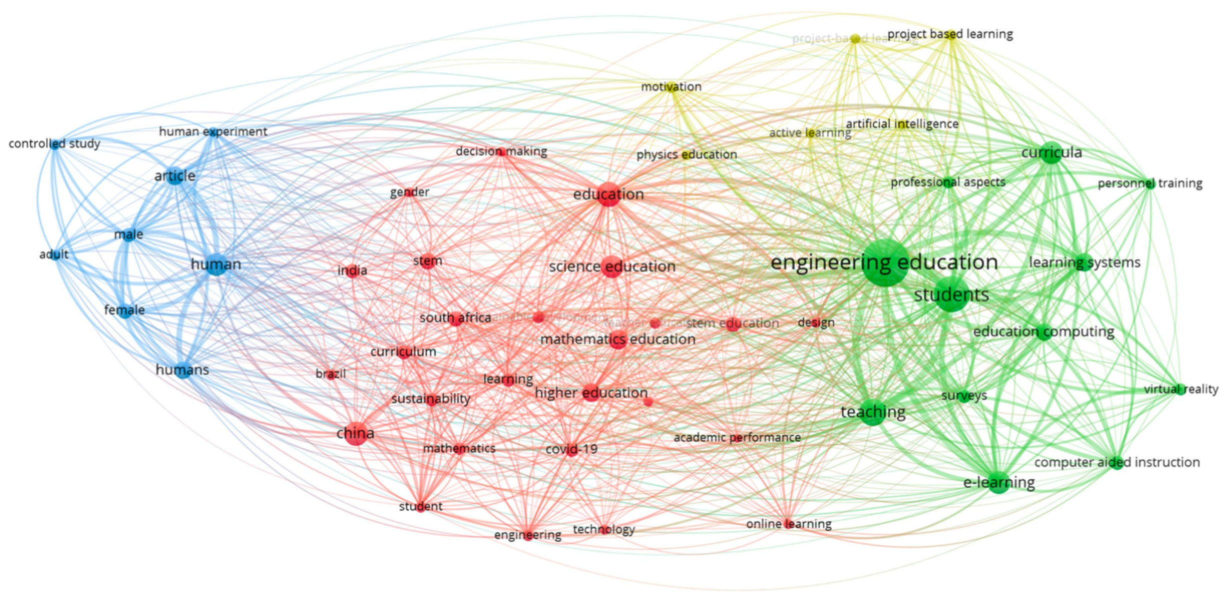

FIGURE 7
Keywords that have been used more than 30 times.

TABLE 2 A list of keywords in clusters.

Clusters	Keywords
Cluster 1 (Red color in Figure 7)	Education, science education, higher education, mathematics, mathematics education, higher education, South Africa, STEM, sustainable development, sustainability, COVID-19, China, decision-making, India, Brazil, student, engineering, technology, online learning, academic performance, and design.
Cluster 2 (Green color in Figure 7)	Engineering education, students, teaching, and curricula, e-learning, learning systems, education computing, computer-aided instruction, professional aspects, personal training, and virtual reality.
Cluster 3 (Blue color in Figure 7)	Human, female, male, article, humans, human experiment, adult, and controlled study.
Cluster 4 (Yellow in Figure 7)	Artificial intelligence, active learning, motivation, physics education, and project-based learning.

about having a career in STEM fields. The study of Santos et al. (2022) examined the low participation of women in STEM careers and the gender-specific differences in STEM education.

The fourth cluster (yellow color) includes six keywords. These keywords suggest that research in the fourth cluster explored the effects of artificial intelligence, project-based learning, and active learning. Among the studies in this cluster, a study implemented active flipped learning instruction to improve the teaching and motivation of engineering students in STEM education in a three-year longitudinal research (Yan et al., 2024). Another study developed an artificial intelligence-based prediction model for students' academic performance based on students' learning data in online engineering education (Jiao et al., 2022). A different study explored the effects of a project-based STEM learning course integrated with virtual reality in an elementary school on students' understanding of scientific knowledge, students' design, and teachers' and students' acceptance (Xie and Zhang, 2024).

Table 3 shows the top 10 keywords researchers used in STEM education research from 2014 to 2023. These results demonstrate that research mainly focused on "engineering education." The other keywords show that the number of studies conducted in China is the highest. Also, the results show that many studies were conducted on "e-learning" between 2014 and 2023. The keywords "science education" and "mathematics education" are among the first ten. These results show that many studies have been conducted on engineering education more than science and mathematics education fields. Furthermore, the results suggest that the research examined the effects of e-learning.

