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Review Article

A bibliometric overview of science communication research in STEM education

Alfia M. Ishmuradova [1*]
0000-0002-3395-2919

Marina N. Svintsova [2]
0000-0002-9402-0816

Nataliia A. Kondakchian [3]
0000-0002-9511-4064

Natalia A. Zaitseva [4]
0000-0002-9511-4064

Natalia L. Sokolova [5]
0000-0002-0667-5098

Elmira R. Khairullina [6]
0000-0002-2125-4283

[1] Department of Foreign Languages, Kazan (Volga region) Federal University, Kazan, RUSSIA
[2] Department of Humanities, Financial University under the Government of the Russian Federation, Moscow, RUSSIA
[3] Institute of Linguistics and Intercultural Communication, Sechenov First Moscow State Medical University, Moscow, RUSSIA
[4] Department of Hospitality, Tourism and Sports Industry, Plekhanov Russian University of Economics, Moscow, RUSSIA
[5] Institute of Foreign Languages, Peoples' Friendship University of Russia (RUDN University), Moscow, RUSSIA
[6] Institute of Light Industry, Fashion, and Design, Kazan National Research Technological University, Kazan, RUSSIA
[*] Corresponding author: alfiaishmuradova@mail.ru

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ABSTRACT

Science communication has recently gained importance in many countries worldwide. This study conducted a bibliometric analysis to evaluate the scientific output of science communication in STEM education in the SCOPUS database for 2000-2022. For this purpose, the published studies on science communication were analyzed bibliometrically, and the trend of the last 22 years was shown. The database SCOPUS was used for data collection. The studies were analyzed under the following subheadings: Number of publications per year, type of publications, the language of publications, citation analysis, country collaborations, common citation networks, and conceptual trends. The results showed that the number of articles increased between 2019 and 2022. The United States and the United Kingdom had the most publications. The results also showed that the countries with the most collaboration in co-authored studies were Germany, the United States, Finland, Australia, and the Netherlands. Most published authors were mainly from the United States and Australia. The results of peer-reviewed journals demonstrated that the highest bibliographic link strengths included the International Journal of Science Education-Part B, Journal of Research in Science Teaching, Science Communication, Public Understanding of Science, and Journal of Science Communication. In addition, the most frequently used keywords were science communication, science education, education, human, communication, public understanding of science, and stem. Educational implications are drawn in the conclusion.

Keywords: bibliometric, science communication, SCOPUS, STEM education

INTRODUCTION

Science communication is a part of STEM (science, technology, engineering, and mathematics) education to teach individuals they need concepts scientifically and effectively (Shivni et al., 2021). It is essential for effective outreach to students or individuals because it helps bridge the gap between the scientific community and the public (Bickford et al., 2012; Malik et al., 2022; Suprapto et al., 2021; Al-Momani, 2021). By communicating scientific ideas and findings concisely and understandably, STEM educators and teachers can help engage their students and inspire them to pursue careers in STEM fields (Donohue et al., 2021; Panferov et al., 2022). For example, effective science communication can help demystify complex scientific concepts and better relate them to everyday life (Matta, 2020; van Dijk, 2011). This type of science communication can help students understand the relevance of STEM topics and how they can be applied in different contexts to use scientific knowledge to solve problems (Hu et al., 2018; Shivni et al., 2021; Badru & Owodunni, 2021). In addition, science communication can help improve the public's understanding of scientific research, which is essential for making informed decisions (Leydesdorff & Hellsten, 2005). To foster dialog between scientists and the public, science communication can help build trust and support for scientific research between the public and scientists (Sinai et al., 2022). In short, science communication is important for everyone in all societies because it can help inspire students, improve public understanding of science, and promote scientific progress for human beings' future (Sinai et al., 2022; van Dijk, 2011).

As it is well known, STEM education is an essential area of research and teaching because it prepares students and individuals to contribute to the innovation and progress of society in the future. Over the past decade, STEM fields have gained interest among educators, policymakers, and teachers who want to understand better the factors that influence student learning and success in these areas (Hasanah, 2020). In addition, STEM education research is an interdisciplinary field that encompasses a variety of topics, from pedagogy and curriculum development to the impact of technology and cultural factors on student learning (Hasanah, 2020). The large number of research studies in STEM education is likely due to the field's importance, interdisciplinary nature, and the availability of funding opportunities.

Due to the increasing interest of researchers in STEM fields and topics, the number of academic studies in almost all branches of science increases significantly every year (Phuong et al., 2023). A huge amount of information in the literature makes it difficult to determine important directional points for researchers in a particular field. Bibliometrics, which allows the historical development of a scientific field to be examined by publications, citations, authors, countries, sources, and institutions using mathematical and statistical methods, provides researchers with a well-designed method to evaluate the increasing number of research papers each year (Kushairi & Ahmi, 2021; Ninkov et al., 2022). However, increasing studies on a topic or research area requires computer programs to evaluate research development. From this point of view, bibliometric mapping is relatively new and bright for researchers (Ninkov et al., 2022). It allows for a more holistic evaluation of studies in a particular field using various software and programs developed at the time to map the scientific structure (Aparicio et al., 2021; Phuong et al., 2023; Wang et al., 2018). The bibliometric analysis programs provide researchers with much information about co-authorship, co-citations, bibliographic matching, and concept association analysis based on network, bibliographic, and textual data from studies in a particular topic or field. These programs allow researchers to map through measurements and analyses such as author, institution, country, document, the key concept, abstract, and resources (Karampelas, 2023; Phuong et al., 2023; Wang et al., 2018).

The relevant literature shows that bibliometric analysis programs such as Bibliometricx, BiblioShiny, RStudio, and VOSviewer program have been used by researchers in the last decade (e.g., Marín-Marín et al., 2019; Phuong et al., 2023; Wang et al., 2018) to map research on a particular topic or research area in the literature. The main purpose of these programs is to provide a general overview of the topics studied in the research area, identify research trends, highlight concepts emphasized in the research, and draw attention to the leading researchers contributing to the field. The analysis techniques used in these programs are bibliographic matching, co-citation, co-authorship, citation network, and concept association.

