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A BIBLIOMETRIC ANALYSIS OF LITERATURE ON ATTITUDES IN STEM EDUCATION IN 2008-2022

Ke Ma,
Bei-He Hui

Abstract. *This study employed a bibliometric analysis of research on attitudes in STEM education to identify patterns and themes within scholarly publications to address a research gap in the current literature. The publications indexed in the SCOPUS database on attitudes and STEM were analyzed to collect data. 173 articles were chosen for analysis. Bibliometric analysis revealed an upward trend in research publications between 2008-2022, with notable increases in 2013 and 2018 and between 2018 and 2022. Curtin University was the institution that contributed the most to the literature during this period. The results also showed that institutions from Australia, Taiwan, and the United States contributed equally to research on attitudes and STEM. Another finding is that the United States had the most publications on attitudes and STEM. The International Journal of Science Education was cited the most, followed closely by The Journal of Research in Science Teaching and Science Education. Barry J. Fraser and Jaquelynne S. Eccles are authors who were cited more than one hundred times in the publications. Based on the findings, implications for further studies are drawn.*

Keywords: *attitudes in STEM, bibliometric mapping, STEM education, science education*

Ke Ma, Bei-He Hui
Zhejiang SCI-TECH University, China

Introduction

Developing students' attitudes towards STEM courses in applying scientific knowledge and fundamental problem-solving skills are the primary objectives of education in schools. Hence, researchers have placed attitudes at the center of their studies. Attitude is one of the affective factors influencing student performance in a particular course or subject area (Martynenko et al., 2023; Ozel et al., 2013). For this reason, many researchers have studied the effects of students' attitudes toward STEM courses (Araújo et al., 2022; Martynenko et al., 2023). STEM education provides skills increasingly in demand in today's labor market (Ellison & Allen, 2016). Exploring student attitudes toward STEM (science, technology, engineering, and mathematics) is important for researchers as it can significantly impact their engagement and interest in choosing a career in one of the related fields (Perdana et al., 2021; Zhou et al., 2019). People's thoughts, beliefs, and opinions about science, technology, engineering, and mathematics (STEM) are attitudes toward STEM (George, 2006; Kurniawan et al., 2019; Musengimana et al., 2021). Personal experiences, cultural backgrounds, educational settings, and social factors shape these attitudes (George, 2006; Musengimana et al., 2021). Positive attitudes involve being interested, recognizing career potential, appreciating practical uses, and supporting STEM education (Osborne et al., 2003; George, 2006). Negative attitudes include a lack of interest or relevance, perceived difficulties, stereotypes, and an unwelcoming environment (George, 2006). Therefore, it is crucial to cultivate a positive attitude toward STEM, as it can inspire interest, engagement, and creativity, ultimately resulting in progress and innovation in the STEM fields (Razali et al., 2018; Tseng et al., 2011; Vennix et al., 2018).

Analyzing students' attitudes toward STEM can provide valuable insights into the barriers or biases preventing certain groups from pursuing STEM education and careers (Ball et al., 2017; Nasri et al., 2021). By understanding these attitudes, evidence-based policies and curricula can be developed that align better with student needs and interests. Furthermore, this process can help create a supportive environment that empowers students to explore, embrace, and excel in STEM fields. In addition, studying student attitudes toward STEM can help identify obstacles and challenges in guiding career

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paths and fostering a future STEM workforce (Musengimana et al., 2021; Rahmayani & Istiyono, 2022). Thus, educators who know their students' attitudes can design instructional methods and content to encourage curiosity, interest, and enthusiasm for STEM (Musengimana et al., 2021).

