

Research on mentoring in science education: A bibliometric analysis

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Abstract

Mentoring plays a crucial role in the professional development of science teachers by providing invaluable career-long support, guidance, and resources. Numerous prior studies have emphasized the significance of mentoring for the professional development of beginning and experienced science teachers. This study analyzed articles published in Scopus-indexed, peer-reviewed journals on STEM mentoring. Based on the inclusion and exclusion criteria, 67 articles were chosen for analysis. The data were analyzed using VOSviewer software. According to the results, almost half (n=33) of the journal articles indexed in the database were published between 2019 and 2022. The articles with the most citations were published between 2012 and 2015. *Journal of Science Education and Technology* had the most citations on mentoring. Most research has been conducted in developed countries such as the United States, Australia, and Germany. The United States has performed the most mentoring research. Rockinson-Szapkiw, Wendt, and Mondisa are the authors who published the most mentoring-related articles. In addition, mentoring, STEM, women, higher education, and science education were the most frequently used keywords. The co-citation analysis of the cited sources yielded two distinct clusters, one of which consisted of a comprehensive evaluation and synthesis of research works focusing on mentorship and practices at the undergraduate level. Our co-citation study of published sources resulted in the categorization of the 13 sources into three distinct clusters.

Keywords: mentoring, science education, STEM, professional development, review

INTRODUCTION

Mentoring plays a critical role in the professional development of pre-service and in-service teachers and educators by providing valuable support, guidance, and resources throughout their careers (Cornelius et al., 2020; Hudson, 2013; Yan, 2021). Multiple previous studies have emphasized the importance of mentorship in the professional growth of science teachers, either in training or already working (Hudson, 2010, 2013; Hudson & Hudson, 2010; Roff, 2012). Mentoring plays an essential role in the professional growth of teachers as it enables the exchange of knowledge and skills between science teachers in training and those already in service.

It also promotes personal and professional development, provides emotional support, enhances job satisfaction, encourages professional networking and collaboration, and nurtures potential educational leaders (Hathazi, 2020; Hudson, 2013; Pandey & Sharma, 2022; Westervelt et al., 2020). In addition, mentoring practices can enhance classroom practices (Ingersoll & Strong, 2011; Muraya & Wairimu, 2020; Okumu et al., 2021) and enhance student learning outcomes (Jones, 2012; Sibiya et al., 2018).

Mentoring helps new and novice teachers by facilitating knowledge and skill transfer from experienced mentors who have teaching experience as teachers or educators (Hobson et al., 2009; Spooner-

Contribution to the literature

- Although mentoring is receiving more and more attention in the literature, little is known about the current state of mentoring research.
- This study contributes to existing knowledge by providing an up-to-date overview of research in this area.
- The findings allow researchers to track the impact and development of mentoring in science education research over time.

Lane, 2017). By transferring expertise and adopting effective practices, teachers can enhance their teaching techniques, deepen their material understanding, and develop their instructional strategies, bridging the distance between their pedagogical content knowledge and classroom practices (Appleton, 2008; Barnett & Friedrichsen, 2015; Can-Kucuk et al., 2022). For example, mentors who are experienced and experts in teaching a specific discipline like biology, chemistry, and physics provide feedback to new and novice teachers based on their own experiences to assist them in identifying development opportunities, increasing their self-efficacy, developing their classroom practices, and pedagogical content knowledge (Hudson, 2004, 2014; Roff, 2012).

In particular, teaching can be demanding and difficult for new and novice teachers, even experienced teachers (Roff, 2012; Wiens et al., 2019). In this case, mentoring support by teachers' peers can yield greater employee satisfaction, positively affecting teacher retention (Maready et al., 2021), educational quality (Torrejón, 2022), and student outcomes (Graham & Jefferson, 2019). Research (Appleton, 2008; Can-Kucuk et al., 2022; Hudson, 2013) has indicated that the professional development and pedagogical content knowledge of teachers and educators are accelerated by mentoring. Mentoring helps teachers acquire knowledge and experience for problem-solving and decision-making during teaching (Hudson, 2010). Specifically, teacher education programs require knowledgeable mentors to collaborate with aspiring teachers inside the school environment (Orland-Barak & Wang, 2021). According to Giebelhaus and Bowman (2002), mentors with mentoring training can improve the teaching quality of prospective instructors while enhancing their skills and their students' learning outcomes.

Mentoring in science education literature has continued to expand and now encompasses many topics. These topics range from enhancing the professional development of science teachers to assessing teachers' perspectives on mentoring. There has been a rise in mentoring studies in the literature on teacher education. This study used bibliometric analysis as the primary research method to examine current mentoring research. Bibliometric analysis combines quantitative research techniques to obtain an in-depth understanding of research topics and fields and more information about them (Hamidah et al., 2021). Indicators of the

progression of scientific research can be gleaned from bibliometric analysis of published literature. In addition to bibliographic linkages, co-citations, and co-authorships, the data and results acquired from these programs provide a wealth of information regarding research on a specific topic or issue (van Eck & Walton, 2010). Bibliometric analysis software also provides text-mining functionalities to create and display networks of important terms derived from the study literature.

Although the number of research papers on mentoring has increased in the science education literature, no study has used the bibliometric method to examine the current state of mentoring research in science education and to define the relationships between the researchers driving this research and the contextual factors of mentoring research. The bibliometric analysis in this study provides a solid foundation and direction for future research to address this gap. To address this deficiency, the study analyzed articles from peer-reviewed journals published from 2000 to 2022 indexed in Scopus on mentoring in STEM disciplines. The five research questions listed below guided the study.