In the research literature, a few research have been conducted on science communication and STEM education. For example, Sugimoto and Thelwall (2013) examined TED videos using a range of bibliometrics indicators to gain insight into the nature and extent of their impact. The results showed that TED Talks, with

about three-quarters of a billion total views, primarily influenced the general public rather than academia. Differences were found across disciplines, with art and design videos generally achieving lower impact, while science and technology videos accomplished average impact for TED. Many of the metrics were loosely related. However, there was a consensus on the most popular videos measured by views or comments on YouTube and the TED website. Furthermore, most videos were found in at least one online curriculum, and videos in online curricula tended to be viewed, discussed, and blogged about more frequently. Less popular videos sparked more discussion, which may be because they are more controversial. Science and technology videos presented by academics were more popular than those offered by non-academics. Rauchfleisch and Schäfer's (2018) study analyzed citation network structures to determine whether scholarly communication research shows signs of becoming a research field or a discipline in its own right. They included scholarly publications analysis of a co-citation analysis of scholarly publications published between 1996 and 2015. Their results show a coherent communication network within scholarly communication research. It is a field with a diverse internal structure and clear internal changes over time. In another study, Chen et al. (2022) aimed to visualize and analyze the global literature on climate change science communication since 2000 through bibliometric analysis. They analyzed 1,175 articles published in the Web of Science database between 2000 and 2021. Their results show that research on climate change communication has become a relatively distinct research field with rapid development and offers a broad research perspective given the new understanding of climate change. They also found that developed countries have dominated research on this topic. In addition, their findings demonstrated that the public's understanding and presentation of information in the media had been a hot topic in climate communication research.

Kessler et al. (2019) investigated the state of science communication research in German-speaking countries using content analysis. They collected and analyzed all extended abstracts submitted to the annual conferences of the German Society for Communication on Science communication from 2014 to 2018. Their results showed that science communication had become an established community and represented an institutionalization of the research field.

Although bibliometric research studies on specific topics or research areas have been increasingly used in STEM education over the past decade due to their functionality and reliable results, to our knowledge, we have not found any research that has analyzed the publications on science communication studies and STEM education. Although the number of research papers on STEM education seems to be increasing, the number of bibliometric studies on science communication is very rare. In addition, previous studies have not conducted a detailed analysis of science communication research in STEM education. Therefore, this study aims to examine the current status of STEM education research in science communication using bibliographic data from the Scopus database from 2000 to 2022. A bibliometric analysis of science communication and education STEM can provide a comprehensive overview of current research on the practical implementation of education STEM. To the knowledge of the authors of this paper, such an analysis is currently lacking in the research literature. Moreover, the results would provide valuable and insightful findings to scholars who wish to study this topic in the future.

METHOD

Bibliometric analysis, one of the systematic analysis methods, was initially used to identify the studies, authors, journals, and trends in science communication in STEM education. Bibliometric analysis is important because it identifies the current status of studies, authors, journals, and trends influencing the field and shows their relationships to a research topic or area. Bibliometric analysis allows researchers to position the research topic they are working on and identify its limitations and strengths. In this study, the Vosviewer program was used for the analysis. The researchers analyzed the main studies identified due to the bibliometric analysis. For this aim, researchers searched to collect research studies on science communication and STEM education in Scopus database with advanced search options to ensure more related search terms and peer-reviewed articles. A search of the database found 175 studies after applying the search criteria. All 175 studies published in journals of the Scopus index were analyzed using the criteria of this research on science communication and STEM education. The year of publication was selected from 2000 to 2022. During the search in the database, the researchers limited the results to peer-reviewed articles only and publications

in English. Researchers filtered the results to social sciences to access the articles concerning science communication and STEM education. The following keywords and parameters were used for data collection:

(TITLE-ABS-KEY ("science communication") AND TITLE-ABS-KEY ("STEM education") OR TITLE-ABS-KEY (stem) OR TITLE-ABS-KEY ("science education") OR TITLE-ABS-KEY ("mathematics education") OR TITLE-ABS-KEY ("engineering education") OR TITLE-ABS-KEY ("technology education")) AND PUBYEAR>1999 AND PUBYEAR<2023 AND PUBYEAR>1999 AND PUBYEAR<2023.

After applying the search criteria, all information about the peer-reviewed articles was downloaded in CSV and Bibtext format from the database as one file to perform bibliometric analysis. Later, the researchers converted this file to a TAB delimited file format. After this process, the file was transferred to the VOSviewer program. This program provides researchers with many options to meet their bibliometric study needs. The VOSviewer program is a fast and versatile solution for bibliometric analysis. This program allows researchers to obtain quantitative data on works, authors, journals, organizations, coordination, co-authorship, citation networks, trends, factors, topic analysis, association analysis, and maps. VOSviewer focuses more on visualization than the other statistical program R. Like the other bibliometric package programs, Vosviewer allows visualization co-sequence, co-authorship, citation, and co-citation networks and performing association analysis. The researchers performed various measurements on the data. They used some analytical techniques to extract information about the collection of publications. They examined general statistics to obtain quantitative information, such as annual publications and publication trends, journals with the highest number of publications and authors, or organizations with the highest productivity. In addition, they analyzed co-authorship between countries to examine the collaboration between the most productive countries in published articles.

RESULTS

Figure 1 shows the number of articles published each year. The search results show no articles on science communication from 2000 to 2003. Between 2003 and 2022, there were 175 published articles on science communication. In addition, no published articles were found about science communication in 2006 and 2008. As shown in **Figure 1**, scientists' interest and science communication studies in STEM education has increased since 2018. It can be concluded that the number of articles in the number of articles between 2019 and 2022. The results in **Figure 1** also show that the first articles on science communication were published in 2003 and gradually increased from 2014 to 2022.