A positive attitude towards STEM subjects can encourage students to choose careers in related fields (Razali et al., 2018; Vennix et al., 2018). Educators and stakeholders can assess students' attitudes to determine if they possess the necessary dispositions for success in STEM careers, such as problem-solving and critical thinking (Hasanah, 2020; Razali et al., 2018; Rehman & Butt, 2020). By doing so, they can create supportive learning environments and interventions that inspire and empower students to succeed in STEM (Vennix et al., 2018). This information can help curriculum makers, researchers, and teachers allocate resources, implement initiatives, and evaluate outcomes for more effective interventions. Furthermore, students' STEM attitudes can provide insight into the factors influencing their career decisions in STEM fields (Razali et al., 2018; Siani & Dacin, 2018). This data can aid in aligning various software to provide targeted guidance and support to students interested in STEM.

Researchers have made numerous attempts to measure students' attitudes toward STEM (Anastasiadis & Zirinoglou, 2022), developing their attitudes to encourage them to pursue a career in STEM subjects (Nugent et al., 2010; Sahin et al., 2014) and providing assessments or data collection tools to measure their attitudes (Guzey et al., 2014; Mahoney, 2010). Numerous studies have explored students' attitudes toward STEM fields in the literature. Although research on student attitudes has made considerable progress in STEM, some gaps should be further explored. One of these gaps is related to bibliometric studies. Although the literature on attitudes in the STEM fields is growing steadily, the current literature lacks research on bibliometric studies related to attitudes and STEM. A few studies have been conducted similarly to the present study. No study conducted a bibliometric analysis regarding attitudes in STEM education. For example, LeThiThu et al. (2021) analyzed SCOPUS publications in middle school STEM education from 2000 to 2020. Their findings indicated that middle school STEM education research has exploded over the past five years, particularly in the United States. The research topics vary and cover various issues, including gender, engineering education, curriculum, etc. Recently, the research conducted by Phuong et al. (2023) involved analyzing the bibliographic content of research papers on STEM education from 2006 to 2022. Their findings showed a significant and consistent increase in research in this area over the past 5 years. They also discovered that highly-regarded journals publishing case studies in STEM education are widely read.

Important insights can be obtained from bibliometric studies by LeThiThu et al. (2021) and Phuong et al. (2023). However, these studies have not specifically examined the bibliometric studies regarding the attitudes of students or individuals toward STEM fields. Previous analyses have not provided a complete literature overview of students' attitudes toward STEM. With the significant increase in studies on this topic in recent years, it is important to have an accurate understanding of the current state of research. Thus, a dearth of research comprehensively analyzing the scholarly knowledge about attitudes generated in STEM fields is appearing in the current literature. Because of this reason, this research employs bibliometric methodology to identify patterns and themes in attitudes and STEM education within scholarly publications to address this deficiency. The current research gaps regarding attitudes, STEM education, and bibliometric studies are addressed in this research.

Bibliometrics is a field that overlaps with scientometrics and informetrics and measures scientific research development by analyzing published literature (Waltman et al., 2010). VOS-Viewer has been a widely used software for creating and displaying bibliometric networks based on citations, bibliographic links, co-citations, and co-authorships (van Eck & Waltman, 2010). This study aims to make a bibliometric analysis of research on attitudes in STEM education. The results from this study provide valuable information about researchers, research trends, authors, countries, institutions, and publication sources that have contributed to STEM education research in the last fifteen years.

Research Methodology

General Background

Bibliometric methods are often utilized in literature searches to enhance understanding of a specific research field. This method guides researchers in identifying relevant work and mapping its connections within a field. It allows researchers to use data mining techniques that analyze relationships among research, such as the co-occurrence of keywords and co-citation networks (van Eck & Waltman, 2010). The researchers can use objective search criteria to minimize subjective bias in selecting publications. It is worth noting that bibliometric reviews do not summarize

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the actual findings of a set of studies but rather examine the bibliographic metadata associated with a group of documents to identify trends in knowledge production. Since the literature on attitudes toward science in STEM education is relatively high, the descriptive aspects of bibliometric analysis were used in this research.