1. What was the annual mentoring trend in science education fields?
2. Which publication sources and nations/regions were the most prominent?
3. What are associated keywords with mentoring?
4. Which 10 publications received the most citations?
5. What resulted from the co-citation analysis between the referenced source and the publishing reference?

The results of bibliometric research on mentoring can provide insightful information for future research. First, various science education stakeholders can use the results of such research to identify knowledge gaps. These identified research gaps can then serve as valuable starting points for future research studies, allowing researchers to investigate unanswered questions or specific aspects of mentoring in scientific education in greater depth. Second, the findings can help researchers comprehend the methods, approaches, and research designs typically employed in mentoring studies in science education. Using the bibliometric research findings on research trends and patterns, researchers can make informed decisions regarding the study's research design, data collection methods, and analysis

techniques. Third, the findings can help researchers monitor the impact and evolution of mentoring in science education research over time. By analyzing citation patterns, publication trends, and collaborative networks, researchers can understand how the field has evolved, what topics have gained prominence, and how various research strands or theories have evolved. In conclusion, bibliometric research on mentoring in science education can benefit researchers by identifying research gaps, providing information for research planning, highlighting key authors and institutions, tracking the impact and evolution of research, and providing policy and practice implications. Researchers can contribute significantly to the theory, practice, and policy surrounding science education mentoring by utilizing the results of bibliometric analysis.

METHOD

Bibliometrics is a quantitative analysis of scientific publications to provide insightful information to researchers about a research field or topic based on the various characteristics of the existing publications in the literature, such as titles, abstracts, keywords, references, authors, and author biographies. Due to widespread use within the scientific community, bibliometric analysis techniques are the most valued for evaluating scientific publications in a specific research field or topic. In particular, bibliometric mapping is a tool that helps to visually represent the connections between disciplines, fields, specific publications, and authors. This method can identify trends in a field by quantifying and evaluating a specific aspect of research, making it easier to track studies, researchers, institutions, and scientific streams relevant to a particular scientific topic. Bibliometric analysis can be a valuable tool for researchers looking to gain insights into the scientific landscape and stay up-to-date on the latest developments in their field.

The analysis of bibliometric studies has been increasingly conducted in research evaluations across various educational settings. Specifically, a bibliometric analysis was performed to present a comprehensive summary of authors, countries, affiliations, sources, and documents related to mentoring in STEM education. Co-authorship analysis, citation analysis, and co-occurrence of author keywords were used to determine the connection between these relevant components. We used VOSviewer software to analyze the data to present more detailed information and analysis about research trends on mentoring in science education. For this aim, peer-reviewed articles on mentoring and STEM education were searched in the Scopus database. It is a bibliographic database of literature, scientific journals, publications, and conference proceedings that have been peer-reviewed. It provides researchers access to a vast compilation of high-quality scientific literature, making it an indispensable instrument. Scopus is significant and

beneficial to researchers due to its exhaustive coverage of high-quality scientific literature, advanced search capabilities, citation analysis, and collaboration tools, making it an indispensable resource for researchers. Elsevier owns the Scopus database, which contains more than 14,000 indexed journals in various disciplines and has unique features.

Due to all these reasons, Scopus was chosen to collect data for a bibliometric study to gain access to exhaustive publications on mentoring in STEM education. The researchers initially focused on two search terms, "mentoring" and "STEM" or "STEM education," to find relevant publications. The following commands were utilized to search the Scopus database, which yielded 67 results:

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(TITLE (mentoring) AND KEY ("science education") OR KEY ("biology education") OR KEY ("chemistry education") OR KEY ("physics education") OR KEY ("STEM education") OR KEY (stem)) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")) AND (EXCLUDE (PUBYEAR, 2023))
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The Scopus database had filtering options for researchers. For instance, after searching using the abovementioned keywords, researchers restricted their findings to social science, journal publications, and only English content. After obtaining the final search results for the bibliometric analysis from the Scopus website, the researchers collected files from the database. They downloaded BibTeX and CSV files for the bibliometric analysis of 67 publications. Later, researchers converted these files to TAB file format to use in the analysis program for bibliometrics. Tab-delimited (Win format) for bibliometric analysis (along with complete data set and cited references). For this study's bibliometric analysis, VOSviewer program was utilized to display the network visualization of the most frequently used keywords, abstract words, citation analysis, and co-citation analysis. File has been submitted to VOSviewer software. Two researchers performed data analysis.

RESULTS

Figure 1 shows the number of mentoring-related articles. The results indicate that nearly half ($n=33$) of the journal articles indexed in the database were published between 2019 and 2022. This result suggests that the number of articles on mentoring to support teachers' professional development has increased.

The most commonly referenced papers on mentoring in science education were released more recently and exhibited a consistent increase from 2012 to 2015 (see **Figure 2**). The most citations appeared in 2012, with 181 from a single publication by Wilson et al. (2012).