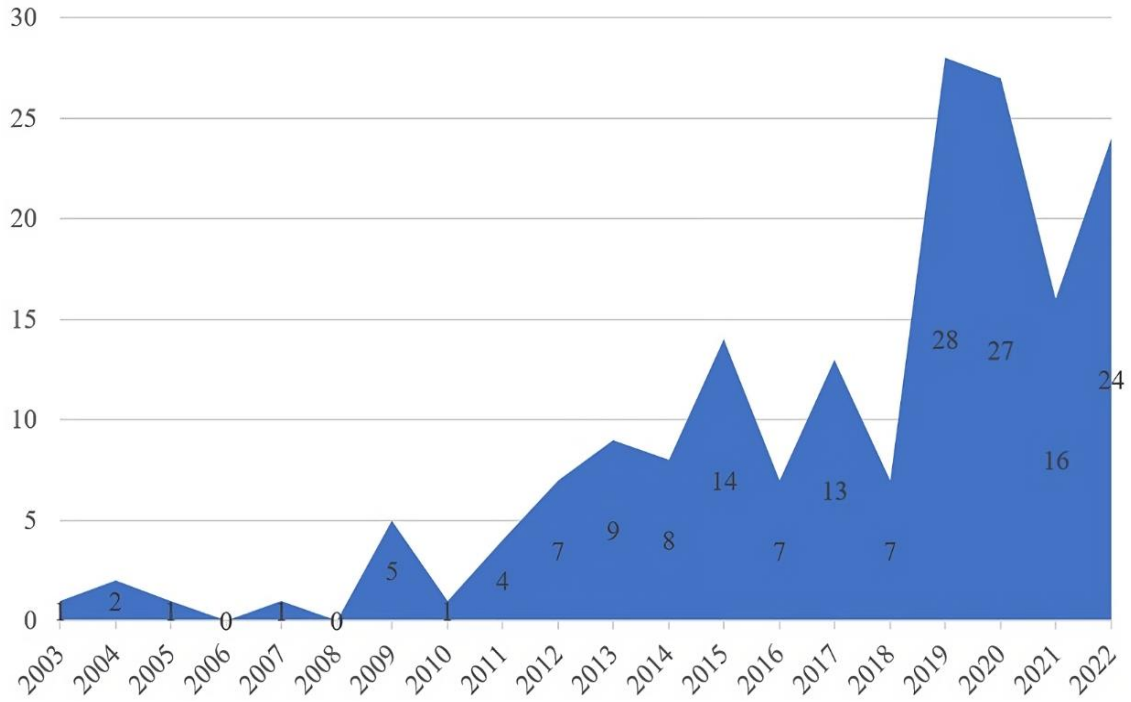

Figure 1. Distribution of studies according to years (Source: Authors, using Microsoft's Excel program)

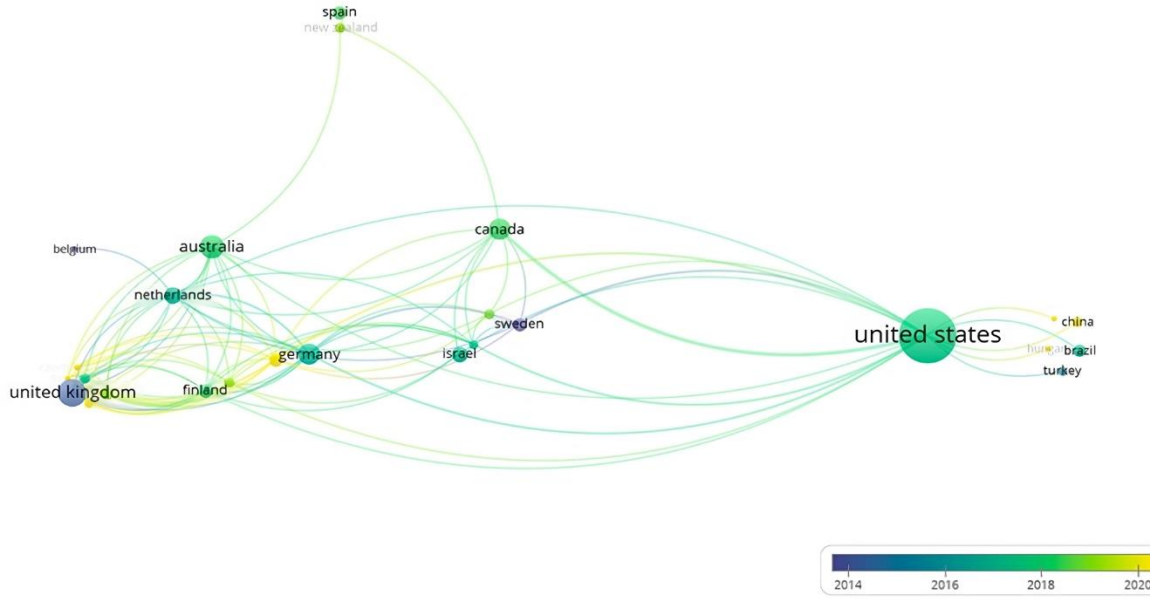

Figure 2. Cooperation network analysis between partner countries on science communication in STEM education (Source: Authors, using VOSviewer 1.6.19)

Contribution by Nations

Science communication research in STEM education between partner countries worldwide is shown in **Figure 2**. A total of 26 countries were found in this analysis. This analysis yielded five clusters. The first cluster included nine countries, including the United Kingdom and Austria. For each of the 26 countries, the total strength of co-authorship links with other countries was calculated. The countries with the largest total strength of ties were selected. The number of countries to be selected is 26, and the minimum number of documents in a country was 1. As **Figure 2** shows, the United States has the most publications. The countries with the most publications are the United Kingdom, Australia, Canada, Germany, the Netherlands, Israel, Spain, Finland, and Portugal. The authors from the United Kingdom, the United States, and Canada mainly collaborate with authors from other countries.