Bibliometric analysis is a quantitative evaluation of scientific publications that provides researchers with insightful information about a research area or topic based on the various characteristics of existing publications, including abstracts, authors, citations, countries, funding sources, keywords, organizations, publishers, and purposes (Waltman et al., 2010). Due to bibliometric analysis's effectiveness and widespread application in the research literature, its techniques are the most highly regarded method for evaluating scientific publications in a particular research field or topic (Wang et al., 2018). Bibliometric mapping illustrates the relationships between nations, disciplines, subject areas, organizations, specific publications, and authors. Quantifying and assessing a specific aspect of research, bibliometric research facilitates the identification of trends in a field. The bibliometric analysis enables the monitoring of studies, researchers, institutions, and scientific developments pertinent to a particular scientific topic. The analysis of bibliometric studies is increasingly used to evaluate academic disciplines across the literature. The bibliometric analysis provided a comprehensive summary of relevant research based on numerous criteria. The relationship between relevant objects like authors, countries, sources, affiliations, and documents was subsequently determined using co-authorship analysis, citation analysis, and co-occurrence of author keywords (Waltman et al., 2010). In this study, researchers used VOSviewer software to analyze the data to comprehensively understand the research trends on attitudes and STEM.

Data Collection

This analysis was conducted by searching the SCOPUS database for scholarly articles on STEM attitudes. The researchers chose SCOPUS because it is one of the bibliographic databases of peer-reviewed literature, scholarly journals, publications, and conference proceedings. It offers access to a vast collection of high-quality scientific literature, rendering it an indispensable resource. SCOPUS is an essential and useful resource for researchers due to its comprehensive coverage of high-quality scientific literature, advanced search capabilities, citation analysis, and collaboration tools. It contains over 14,000 indexed journals from a variety of disciplines. Due to these factors, researchers utilized it to collect data for bibliometric research and to gain access to exhaustive publications on STEM and attitudes. The researchers initially used basic keywords such as "attitude,""attitudes," and "STEM" to locate pertinent publications. Researchers used filtering options to limit their database search results to social science publications, journals, and English-only content. In addition, the search covered the years 2008-2022. Consequently, 222 studies were retrieved from the database. These search terms ((KEY (attitude) OR KEY (attitudes) AND KEY (stem)) AND (EXCLUDE (PUBYEAR, 2023)) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBYEAR, 2022) TO (PUBYEAR, 2008))) were employed to retrieve 222 studies from the database.

In May 2022, the researchers searched the database. Later, two researchers independently examined all the studies. They read all 222 studies identified in the initial database analysis. They excluded studies unrelated to STEM attitudes or STEM education during this examination. 49 studies unrelated to the search criteria were excluded. Thus, a total of 173 studies were included in the bibliometric analysis. The results of the literature search were 173 documents. Document types included original articles (n = 157, 90.7%), conference papers (n = 13, 7.51%), book chapters (n = 2, 1.15%), and notes (n = 1, 0.05%). Two types of analyses were conducted. Excel (2007; Microsoft) initially generated the initial data statistics. The data was processed using VOSviewer.

Data Analysis

After obtaining the final search results from the SCOPUS website, the researchers extracted database files for the bibliometric analysis. They downloaded BibTeX and CSV files for the bibliometric analysis of 67 publications. Later, the researchers converted these files to the TAB file format so that the program for bibliometric analysis could use them. Tab-separated (Win) files for bibliometric analysis, in addition to the complete dataset and cited references. For the bibliometric analysis of this study, the VOSviewer was used to display the network visualization of the most frequently used keywords, abstract words, citation analysis, and co-citation analysis. The file was uploaded to the VOSviewer software. Two researchers conducted the data analysis.

The researchers used the software because it allowed to analyze literature networks and create visual graphics. Thus, the researchers performed network analysis using co-citation or co-citation analysis to identify the most

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influential component based on keywords, authors, sources, and references. This study's co-citation analysis determines which author, source, or reference is frequently cited.

Research Results

Number of Publications

Figure 1 demonstrates the upward trend in publications between 2008 to 2022. In 2022, 33 publications were published. In 2013 and 2018, and between 2018 and 2022, the number of publications increased substantially. In 2010, no publications were published on the research topic in this study.