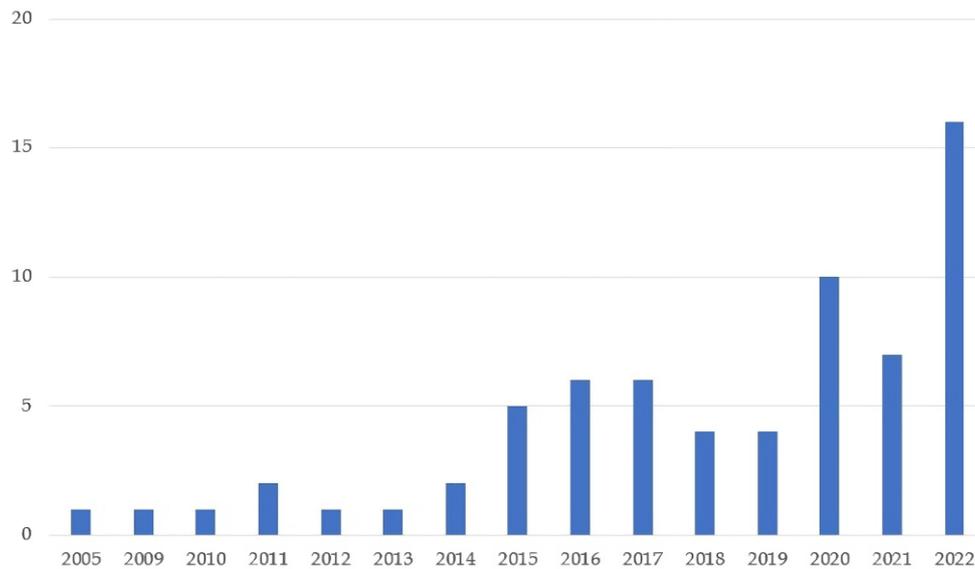


Figure 1. Distribution of published articles on mentoring between 2000 and 2022 (Source: Authors’ own elaboration)

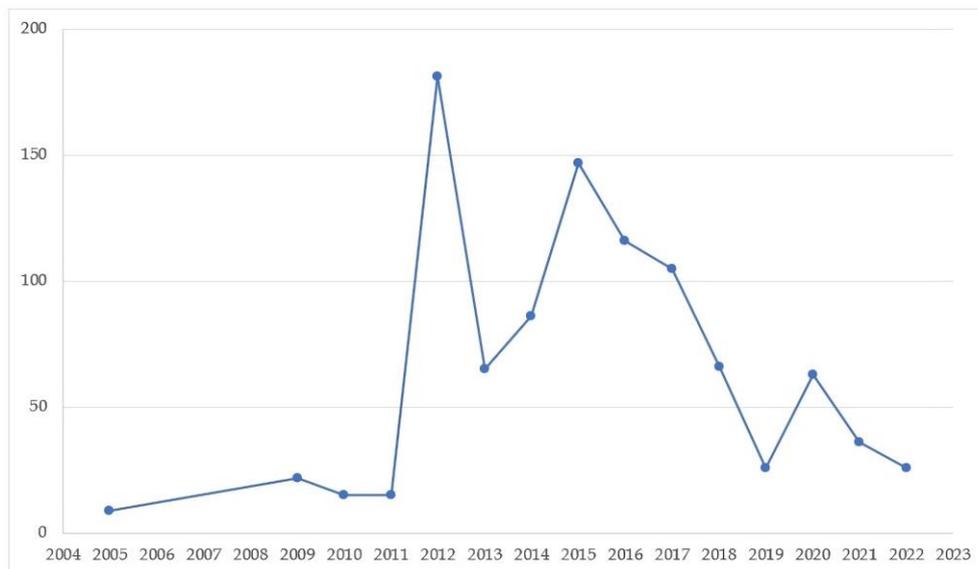


Figure 2. An analysis of citations of published articles from 2000 to 2022 on mentoring (Source: Authors’ own elaboration)

Table 1. A list of journals that published most articles

No	Journal	Documents	Citations	Total link strength
1	International Journal of Mentoring and Coaching in Education	7	19	129
2	Mentoring & Tutoring: Partnership in Learning	7	80	98
3	International Journal of STEM Education	4	122	73
4	Journal of Women and Minorities in Science and Engineering	3	18	52
5	Journal of Science Education and Technology	3	190	43
6	Innovative Higher Education	3	142	37

Table 1 shows that international journals that published more than three articles between 2000 and 2022 include *International Journal of Mentoring and Coaching in Education*, *Mentoring & Tutoring: Partnership in Learning*, *International Journal of STEM Education*, *Journal of Women and Minorities in Science and Engineering*, *Journal of Science Education and Technology*, and *Innovative Higher Education*.

The journal with the most publications and citations on mentoring was *Journal of Science Education and Technology*, with three publications and 190 citations.

Regarding the countries of origin of the articles on mentoring, the majority of research on this subject was carried out in industrialized nations, including the United States, Australia, and Germany. Approximately 78% of the research on this subject was conducted in the United States, followed by Australia (six studies) and Germany (n=2). Almost all studies, except Turkey (n=3), were conducted in developed countries (Table 2).

Table 3 displays the authors who have published the most articles on mentoring. Table 3 reveals that Rockinson-Szapkiw, Wendt, and Mondisa were the

Table 2. Countries, where mentoring research was conducted

No	Country	Documents	Citations	Total link strength
1	The United States	52	780	51
2	Australia	6	59	131
3	Turkey	3	55	103
4	Germany	2	95	29

Table 3. Authors with the most publications on mentoring

No	Author	Author's institution	Documents	Citations	Total link strength
1	Rockinson-Szapkiw, A.	University of Memphis	3	23	274
2	Wendt, J. L.	University of District of Columbia	3	23	274
3	Mondisa, J. L.	University of Michigan	3	38	68