Discussion

This paper analyzed research patterns and trends related to STEM education in BRICS countries. Our analysis of 3,580 journal articles from 2014 to 2023 revealed a significant increase in research on STEM education in BRICS countries. We found that almost 85% of the articles were published after 2017. This result shows a constant rise in the number of articles after 2017. This finding confirms the findings of previous studies on STEM education (e.g., Cai et al., 2023; Zhan et al., 2022). Previous studies and the present study demonstrate a

TABLE 3 Top 10 keywords with strongest occurrences and total link strengths.

	Occurrences	Total link strength
Engineering education	763	1,015
Students	446	843
Teaching	262	599
Education	210	347
China	198	84
E-learning	184	394
Curricula	183	461
Science education	179	54
Human	178	84
Mathematics education	127	29

high level of interest in STEM education research. In this research, the substantial growth in the number of publications on STEM education research can be explained by a few factors. First, with a significant emphasis on the importance of STEM education in BRICS countries, researchers may have conducted more research. Second, the increasing role of STEM education in promoting economic growth in the countries may lead to a constant rise in research. Third, social, cultural, and economic factors, which are beyond the scope of this research, can strongly influence the implementation of STEM education in different countries (Zhan et al., 2022). Thus, there is a need for future research to understand these factors and the unique contexts of STEM education in the BRICS countries.

The findings regarding publication sources on STEM education in BRICS countries show that the Journal of Engineering Education Transformations, Sustainability, and the International Journal of Emerging Technologies in Learning are the top three journals publishing STEM education studies in BRICS countries (out of 3,580 articles). These three journals published over 100 STEM education articles each between 2014 and 2023. Our results based on the top 10 journals in which studies on STEM education were published (25% of articles) indicate that studies on STEM education are published in journals with a specific STEM focus. This result is very similar to the findings of Li et al. (2022), who suggest that the publication of STEM research has shifted to journals that focus specifically on STEM content. In addition, of the 3,580 articles published by 160 different journals, the top 10 journals account for 25% of the total. This result could be due to the visibility, publication policies, and readership of the journals that publish the most articles.

The results regarding the countries show that China has the highest number of articles on STEM education. South Africa, India, Brazil, and Russia followed China, respectively. This result confirms the findings of previous studies that STEM is on the rise in the BRICS countries (Narayan et al., 2021). Another finding is that the authors' collaboration shows that China has the most robust links compared to other countries. These results could be because China has significantly increased its investment in research and development (Narayan et al., 2021). This increased investment has enabled Chinese researchers to conduct more research on STEM education. In addition, the results in terms of authors' affiliations show that the first ten affiliations with more articles were from South Africa, China, and Brazil. This result suggests that the institutions in these countries are more productive in STEM education research.

The keyword analysis, which reveals research trends, revealed four clusters. The result showed that the articles in the first cluster focused on the impact of STEM education on sustainable development, sustainability, decision-making, online learning, academic performance, and design skills. This finding shows that STEM education has developed learners' knowledge and skills, such as decision-making, design skills, and academic performance (Geng, 2023; Hyllegard et al., 2020; Sun et al., 2023). In addition, research has mainly utilized the technology of online learning environments to teach and develop STEM knowledge and skills after the pandemic (Geng, 2023). In the second cluster, research has mainly focused on engineering education and explored understanding the effects of instructional strategies, including learning systems, educational computing, computer-assisted instruction, e-learning, personnel training, and virtual reality. This result shows a close relationship between computer-based engineering education and distance education systems (Yalcin and Vatansever, 2016). In addition, web-based teaching methods and virtual tools have created a supportive, innovative platform for teaching in engineering education (Vatansever and Yalcin, 2017). These teaching methods and tools may have been used to support learning environments and improve technology integration into teaching and learning practices in engineering and STEM education.

In addition, research in the third cluster focuses on gender differences in STEM education. Previous research examined gender differences in STEM education and examined the low participation of women in STEM careers (e.g., Gupta, 2023; Sahoo and Klasen, 2021; Santos et al., 2022). This finding is closely related to gender differences in educational choice by highlighting women's traditional inclination towards the humanities and men's traditional inclination towards STEM subjects (Trusz, 2020). Thus, we understand that research in this cluster has contributed to a deeper understanding of the relationships between gender and STEM education.