Figure 1
Number of Publications

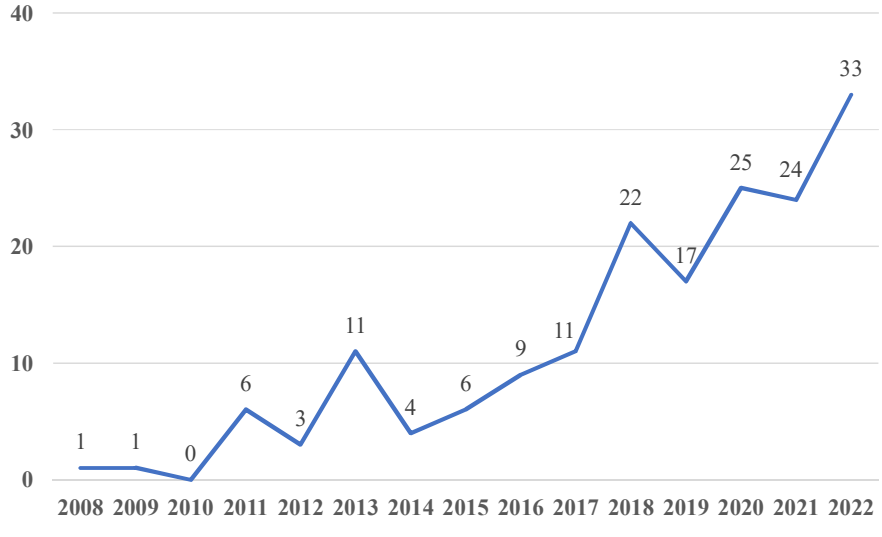

Table 1 shows the institutions that contributed most to the literature between 2008 and 2022. These institutions were Curtin University (n = 8), followed by the National Pingtung University of Science and Technology (n = 4), The University of Texas at Austin (n = 4), National Taiwan Normal University (n = 4), and the Michigan State University (n = 4), Universiti Kebangsaan Malaysia (n = 3), Zhejiang Normal University (n = 3), NC State University (n = 3), South China Normal University (n = 3), and the University of Wyoming (n = 3). The results revealed that only Curtin University had contributed to research on STEM attitudes. Regarding attitudes toward STEM education, the other institutions from Taiwan, USA, Malaysia, and China did contribute. These institutions were from Chinese, Malaysian, and Taiwanese universities. Universities in the United States of America (USA) and Australia have been at the forefront of attitude and STEM research. Taiwan was the most significant contributor (see Table 1).

Table 1
Top 10 Institutions Contributing to Research on Attitudes and STEM between 2008 and 2022

Institutions	Country	Number of Publications
Curtin University	Australia	8
National Pingtung University of Science and Technology	Taiwan	4
The University of Texas at Austin	USA	4
National Taiwan Normal University	Taiwan	4
Michigan State University	USA	4

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Institutions	Country	Number of Publications
Universiti Kebangsaan Malaysia	Malaysia	3
Zhejiang Normal University	China	3
North Carolina State University	USA	3
South China Normal University	China	3
University of Wyoming	USA	3

Table 2 shows that the United States had the most publications (*n* = 73, or 42.1%). Turkey is the second most productive nation (n = 16, 9.2%). Australia ranked third with 15 publications (*n* = 15, or 8.6%). Taiwan ranks the fourth with 11 publications (*n* = 11, 6.3%). It was found that China was ranked fifth. The following countries are Malaysia (*n* = 8, 4.6%), United Kingdom (*n* = 8, 4.6%), Netherlands (*n* =7, 4%), Spain (*n* =6, 3.4%), Belgium (*n* = 5, 2.9%), and Indonesia (*n* = 5, 2.9%) in terms of numbers of publications on attitudes and STEM.