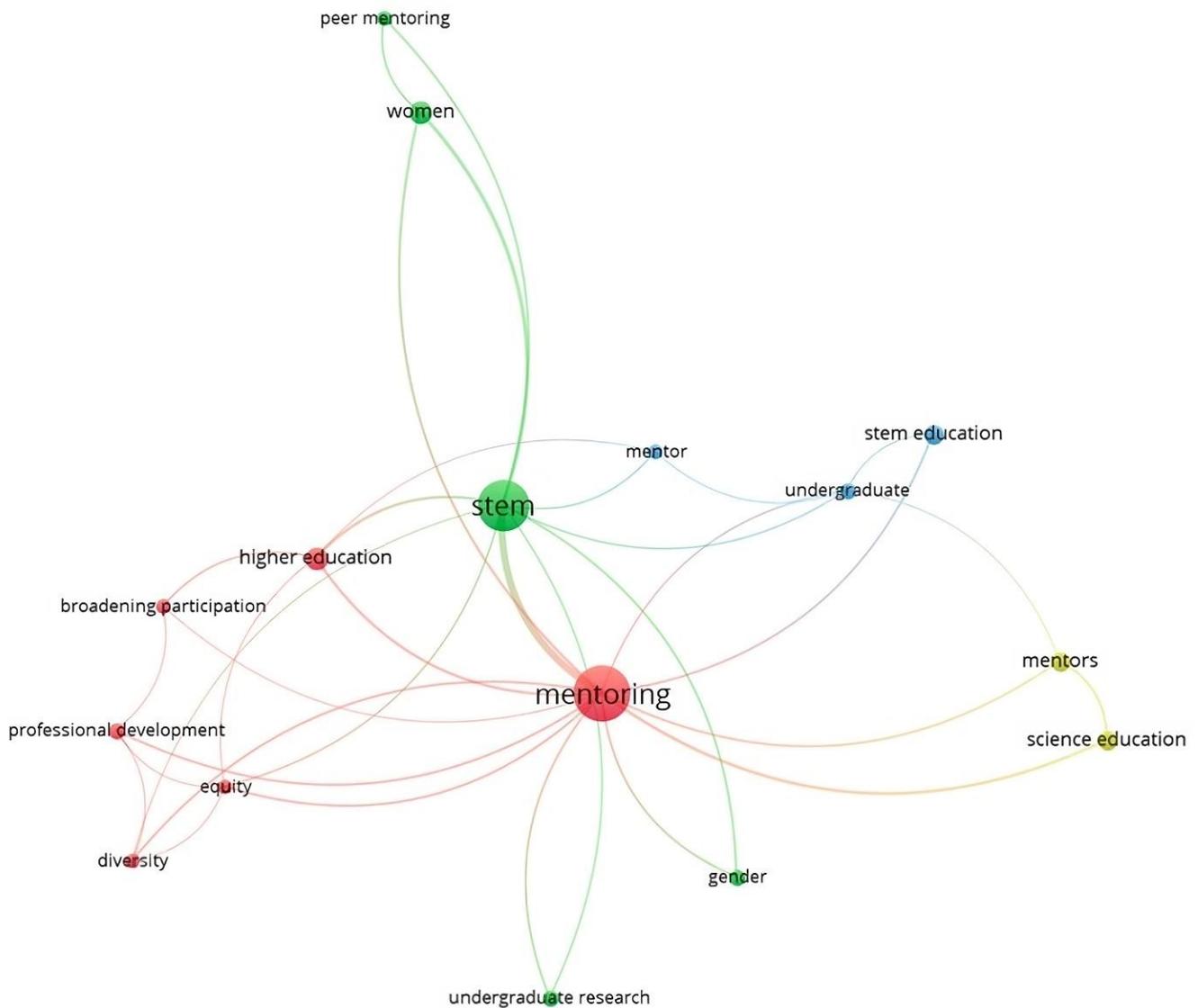


Figure 3. Analysis of keywords used in articles (Source: Authors' own elaboration, using VOSviewer software)

authors with more than three published mentoring-related articles in the database.

Keywords

Keyword analysis is a highly important bibliometric indicator. The authors' study (Figure 3) included keywords found more than three times in the Scopus database. Mentoring (42 articles), STEM (35 articles), women (seven articles), higher education (seven

articles), and science education (five articles) were the five keywords that appeared most frequently in the chosen articles.

Based on the 16 terms that occurred more than three times, the cluster analysis performed with VOSviewer 1.6.15 identified four clusters. Cluster 1 includes broadening participation, diversity, equity, higher education, mentoring, and professional development, whereas cluster 2 contains gender, peer mentoring,

Table 4. Clusters in keywords analysis

Label	Weight (occurrences)	Weight (links)	Weight (total link strength)
Cluster 1 (six items)			
Broadening participation	3	3	4
Diversity	3	4	6
equity	3	5	8
Higher education	7	5	12
mentoring	42	13	63
Professional development	4	4	6
Cluster 2 (five items)			
Gender	4	2	6
Peer mentoring	3	2	6
STEM	35	10	52
Undergraduate research	4	2	5
Women	7	3	14
Cluster 3 (three items)			
Mentor	3	3	4
STEM education	5	2	4
Undergraduate	4	5	7
Cluster 4 (two items)			
Mentors	5	3	7
Science education	5	2	8