Figure 3 shows co-authorship analysis among countries using the country analysis unit. The results yielded 26 items in four clusters. The results show that the countries with the greatest collaboration in co-authored studies using the VOSviewer program in science communication are Germany, the United States, Finland, Australia, Netherlands, Portugal, Austria, the United Kingdom, Italy, and Ireland (**Figure 3**).

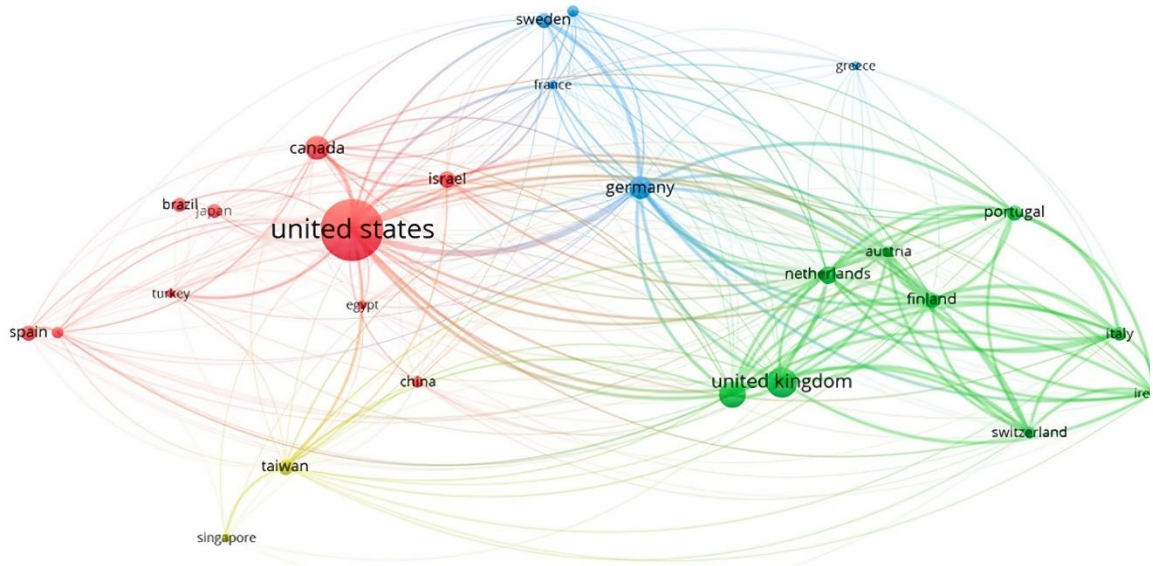

Figure 3. Co-authorization map according to countries (Source: Authors, using VOSviewer 1.6.19)

Table 1. Top-10 most productive affiliations published on science communication in STEM education

No	University	Country	Documents	Citations
1	Tel Aviv university	Israel	3	46
2	University of the West of England	United Kingdom	3	33
3	University of Wisconsin-Madison	United States	2	315
4	University of Minnesota	United States	2	69
5	The University of Queensland	Australia	2	69
6	George mason university	United States	2	5
7	National Center for Atmospheric Research Integrated Science Program	United States	2	5
8	University of Waterloo	Canada	2	5
9	Michigan State University	United States	2	3
10	University of Tennessee at Chattanooga	United States	2	3

Table 2. Top-10 most productive authors published on science communication in STEM education

No	Author	Institution	Country	Documents	Citations
1	Besley, J. C.	Michigan State University	United States	4	93
2	Kuchel, L.	The University of Queensland	Australia	4	87
3	Chang, C.-Y.	National Taiwan Normal University	Taiwan	3	4
4	Wu, L. Y.	Chung Yuan Christian University,	Taiwan	3	4
5	Zahry, N. R.	University of Tennessee at Chattanooga	United States	3	7
6	Baram-Tsabari, A.	Technion–Israel Institute of Technology	Israel	3	72
7	Mercer-Mapstone, L.	University of Queensland	Australia	2	69
8	Osborne, J.	King's College London	United Kingdom	2	666
9	Bultitude, K.	University of the West of England	United Kingdom	2	71
10	Allchin, D.	University of Minnesota	United States	2	69

Contribution by Institutions

Table 1 shows top-10 affiliations with the number of published articles on science communication in STEM education. Among these institutions, the United States has six affiliations, Australia, Canada, Israel, and the United Kingdom have one article associated with these countries. **Table 1** shows that top-10 science communication and STEM education articles were written in developed countries. The articles with the most citations were published by researchers who studied at the University of Wisconsin-Madison.

Contribution by Authors

Table 2 shows top-10 authors with the most published articles on science communication and STEM education. The authors of the most published are J. C. Besley and L. Kuchel from two countries, including the United States and Australia, with four articles. These authors are followed by researchers (C.-Y. Chang, L. Y. Wu, N. R. Zahry, and A. Baram-Tsabari) with three articles each. In addition, the analysis revealed that Osborne et al. (2003) is the researcher with the most citations on science communication, with 666 citations in Scopus database. Co-authorship analysis revealed a cluster of 22 articles.

Another analysis conducted as part of the research was the citation network map based on the unit of analysis in the document. This analysis included studies with at least 20 citations out of 175 documents. By selecting studies that met this condition, 37 related items were obtained in eight clusters. It is common practice to set a lower limit to obtain more refined results in this type of research with intensive data. The illustration of the documents whose citation network map is shown in **Figure 4**.

Accordingly, the research papers with the highest citation network connection can be listed as Kohen and Dori (2019), Besley et al. (2015), Wu et al. (2019), Mercer-Mapstone and Kuchel (2017), Feinstein (2015), respectively. In addition, the first five researchers who have the highest citations on science communication are Osborne et al. (2003), Simis et al. (2016), Tataolovic (2009), Schäsignfer (2009), and Besley et al. (2015). A citation network map is a technique used to identify seminal research papers in a particular field or topic to disseminate an idea developed in a given period.

In the case of co-citation analysis, which is used to determine the sources, references, or authors of central importance in the field, the unit of analysis was chosen as the author for use in this research, the threshold limit for the minimum number of citations received by an author was set at 20, and 3 clusters were identified out of 28 researchers who met this condition.