Table 2
Top 10 Contributing Countries

Countries	Number of Publications
United States	73
Turkey	16
Australia	15
Taiwan	11
China	10
Malaysia	8
United Kingdom	8
Netherlands	7
Spain	6
Belgium	5
Indonesia	5

Network Analysis of Sources

Table 3 presents the top 10 sources identified by co-citation analysis using the VOSviewer software. The International Journal of Science Education (IJSE) emerged with the highest number of citations, surpassing all other sources by being cited more than 200 times. A close connection exists between individuals' views towards Science, Technology, Engineering, and Mathematics (STEM) and the research focus of articles published in the International Journal of Science Education (IJSE). The International Journal of Science Education (IJSE) achieved a 5-year impact factor of 2.776 in 2021. In the cluster analysis, numerous researchers cited articles from the International Journal of Science Education, International Journal of STEM Education, School Science and Mathematics, International Journal of Technology and Design Education, and Research in Science Education. These journals are long-term publications that larger publishers have published for over 30 years. Since 2014, only the International Journal of STEM Education has been published. In addition to IJSE, the Journal of Research in Science Teaching was cited over 150 times, with Science Education receiving the most citations (124 times).

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Table 3
Top 10 Sources by Co-Citation

		Citations	Total link Strength	Cluster
1	International Journal of Science Education	202	2793	1
2	Journal of Research in Science Teaching	168	2701	5
3	Science Education	124	2177	5
4	International Journal of STEM Education	102	1335	1
5	Journal of Personality and Social Psychology	92	1541	2
6	School Science and Mathematics	92	1357	1
7	International Journal of Technology and Design Education	90	1289	1
8	Journal of Educational Psychology	86	1387	2
9	Computers & Education	78	984	3
10	Research in Science Education	69	1108	1

Network Analysis of Authors

Table 4 lists the 10 most co-cited authors. Only Barry J. Fraser and Jaquelynne S. Eccles were cited more than one hundred times. After these two authors, eight other authors were co-cited over fifty times, including Jonathan Osborne, Louise Archer, Albert Bandura, Tamara J. Moore, Jennifer Dewitt, Allan Wigfield, and Gillian H. Roehrig.

Table 5 displays the top ten references based on co-citation analysis. The only reference co-cited more than ten times is Osborne et al. (2003). Four references, including Breiner et al. (2012), Wang (2013), Kelley and Knowles (2016), and Unfried et al. (2015), were cited more than 5 times. Two of the top 10 references based on co-citation were from School Science and Mathematics.

Table 4
Top 10 Authors by Co-Citation

		Organization	Country	Citations	Total link Strength	Cluster
1	Barry J. Fraser	Curtin University	Australia	124	698	3
2	Jaquelynne S. Eccles	University of California	United States	107	1376	1
3	Jonathan Osborne	King's College London	United Kingdom	86	1441	2
4	Louise Archer	University College London	United Kingdom	67	1337	4
5	Albert Bandura	Standford University	United States	62	793	1
6	Tamara J. Moore	Purdue University	United States	62	467	3
7	Jennifer Dewitt	University College London	United Kingdom	60	1243	2
8	Allan Wigfield	University of Maryland	United States	60	818	1
9	Gillian H. Roehrig	University of Minnesota	United States	52	473	3
10	Robert H. Tai	University of Virginia	United States	47	572	1

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Table 5
Top 10 References by Co-Citation

		Authors(s)	Source	Citations	Total link Strength	Cluster
1	Attitudes towards science: A review of the literature and its implications	Osborne et al. (2003)	International Journal of Science Education	13	7	2
2	What is STEM? A discussion about conceptions of STEM in education and partnerships	Breiner et al. (2012)	School Science and Mathematics	7	8	2
3	Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support	Wang (2013)	American Educational Research Journal	7	5	1
4	A conceptual framework for integrated STEM education	Kelley & Knowles (2016)	International Journal of STEM Education	6	7	2
5	The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM)	Unfried et al. (2015)	Journal of Psychoeducational Assessment	6	6	1
6	Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PJBL) environment	Tseng et al. (2013)	International Journal of Technology and Design Education	5	9	2
7	Advancing STEM education: A 2020 vision	Bybee (2010)	Technology and Engineering Teacher	5	8	1
8	Learning for stem literacy: STEM literacy for learning	Zollman (2012)	School Science and Mathematics	5	6	2
9	A conceptual framework for integrated stem education	Kelley & Knowles (2016)	International Journal of STEM Education	5	5	1
10	Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students	Maltese & Tai (2011)	Science Education	5	5	1