Table 5. A list of the 10 most cited articles

No	Author(s)	Title	Year	Journal	CCA	NC
1	Wilson et al. (2012)	Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines	2012	Journal of Science Education and Technology	US	181
2	Tenenbaum et al. (2014)	An innovative near-peer mentoring model for undergraduate and secondary students: STEM focus	2014	Innovative Higher Education	US	75
3	Zaniewski and Reinholz (2016)	Increasing STEM success: A near-peer mentoring program in the physical sciences	2016	International Journal of STEM Education	US	72
4	Stoeger et al. (2017)	The effectiveness of a one-year online mentoring program for girls in STEM	2013	Computers and Education	Germany	65
5	Thomas et al. (2015)	Changing institutional culture through peer mentoring of women STEM faculty	2015	Innovative Higher Education	US	61
6	Buzzanellet al. (2015)	Mentoring in academe: A feminist post-structural lens on stories of women engineering faculty of color	2015	Management Communication Quarterly	US	47
7	Stoeger et al. (2013)	Online mentoring as an extracurricular measure to encourage talented girls in STEM (science, technology, engineering, and mathematics): An empirical study of one-on-one versus group mentoring	2017	Gifted Child Quarterly	Germany	30
8	Rodríguez Amaya et al. (2018)	Undergraduate research experiences: Mentoring, awareness, and perceptions—A case study at a Hispanic-serving institution	2018	International Journal of STEM Education	US	28
9	Nelson et al. (2017)	How do undergraduate STEM mentors reflect upon their mentoring experiences in an outreach program engaging K-8 youth?	2017	International Journal of STEM Education	US	24
10	Windchief and Brown (2017)	Conceptualizing a mentoring program for American Indian/Alaska native students in the STEM fields: A review of the literature	2017	Mentoring and Tutoring: Partnership in Learning	US	22

Note. US: The United States; CCA: Country of corresponding author & NC: Number of citations

STEM, undergraduate research, and women. Cluster 3 comprises mentoring, STEM education, and undergraduate education, whereas cluster 4 comprises mentoring and science education. These clusters contain sixteen elements. The results for each cluster and item are shown in **Table 4**.

Top-10 Publications With the Most Significant Number of Citations

The results indicate that 80% of the studies in the 10 most-cited mentoring publications were conducted in the United States. At the same time, the remaining two articles were published in Germany. **Table 5** provides the results. This result indicates that developed nations were more likely than developing nations to focus on mentoring in science education to promote teachers'

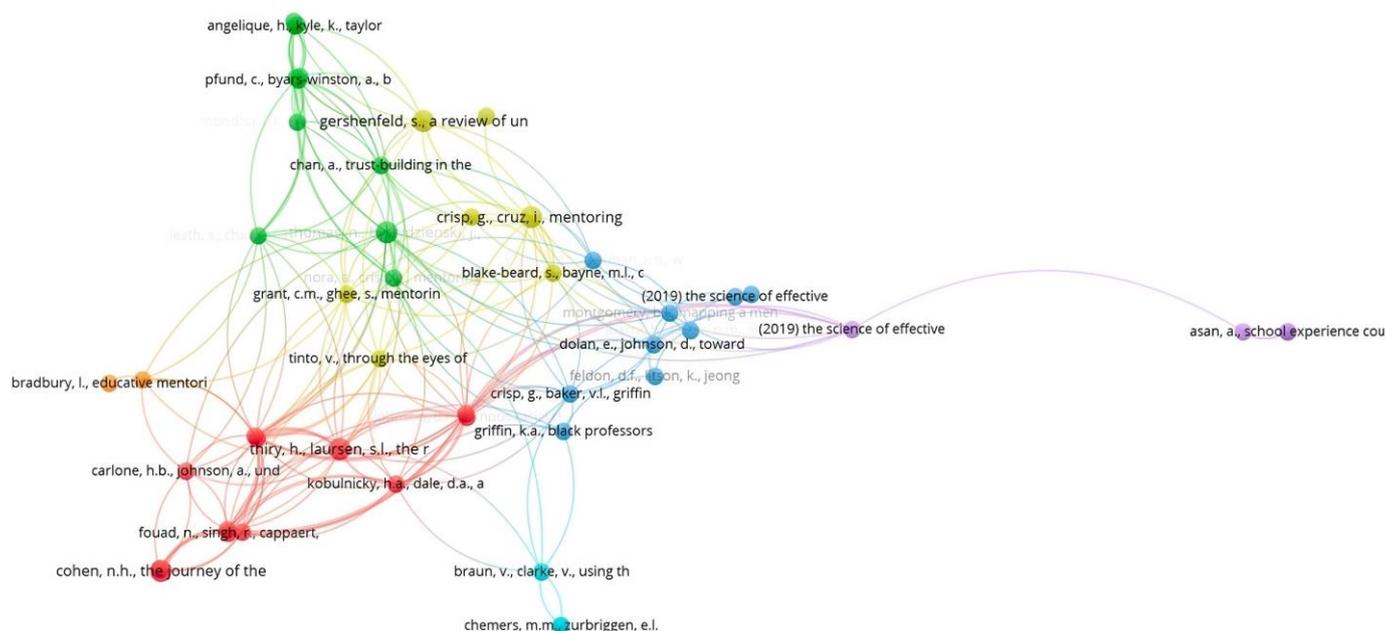


Figure 4. Co-citation analysis of cited references on mentoring (Source: Authors' own elaboration, using VOSviewer software)

professional development. The article's greatest citation tally ranged between 21 and 181. The oldest article among those with the most citations was published in 2021 and received 181 (Wilson et al., 2012).

The list of the 10 most cited publications in academic journals is, as follows: *Journal of Science Education and Technology*, *Innovative Higher Education*, *International Journal of STEM Education*, *Computers and Education*, *Innovative Higher Education*, *Management Communication Quarterly*, *Gifted Child Quarterly*, *International Journal of STEM Education*, *International Journal of STEM Education*, and *Mentoring and Tutoring: Partnership in Learning*.