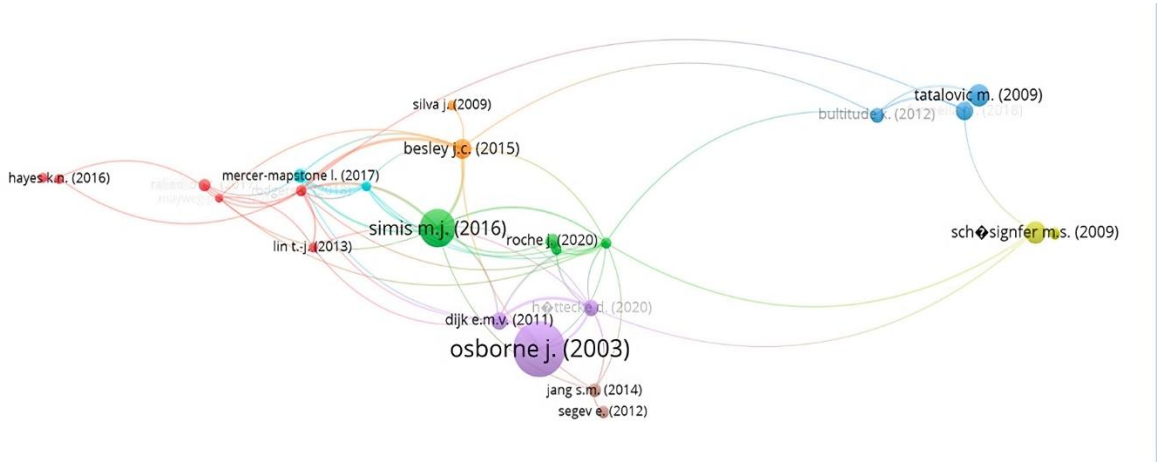

Figure 4. Authors' citation network map (Source: Authors, using VOSviewer 1.6.19)

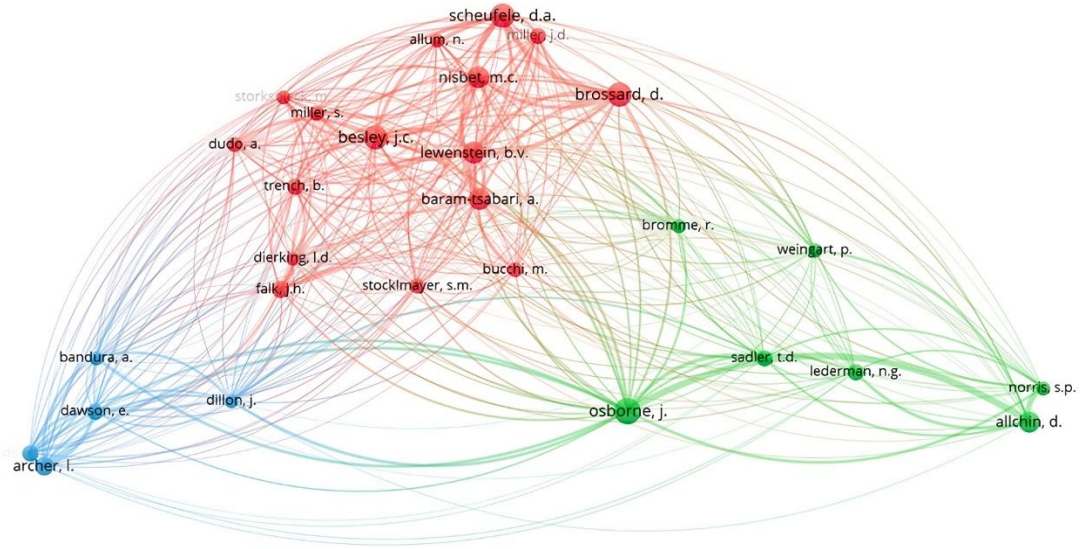

Figure 5. Authors' co-citation map (Source: Authors, using VOSviewer 1.6.19)

As can be comprehended in **Figure 5**, it was determined that the three researchers who contributed the most to this area were Osborne et al. (2003), Besley et al. (2015), Scheufele (2022), respectively.

Contribution by Journals

When analyzing peer-reviewed journals that have published articles on science communication and STEM education, the results in **Table 3** show ten journals with the highest number of articles. These journals are Public Understanding of Science, Journal of Science Communication, International Journal of Science Education, Part B: Communication and Public Engagement, Frontiers in Communication, Journal of Microbiology and Biology Education, Science Communication, Journal of Research in Science Teaching, International Journal of Science Education, Science and Education, and Frontiers in Education, respectively. The results show that most articles were published in Public Understanding of Science, Journal of Science Communication, and International Journal of Science Education, Part B: Communication and Public Engagement. On the other hand, the journals with the most citations are the Journal of Research in Science Teaching, Public Understanding of Science, and Journal of Science Communication. In addition, the results show that the largest academic publishers published these journals.

Table 3. Top-10 most active journals published on science communication in STEM education

No	Journals	NPA	Citations
1	Public Understanding of Science	17	524
2	Journal of Science Communication	16	246
3	International Journal of Science Education, Part B: Communication and Public Engagement	12	91
4	Frontiers in Communication	11	43
5	Journal of Microbiology and biology Education	11	41
6	Science Communication	8	240
7	Journal of Research in Science Teaching	6	842
8	International Journal of Science Education	6	118
9	Science and Education	4	22
10	Frontiers in Education	4	8