The cluster analysis results indicated that the top 10 references by co-citation were frequently cited together. The findings for this result produced four clusters, including the top 10 references. The studies of Wang (2013), Tseng et al. (2013), Maltese and Tai (2011) comprised the first cluster. The second cluster consisted of Breiner et al. (2012), Kelley and Knowles (2016), and Zollman (2012) studies. The third cluster was comprised of the research conducted by Bybee (2010), Maltese and Tai (2011), and Unfried et al. (2015). The fourth cluster contained the Osborne et al. (2003) article. The frequency analysis revealed that the 10 most frequently occurring keywords were associated with the following topics: STEM, attitudes, STEM education, students, attitude, STEM (science, technology, engineering, and mathematics), gender, STEM attitudes, engineering education, and education (see Table 6).

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Table 6
Ten Most Commonly Used Keywords

Keyword	Occurrences	Total Link Strength
STEM	64	72
Attitudes	33	35
STEM education	32	32
Students	23	46
Attitude	20	33
STEM (science, technology, engineering and mathematics)"	15	33
Gender	13	19
STEM attitudes	13	6
Engineering education	12	35
Education	11	22
Teaching	10	23

Based on a cluster analysis, the keywords have been grouped into six natural clusters (refer to Figure 2 and Table 7). Keywords appearing in the same cluster are commonly found in the research literature. Each cluster can indicate multiple hotspots for research. Although the keywords from different clusters differ, some research literature may address the same research objective that different clusters point to. By analyzing each cluster's keywords, readers can better understand the research hotspots regarding attitudes and STEM. Cluster 1 primarily examined students' attitudes and the effects of their genders on their attitudes toward STEM or STEM attitudes.

Table 7
Clusters of Keywords

Number	Cluster name	Main keywords
1	Attitude	Attitude, attitudes toward science, female, gender, human, human experiment, male, mathematics, motivation, science, stereotype
2	STEM	Attitudes, computational thinking, education computing, integrated STEM, middle school, secondary school, self-efficacy, STEM, STEM attitude, STEM attitudes, STEM career interest, STEM education
3	Students	Engineering education, learning attitude, learning attitudes, STEM (science, technology, engineering and mathematics), student attitudes, students, surveys
4	Education	Education, learning, perception, public attitude, student, sustainability, teaching

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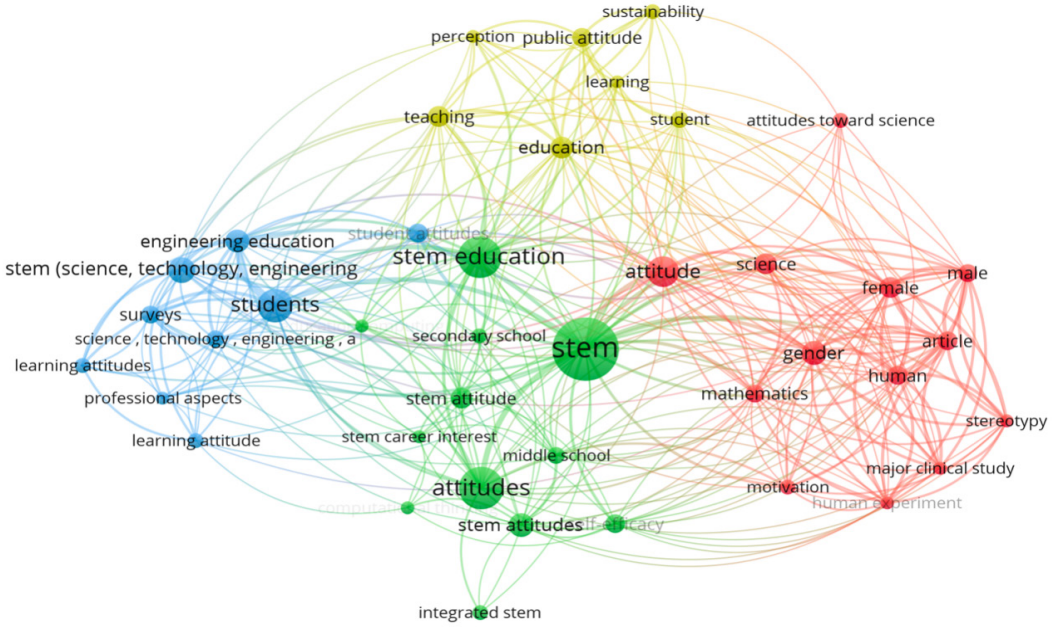
Figure 2
A Visualization of Keywords' Networks