Co-Citation Analysis of Cited Reference

Co-citation analysis of cited references assists in identifying the most cited and influential mentoring research documents. For this analysis, 67 documents cited more than twice were identified using a full count procedure in VOSviewer program. This resulted in 48 articles in the scholarly education literature with two or more references to mentoring. **Figure 4** depicts the co-citation network map of the 48 most cited mentoring references in the science education literature between 2000 and 2022. Each node represents a cited publication and is labeled with the cited publication's author and publication year. The results demonstrate two clusters.

Six documents cited more than twice were identified using a full count procedure in VOSviewer program. However, VOSviewer program collected four articles in two clusters. The first cluster (red color) includes two articles relevant to reviewing and synthesizing the research studies on mentoring. For example, Crisp and Cruz (2009) reviewed the mentoring literature. They provided a summary and evaluation of the empirical

literature on student mentoring published between 1990 and 2007. Before proposing a theoretical framework specific to student mentoring, the article concluded by presenting generalized theoretical perspectives on mentoring from the business, psychology, and education literature. Gershenfeld (2014) summarized the published research on undergraduate mentoring programs between 2008 and 2012. The findings of this review indicate that progress in these three areas has been negligible.

Nonetheless, each study focused on mentoring's functions, and a theory or conceptual framework guided the majority. Unstudied aspects of social validity were evaluated and found to be present in 50% of the studies. 75% of the studies omitted information on the primary components of the mentoring program, a previously unexplored dimension that makes replication difficult.

The second cluster (green color) contains two articles regarding mentoring practices at the undergraduate level. For example, Thiry and Laursen (2011) used a theory of situated learning to investigate the role of student-advisor interactions in undergraduate education, particularly regarding students' acculturation to the norms, values, and professional practices of science. They interviewed students from two research-intensive institutions. In each of these areas, their findings indicate that the requirements of first-year students differ from those of more seasoned students. Students in their first year needed clear expectations, guidelines, and direction for their research project.

In contrast, characteristics, habits, and dispositions are scientific researchers' characteristics, habits, and dispositions. In another study, Thomas et al. (2015) concentrated on peer mentoring circles for female STEM faculty at a large research university in the Midwest.

Table 6. A list of published sources regarding mentoring

No	Journal	Citations	Total link strength
1	Journal of Research in Science Teaching	48	346
2	Journal of Vocational Behavior	47	263
3	Mentoring & Tutoring: Partnership in Learning	46	348
4	American Educational Research Journal	28	256
5	Journal of Science Education and Technology	27	239
6	Science	27	148
7	The Journal of Higher Education	26	188
8	Research in Higher Education	25	181
9	Journal of College Science Teaching	24	218
10	Review of Educational Research	23	176
11	Innovative Higher Education	23	160
12	Teaching and Teacher Education	22	92
13	Science Education	21	193

Participants reported various mentoring context-specific requirements and wanted to share the issues raised in the circles with administrative leaders. Following a workshop for circle participants and administrators, college-wide teams were formed to resolve the issues identified by the circles. They concluded that peer mentoring has tremendous potential to facilitate institutional change.

Co-Citation Analysis of Publication Source

The co-citation analysis of published sources aims to determine which mentoring is referenced in the literature on science education. **Table 6** displays the 13 most-cited published sources within VOSviewer application. We searched the journals for more than 20 citations, which are presented in **Table 6**. The publication’s title facilitates the visualization of co-citation relationships (**Figure 5**). Our co-citation analysis of published sources included the 13 publications into three distinct groups: science education research (green line), science and teacher education research (blue line), and general education research (red line).

Figure 6 presents one of the most relevant clusters of published sources related to mentoring in the science education literature. The results yielded three clusters. Cluster 1 comprises six publications, including *Journal of Vocational Behavior*, *Mentoring & Tutoring: Partnership in Learning*, *American Educational Research Journal*, *Journal of Higher Education*, *Research in Higher Education*, and *Review of Educational Research*. Cluster 2 contains *Science*, *Innovative Higher Education*, *Journal of College Science Teaching*, *Journal of Science Education and Technology*, and *Journal of Science Education and Technology*. Cluster 3 comprises *Science Education*, *Teaching and Teacher Education*, and *Journal of Research in Science Teaching*.

Results Regarding Hotspot Analysis

In mentoring studies in science education, study topics were identified using co-occurrence analysis of noun phrases within the abstract and title fields. Finally, we included noun phrases that occurred at least three

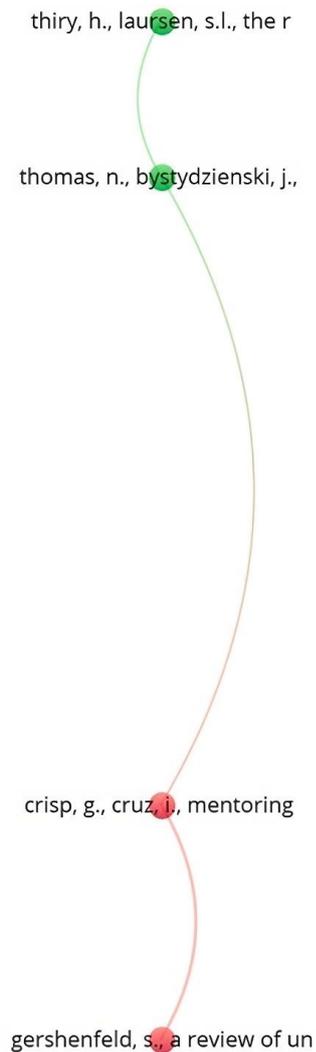


Figure 5. Two clusters in co-citation analysis of cited references on mentoring (Source: Authors’ own elaboration, using VOSviewer software)

times and mapped their co-occurrence network using VOSviewer.