Note. NPA: Number of published articles

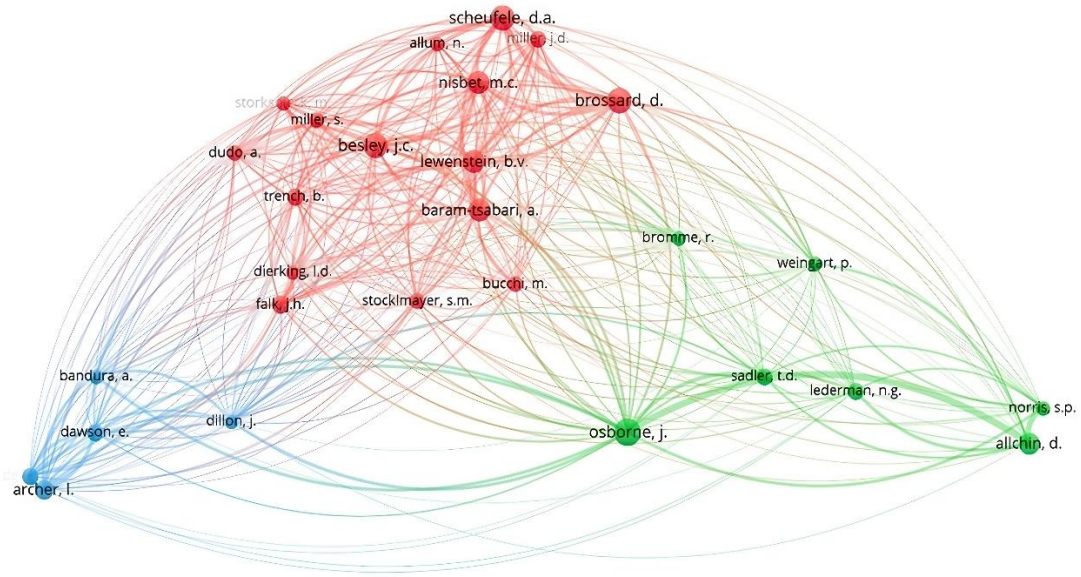

Figure 6. Authors' analysis according to bibliographic matching map (Source: Authors, using VOSviewer 1.6.19)

The results revealed that 77 different sources (publishing organizations) published articles about science communication and STEM education. When the lower limit for the number of studies published by a source was set at one and the number of citations at 10, it was found that 21 journals met these conditions. Accordingly, for publications related to the application of current research, a map of journals most closely associated with a particular focal journal was created (**Figure 6**). The results show the resource network map of studies in the field of social sciences using the VOSviewer program, with 21 sources and five clusters. Accordingly, the sources with the highest bibliographic link strengths included the International Journal of Science Education**,** Part B, Journal of Research in Science Teaching, Science Communication, Public Understanding of Science, and Journal of Science Communication, respectively.

Analysis of Keywords

Figure 7 shows a keyword analysis of the VOSViewer software on science communication research. The type of analysis was co-occurrence analysis based on all keywords. A total of 689 different keywords were found in the analysis. **Figure 7** shows that the most frequently used keywords are science communication, science education, education, human, communication, public understanding of science, and stem, respectively. **Figure 7** also illustrates the research topics based on keywords. It can be concluded that there is a parallel between science communication and science and STEM education.

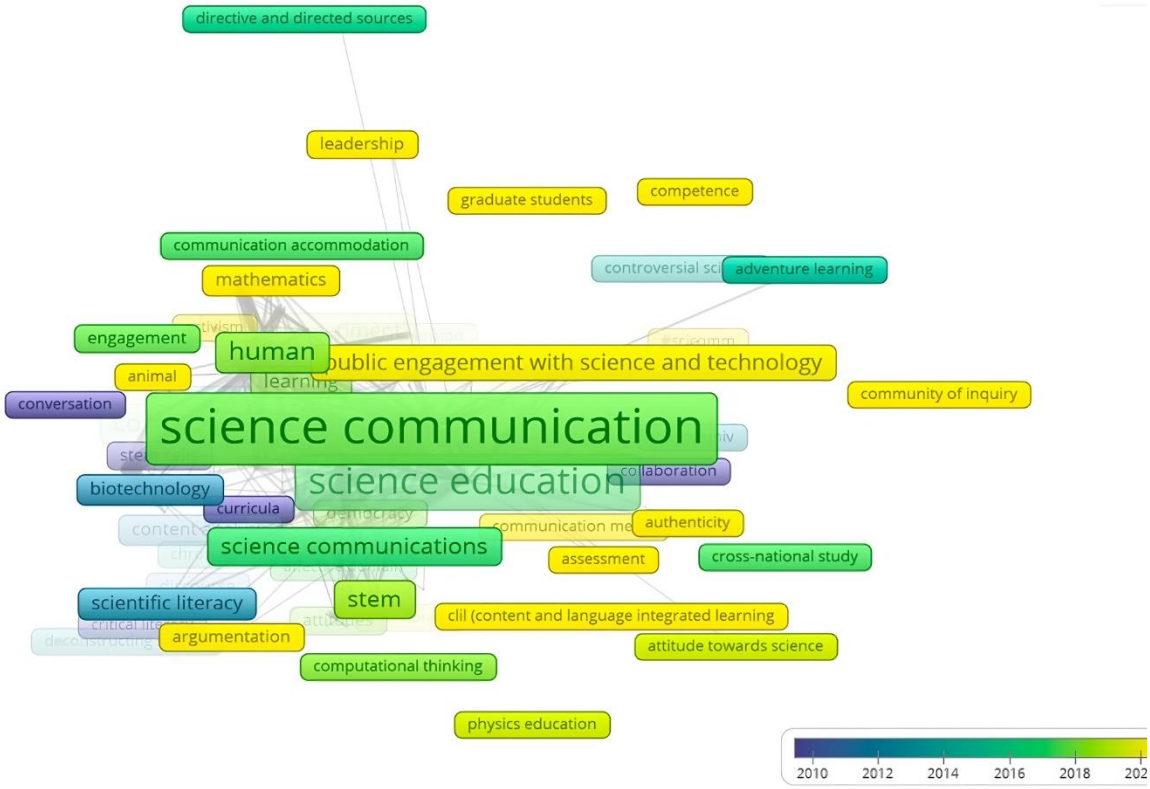

Figure 7. Co-occurrence analysis of index keywords on science communication research in STEM education (Source: Authors, using VOSviewer 1.6.19)