Discussion

This research aimed to employ a bibliometric analysis of research on attitudes in STEM education to identify patterns and themes within scholarly publications to address a research gap in the current literature. First, the results revealed an upward publication trend from 2008 to 2022. In particular, in 2013 and 2018, and between 2018 and 2022, the number of publications increased substantially. Regarding the increase in the number of research in STEM education, this result is remarkably similar to that of Phuong et al. (2023), who found a similar increase in the number of implementations of STEM education. This result is similar to LeThiThu et al. (2021), who found that a growing trend of STEM education in middle school can be divided between 2016 and 2020.

Curtin University was the institution that contributed the most to the literature between 2008 and 2022. National Pingtung University of Science and Technology ($n = 4$), The University of Texas at Austin ($n = 4$), National Taiwan Normal University ($n = 4$), and Michigan State University were the other institutions that contributed the most to the research on attitudes toward STEM during the last fifteen years. When the results in Table 1 are examined, it can be concluded that the institutions from Australia, Taiwan, and the USA contributed equally to the number of research on attitudes and STEM between 2008 and 2022. This result is remarkably similar to that of Phuong et al. (2023) and LeThiThu et al. (2021). Phuong et al. (2023) found that seven of the 10 productive were from the USA, while LeThiThu et al. (2021) studied two decades of STEM education in the middle school level and found that the top 10 productive institutions were from the USA.

The results demonstrated that the United States had the most publications on attitudes and STEM. Turkey is the second most productive nation, while Australia ranked third. Taiwan ranks fourth with 11 publications, and China is ranked fifth. The following countries are Malaysia, the United Kingdom, the Netherlands, Spain, Belgium, and Indonesia. This result is remarkably similar to that of Phuong et al. (2023), who discovered that seven of the top 10 best-performing authors are from the United States, while the remaining three are from Ireland and Turkey. LeThiThu et al. (2021) found a similar finding, revealing that the top countries were the USA, Turkey, and Australia.

The IJSE had the most citations, with The Journal of Research in Science Teaching and Science Education closely behind. This finding aligns with LeThiThu et al.'s (2021) results. Notably, the top 10 journals in co-citation analysis are focused on educational research, technology, engineering education, science, and STEM education and are considered prestigious and influential. There could be several reasons for this outcome. Firstly, highly-regarded journals have

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stricter peer-review processes to ensure that they publish only high-quality articles. Secondly, these publications release more issues and articles than other periodicals. Additionally, we observed that scientists from the United States, the United Kingdom, and Australia wrote more articles. Six of the top 10 authors based on co-citation analysis were from the USA.