We evaluated the significance of three occurrences and generated 18 noun phrases. The top five noun phrases are mentoring, STEM, women, higher education, and science education. The 16 noun phrases

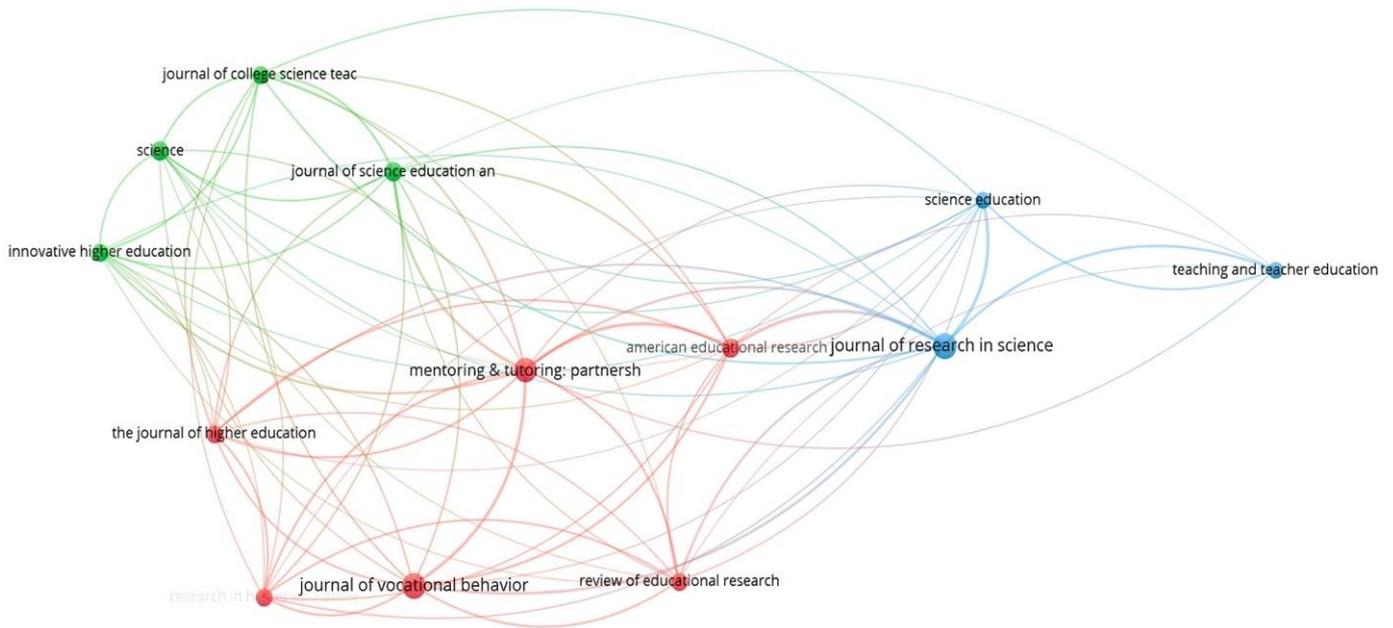


Figure 6. Co-citation network of published articles (Source: Authors' own elaboration, using VOSviewer software)

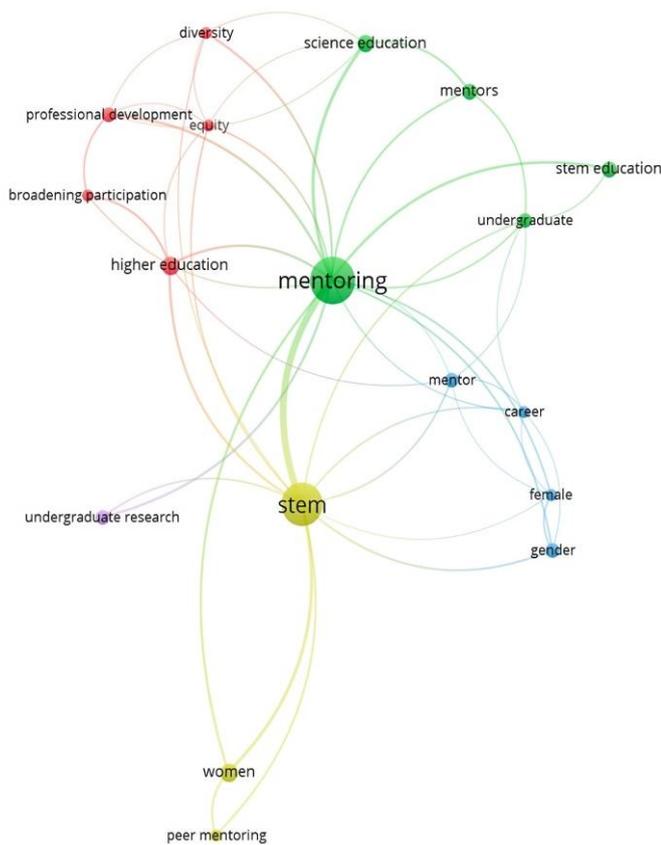


Figure 7. Co-occurrence network of nouns used in articles (Source: Authors' own elaboration, using VOSviewer software)

were divided into five significant groups based on co-occurrence analysis.