DISCUSSION

This research aimed to examine the current status of science communication in STEM education using bibliographic data from the Scopus database from 2000 to 2022. The findings from this research provide a bibliometric assessment of the research on science communication in STEM education. Given that no study has not analyzed the articles on science communication in STEM education as bibliometrics, a comprehensive analysis of the research using analytical tools contributed to the literature. The present study reflects on trends in the status of research in international literature. At the same time, it provides data on collaboration in the literature by visualizing the relationships between influential studies and researchers in the field. Bibliometric studies that use analytical tools are crucial to get the "big picture" of subject areas. They allow researchers to review trends in scientific research on a research topic or area. They can also guide other researchers in the field by identifying effective research institutions and researchers. It contributes to the STEM educational literature on science communication by identifying the research content and directions of researchers in network clusters. Thus, researchers evaluating the current situation in the field can pursue new and original research directions.

The preferred form of academic publication is the article. The articles are essential for the academic production of scientists. This type of publication provides objective indicators for determining scientists' academic effectiveness and scientific productivity. In this regard, the article is expected to be preferred as a document type in the literature. This bibliometric study of science communication in education STEM found that science communication studies in education STEM have increased since 2018. In particular, the number of articles was increased between 2019 and 2022. The first article on science communication was published in 2003 and gradually increased from 2014 to 2022. The great interest of researchers in STEM education can explain this result.

The results show that the most articles published are. The United States, the United Kingdom, Australia, Canada, and Germany are the countries that contribute the most to this topic. The institutions from the United

States had the most articles on science communication. Based on this finding, it can be said that researchers in developed countries did more studies on science communication in STEM education.

The information from institutions in this country is important for knowledge production. We suggest that researchers conducting studies in other countries follow these institutions' academic and scientific results, and the academic publications produced can qualify. The analysis of co-authorship between countries showed that the countries with the greatest collaboration on co-authored studies in science communication are Germany, the United States, Finland, Australia, the Netherlands, Portugal, Austria, the United Kingdom, Italy, and Ireland (**Figure 3**).

The results on the countries of correspondent authors show that the United States has six affiliations among the top ten institutions. Australia, Canada, Israel, and the United Kingdom have one article affiliated with these countries. The top science communication and STEM education articles were written in developed countries. The articles with the most citations were published by researchers who studied at the University of Wisconsin-Madison. In addition, the analysis revealed that Osborne et al. (2003) is the researcher with the most citations on science communication in the Scopus database. In addition, a citation network analysis revealed that the highest citation network link could be listed as Kohen and Dori (2019), Besley et al. (2015), Wu et al. (2019), Mercer-Mapstone and Kuchel (2017), and Feinstein (2015), respectively. In addition, the first five researchers who have the highest citations on science communication are Osborne et al. (2003), Simis et al. (2016), Tataolovic (2009), Schäsignfer M.S. (2009), and Besley et al. (2015). Another finding is that the co-citation analysis determined that the five researchers who contributed the most to this area were Osborne et al. (2003), Besley et al. (2015), Scheufele (2022), respectively. When two documents are included in the bibliography of another document, the co-citation analysis establishes a link between these two studies. The increase in the frequency of co-citations leads to strong co-citation relationships. Finally, the citation network counts direct citations from one document to another, and the more citations refer to the document, the stronger the citation network becomes.

CONCLUSIONS AND LIMITATIONS

Although the present research provides important findings for researchers interested in science communication in STEM education and contributes to the literature, the research has some limitations. First, in this research, researchers collected data only in Scopus. This study did not consider other international databases like the Web of Science, EbscoHost, and ERIC. To determine the publication trend of a particular research area in future research and identify the priority topics based on studies in the research area, the bibliometric map of the research area can be used using other databases. Second, only the VOSviewer program was used in the study. The analyses were conducted based on this program. Other applications, such as Bibliometrix, Biblioshiny, Pajek, and Citespace, were not used. The other programs may help provide more visualizations for readers while presenting the research results. In future studies, researchers could be considered to compare two bibliometric programs using the same research question.

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Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

REFERENCES

Al-Momani, M. O. (2021). Vocational-education students' attitudes towards their academic specialization in Jordan. *Education and Self Development, 16*(3), 10-24. https://doi.org/10.26907/esd.16.3.03

Aparicio, G., Iturralde, T., & Maseda, A. (2021). A holistic bibliometric overview of the student engagement research field. *Journal of Further and Higher Education, 45*(4), 540-557. https://doi.org/10.1080/0309877X.2020.1795092

Badru, A. K., & Owodunni, S. A. (2021). Influence of mathematical language ability and parental supports on students' academic achievement in secondary school sciences (Physics, chemistry and biology) in Ogun state, Nigeria. *Education and Self Development, 16*(1), 10-20. https://doi.org/10.26907/esd16.1.03

Besley, J. C., Dudo, A., & Storksdieck, M. (2015). Scientists' views about communication training. *Journal of Research in Science Teaching, 52*(2), 199-220. https://doi.org/10.1002/tea.21186

Bickford, D., Posa, M. R. C., Qie, L., Campos-Arceiz, A., & Kudavidanage, E. P. (2012). Science communication for biodiversity conservation. *Biological Conservation, 151*(1), 74-76. https://doi.org/10.1016/j.biocon.2011.12.0

Chen, D., Guo, Y., Wang, C., Xu, Y., & Zhang, H. (2022). Dispersion and disparity: Bibliometric and visualized analysis of research on climate change science communication. *International Journal of Environmental Research and Public Health, 19*, 15766. https://doi.org/10.3390/ijerph192315766

Donohue, K., VanDenburgh, K., Reck, C., & Buck, G. (2021). Integrating science communication into a large STEM classroom. *Journal of College Science Teaching, 51*(2), 46-50.