The fourth cluster research explored the effects of artificial intelligence, project-based learning, and active learning. This result can be explained by the fact that artificial intelligence is one of the research topics studied in the STEM field. Artificial intelligence (AI) in education can provide students with opportunities for autonomous learning and has the potential for teaching and learning practices (Rui and Badarch, 2022). In addition, researchers may have thought that combining AI and project-based learning research is a promising way to improve teaching methods and promote learners' experiences and practices in STEM education. Furthermore, our findings regarding the top 10 keywords showed that research mainly focused on engineering education. In addition, our results imply that the number of studies conducted in China is the highest. That research primarily also concentrated on "e-learning." Based on this finding, we noted that research explores the impact of e-learning in BRICS countries. This finding is partly in line with the findings of Zhan et al. (2022). They noted that developed Western countries emphasize educational equity and disciplinary integration while developing countries focus more on pedagogical practices.

Conclusion

This paper examined research on STEM education in the BRICS countries through a bibliometric analysis to examine research patterns and trends. Our results revealed that almost 85% of the articles were published after 2017. This result shows a constant increase in the number of articles after 2017. This finding suggests that research on STEM education is likely to continue in the future. China was the most prominent country in STEM education research and had the highest activity level. South Africa followed China in the number of publications. Given the absence of studies reviewing STEM education research in the BRICS countries, the findings of this research can contribute to the literature. The results show that the term "engineering education" was mainly used in the research. Given the importance of engineering education in STEM education and its relatively recent inclusion in the field, scholars are expected to conduct further research on engineering and STEM education. Because the inclusion of engineering education in STEM education is an important aspect that has not yet been thoroughly explored, future research should prioritize exploring the intersections between engineering and STEM education. The keyword analysis revealed many well-qualified research studies that track and trace research patterns and trends. This present research provides evidence to show an area of study in STEM education research in the BRICS organization, and the results present a valuable resource for future research efforts.

Recommendations

Based on the results of this research, we can suggest recommendations for future research. First, the keyword "engineering education" has been used mostly in the research. Since integrating engineering education into STEM education is essential and has not had a long history in STEM education, we can predict that scholars will conduct more studies on engineering and STEM education in future research. Hence, as the inclusion of engineering education in STEM education is a crucial aspect that has not been explored extensively, future research should focus more on the intersection of engineering and STEM education. Second, many curriculum documents and policy reports emphasize integrating STEM education into the curriculum. Therefore, researchers focused on examining the effects of STEM education on students and teaching. The keywords analysis showed the result of this research. To have a high-quality bibliometric analysis of STEM and BRICS countries, there is a need for more qualified research studies to follow and understand research patterns and trends and to examine the effect of STEM education research on students, teaching, and learning. We believe that scholars will conduct more bibliometric analyses to examine research patterns in the future. Hence, future research should focus on reporting the effects of STEM research on students, teaching, and learning outcomes. Third, we gathered data from the SCOPUS database in this research. Future research should incorporate data from additional databases, such as Web of Science, Scopus, and ERIC (Education Resources Information Center), which offer extensive educational and scientific literature coverage. Fourth, scholars can consider using other analysis programs and software for future bibliometric analyses, such as CiteSpace, Bibliometrix, and SciMAT. These tools can help researchers to generate informative visualizations for forthcoming bibliometric studies. Thus, scholars can reveal areas and hot topics of STEM education research in further studies.

Limitations

This study considered the articles published in the SCOPUS database between 2014 and 2023. The first limitation is that we used the SCOPUS database because using a single database allows us to avoid the challenges of amalgamating metadata from different databases. Hence, we might not have included some documents indexed in other databases. This limitation may affect our results. The second limitation is that we only used the VOSviewer program to analyze the data. This might prevent us from using other programs to display the data analysis, and we might have obtained different information about the presentation of the results from other analysis programs. This limitation could affect our results and comments when presenting the results. The third limitation is that we did not include articles accepted and published in 2024. The inclusion of publications published in 2024 may have affected our results. The last limitation is that we tried to consider all keywords to include all studies on STEM education and BRICS countries, but we might have missed some studies due to the authors' use of keywords.

Author contributions

AF: Writing – original draft, Writing – review & editing. TZ: Writing – original draft, Writing – review & editing. NK: Writing – original draft, Writing – review & editing. JA: Writing – original draft, Writing – review & editing. MK: Writing – original draft, Writing – review & editing. KK: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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