Another result also revealed that Barry J. Fraser and Jaquelynne S. Eccles were cited more than one hundred times in the publications. These authors came from Australia and the United States, respectively. Similarities exist between this result and Phuong et al. (2023) and LeThiThu et al. (2021). Looking at these results, we can expect Australia and the United States to have a strong presence in creating knowledge about STEM education through scholarly participation. It is interesting to note that the top 10 references were often cited together. Finally, the results regarding the frequency analysis revealed that the 10 most frequently occurring keywords were associated with the following topics: stem, attitudes, stem education, students, attitude, stem (science, technology, engineering, and mathematics), gender, stem attitudes, engineering education, and education.

Conclusion and Implications

Although STEM research has received growing attention in the educational literature, very little information about the current status of research on attitudes toward STEM using the bibliometric analysis method is known. The present research is the first bibliometric study that examined the current state of attitudes and STEM research. Consequently, this study contributes to the existing body of knowledge by providing an overview of the current state of research in this field. The research was analyzed to determine the most prominent authors, countries, sources, institutions, and publications within the past 15 years. The primary focus was on examining the interconnectedness of sources, authors, references, and keywords that contribute to the overall productivity in this field. Based on the findings, it can be deduced that Curtin University emerged as the most productive academic institution. At the same time, the United States demonstrated the highest level of productivity in research about attitudes and STEM. This result demonstrates the significant contributions made by the United States academics. It is anticipated that the United States will continue to lead in this field of research. Based on this result, exploring the state of research in other countries is important. Future studies should explore the attitudes in STEM education in other countries.

Together with the JRST and Science Education, the IJSE journals provide a forum for high-quality publications in this field. The IJSE was the source with the most citations for research on attitudes and STEM. Regarding research on attitudes in STEM, renowned academics had strong collaborations, such as between the groups led by Fraser and Eccles, from institutions in the United States and Australia. Based on this finding, these international academic collaborations are anticipated to be strengthened in light of rising STEM-related and attitude-related concerns.

This study's analysis was conducted using studies indexed in the SCOPUS database. Therefore, future research may consider incorporating data from other databases, such as ERIC, EBSCOhost, and Web of Science. Future research can track this field's development and international cooperation networks between various nations and organizations. Future academic studies can also examine changes in research on student attitudes toward STEM or STEM fields. As STEM advances rapidly, researchers often need to provide updates on bibliometric research related to attitudes in STEM education. This analysis helps keep track of the field's progress. To stay up-to-date with the latest research in STEM education, it is important to perform periodic bibliographic analysis.

Limitations

Even though this study provided a comprehensive knowledge map of research on attitudes and STEM, several limitations should be noted. Although this study offers valuable insights into STEM attitudes, it is important to note that the limited time frame used for the search may have affected the breadth and depth of the studies included. While this bibliometric review aimed to provide a thorough overview of research on STEM education attitudes, further studies are needed to conduct a more detailed analysis. Furthermore, there are still some unanswered questions regarding the effectiveness of strategies, methods, and techniques used to influence student attitudes toward STEM education in our search strategy. As a result, there is an urgent need for further research on the impact, design, and application of various technologies and online learning strategies to better understand their influence on student attitudes toward STEM education.

The search parameters used in this research, which included only SCOPUS-provided and English-language documents, might exclude relevant studies unavailable in SCOPUS or written in other languages. It is noteworthy

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that while SCOPUS is widely recognized as the greatest multidisciplinary database for scientific literature and encompasses conference proceedings in the form of journal articles, it is possible that certain conference proceedings about student recruiting and STEM fields may not be encompassed within its scope. Hence, it is essential to comprehend that these constraints can impact the results of this research. Bibliometric studies should consider broadening their search parameters to encompass supplementary scholarly inquiries.

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Declaration of Interest

The authors declare no competing interest.

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Ke Ma Master of Education (M.E.), Zhejiang SCI-TECH University, Zhejiang province, China.
mail: 21009024@qq.com

Bei-He Hui *(Corresponding author)* PhD, Zhejiang SCI-TECH University, Zhejiang province, China.
mail: chinahbh@126.com
ORCID: https://orcid.org/0009-0003-6917-093X