Feinstein, N. W. (2015). Education, communication, and science in the public sphere. *Journal of Research in Science Teaching, 52*(2), 145-163. https://doi.org/10.1002/tea.21192

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education, 16*(3), e2217. https://doi.org/10.29333/ijese/8336

Hu, S., Li, Z., Zhang, J., & Zhu, J. (2018). Engaging scientists in science communication: The effect of social proof and meaning. *Journal of Cleaner Production, 170*, 1044-1051. https://doi.org/10.1016/j.jclepro.2017.09.210

Karampelas, K. (2023). Examining the relationship between TPACK and STEAM through a bibliometric study. *European Journal of Science and Mathematics Education, 11*(3), 488-498. https://doi.org/10.30935/scimath/12981

Kessler, S. H., Fähnrich, B., & Schäfer, M. S. (2019). Science communication research in the German-speaking countries: A content analysis of conference abstracts. *Studies in Communication Sciences, 19*(2), 243-251. https://doi.org/10.24434/j.scoms.2019.02.012

Kohen, Z., & Dori, Y. J. (2019). Toward narrowing the gap between science communication and science education disciplines. *Review of Education, 7*(3), 525-566. https://doi.org/10.1002/rev3.3136

Kushairi, N., Ahmi, A. (2021). Flipped classroom in the second decade of the millenia: A bibliometrics analysis with Lotka's law. *Education and Information Technologies, 26*, 4401-4431. https://doi.org/10.1007/s10639-021-10457-8

Leydesdorff, L., & Hellsten, I. (2005). *Metaphors and diaphorases in science communication. Science Communication, 27*(1), 64–99. https://doi.org/10.1177/1075547005278346

Malik, D., Singh, P., & Dhiman, D. (2022). Science communication in India: Current trends and future vision. *Science Communication in India: Current Trends and Future Vision.* https://doi.org/10.2139/ssrn.4199480

Marín-Marín, J.-A., López-Belmonte, J., Fernández-Campoy, J.-M., & Romero-Rodríguez, J.-M. (2019). Big data in education. A bibliometric review. *Social Sciences, 8*(8), 223. https://doi.org/10.3390/socsci8080223

Matta, G. (2020). Science communication as a preventative tool in the COVID-19 pandemic. *Humanities and Social Sciences Communications, 7*(1), 1-14. https://doi.org/10.1057/s41599-020-00645-1

Mercer-Mapstone, L., & Kuchel, L. (2017). Core skills for effective science communication: A teaching resource for undergraduate science education. *International Journal of Science Education, Part B, 7*(2), 181-201. https://doi.org/10.1080/21548455.2015.1113573

Ninkov, A., Frank, J. R., & Maggio, L. A. (2022). Bibliometrics: Methods for studying academic publishing. *Perspectives on Medical Education, 11*, 173-176 https://doi.org/10.1007/s40037-021-00695-4

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*(7), 692-720. https://doi.org/10.1002/tea.10105

Panferov, V. N., Miklyaeva, A. V., & Bezgodova, S. A. (2022). Classification of sciences and systematization of knowledge for the general and professional integrative education content design. *Education and Self Development, 17*(2), 219-230. https://doi.org/10.26907/esd.17.2.17

Phuong, N. L., Hien, L. T. T., Linh, N. Q., Thao, T. T. P., Pham, H.-H. T., Giang, N. T., & Thuy, V. T. (2023). Implementation of STEM education: A bibliometrics analysis from case study research in Scopus database. *EURASIA Journal of Mathematics, Science and Technology Education, 19*(6), em2278. https://doi.org/10.29333/ejmste/13216

Rauchfleisch, A., & Schäfer, M. S. (2018). Structure and development of science communication research: co-citation analysis of a developing field. *JCOM, 17*(03), A07. https://doi.org/10.22323/2.17030207

Schäfer, M. S. (2009). From public understanding to public engagement: A comparison of mass media coverage on different science issues. *Science Communication, 30*(4), 475-505. https://doi.org/10.1177/1075547008326943

Scheufele, D. A. (2022). Thirty years of science–society interfaces: What's next? *Public Understanding of Science, 31*(3), 297-304. https://doi.org/10.1177/09636625221075947

Shivni, R., Cline, C., Newport, M., Yuan, S., & Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science course. *International Journal of STEM Education, 8*, 47. https://doi.org/10.1186/s40594-021-00304-0

Simis, M. J., Madden, H., Cacciatore, M. A., & Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication? *Public Understanding of Science, 25*(4), 400-414. https://doi.org/10.1177/0963662516629749

Sinai, S., Caffery, L., & Cosby, A. (2022). The culture of science communication in rural and regional Australia: The role of awe and wonder. *JCOM, 21*(6), 1. https://doi.org/10.22323/2.21060801

Sugimoto, C. R., & Thelwall, M. (2013). Scholars on soap boxes: Science communication and dissemination in TED videos. *Journal of the American Society for Information Science and Technology, 64*(4), 663-674. https://doi.org/10.1002/asi.22764

Suprapto, N., Ku, C. H., & Chang, T. S. (2021). "Unless you can explain": Voices of graduate students and their professor regarding the importance of science communication course. *Journal of Turkish Science Education, 18*(1), 32-53. https://doi.org/10.36681/tused.2021.51

Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication, 8*(4), A02. https://doi.org/10.22323/2.08040202

van Dijk, E. M. (2011). Portraying real science in science communication. *Science Education, 95*(6), 1086-1100. https://doi.org/10.1002/sce.20458

Wang, P., Zhu, F., Song, H., & Hou, J. (2018). A Bibliometric Retrospective of the journal EURASIA Journal of Mathematics, Science and Technology Education between 2012 and 2017. *EURASIA Journal of Mathematics, Science and Technology Education, 14*(3), 765-775. https://doi.org/10.12973/ejmste/80911

Wu, L. Y., Wu, S. P., & Chang, C. Y. (2019). Merging science education into communication: Developing and validating a scale for science edu-communication utilizing awareness, enjoyment, interest, opinion formation, and understanding dimensions (SEC-AEIOU). *Sustainability, 11*(17), 4551. https://doi.org/10.3390/su11174551