Figure 7 depicts a co-occurrence analysis of phrases with at least three occurrences in the title and abstract categories. In addition, as depicted in Figure 7 of Mentoring in Science Education Research, the principal

term “mentoring” (41 links, 43 occurrences) functions as the network’s hub. In addition, VOSviewer generated five distinct colors to represent three clusters of 18 terms extracted from the publication’s title and abstract. Term pairs that refer to the same hue frequently occur together. Figure 7 shows that mentoring, mentors, science education, stem tribal education, and undergraduate, all highlighted in green, are strongly related and frequently occur together.

DISCUSSION

This research analyzed peer-reviewed journal articles indexed in Scopus on mentoring in STEM disciplines to address the research gap in the lack of a bibliometric study on mentoring in science education literature. For this aim, this study utilized the Scopus database to provide an exhaustive review of early STEM research published in academic journals between 2000 and 2022. This study summarizes research, including 67 studies in the Scopus on mentoring. This study described research trends, topics, publication sources, researchers, and countries. In addition, the principal keywords used in the database articles were identified to aid researchers in demonstrating current and future research directions. Such a comprehensive bibliographic analysis of mentoring in the literature on science education could be useful to researchers, educators, and policymakers, among others.

The increase in the number of articles published on mentoring in science education between 2019 and 2022 indicates that researchers’ interest in mentoring has been growing in recent years. Indeed, publications on mentoring are relevant to the current literature on science education. Regarding the citations the articles

have, the articles published between 2012 and 2015 were the most often cited. This result may indicate that researchers frequently cite the oldest articles. Especially given that the number of articles published between 2012 and 2015 is less than five and very small, it is reasonable to assume that the most recent articles include citations from those published between 2012 and 2015.

The findings also indicate that mentoring research has not been conducted with the participation of many nations. The findings indicate that most mentoring research has been conducted in the United States, implying a need to learn more about mentoring practices in other nations to disseminate their research findings and promote the professional development of instructors. Most analyzed articles were conducted in the United States (52 articles) and Australia (six publications), as determined by the results of an analysis of the thematic characteristics of the articles to obtain a deeper understanding of the current research focus and its development. This result indicates that developed nations have paid more attention to instructors' pre-service and in-service professional development. In addition, this result suggests that developed nations are more likely than developing nations to prioritize mentoring in science education to improve teachers' professional development. In addition, the results demonstrated that 67 articles were analyzed to determine the citations and publication sources.

The results related to title of the publication source showed that the journals that published the most articles were *International Journal of Mentoring and Coaching in Education*, *Mentoring & Tutoring: Partnership in Learning*, *International Journal of STEM Education*, *Journal of Women and Minorities in Science and Engineering*, *Journal of Science Education and Technology*, and *Innovative Higher Education*. The journal with the most mentoring-related publications and citations was *Journal of Science Education and Technology*, with three publications and 190 citations.

The researchers also performed a co-citation analysis of the published sources. This analysis sought to determine whether mentoring research was included in the research of other disciplines. 13 journals were designated to three clusters based on the co-citation analysis of published sources (Figure 6). These clusters were defined as science education (green line), science and teacher education (blue line), and general education (red line) (Figure 6).

The analysis of mentoring research keywords that appeared more than three times revealed that mentoring (42 articles) and STEM (35 articles) were the two most frequently occurring. This outcome can be explained by the fact that mentoring studies have been conducted in STEM fields. This investigation examined the evolution of mentoring research in science education.

This study's findings provide information on how mentoring research in science education has been

conducted. According to the findings, most investigations have been conducted in developed nations. Therefore, future research should concentrate on applying mentoring practices and research in developing nations, and additional research is required to present mentoring findings from developing nations.

CONCLUSIONS

Although mentoring in science education has received growing attention, little is known about the current state of mentoring research. We contributed to the existing body of knowledge by conducting an up-to-date review of research in this field. Various inferences can be drawn from the results. First, most mentoring research has been conducted in developed nations. Thus, we argue that mentoring research requires greater geographic diversity. Learning more about the mentoring practices and applications of researchers from developing nations is crucial. Second, according to the findings, most mentoring knowledge has been generated in the United States and Australia. Therefore, journal publishers and editors that publish mentoring articles should promote and support research on mentoring practices and applications in developing nations. Third, we identified the past two decades' most productive sources, countries, and articles and the network of sources, authors, and keywords that connect all aspects of this productivity. The United States was the most productive region, reflecting the substantial contribution of American academics. The United States is anticipated to remain the leader in this research field.

Finally, the co-citation analysis of cited references revealed two distinct clusters:

- (1) reviewing and synthesizing mentoring research studies (see Crisp & Cruz, 2009; Gershenfeld, 2014) and
- (2) mentoring practices at the undergraduate level (Thiry & Laursen, 2011; Thomas et al., 2015).

Given that mentoring research has been conducted in developed nations, researchers in developing nations should make greater efforts to comprehend mentoring practices and applications in developed nations and expand their horizons by linking mentoring research conducted in developed nations. From this perspective, additional research is required to determine how mentoring can be implemented in developing nations. This study provides access to publications on mentoring and highlights the mentoring research direction in science education. Future research can track the growth of this field and the formation of international partnerships between developed and developing nations.

Limitations

This study's limitations include that only published articles on mentoring in STEM research were analyzed in the Scopus database. Other academic databases, such as EBSCO, ERIC, and Web of Science, could be utilized for additional research in the future. In this regard, future research using similar databases should be conducted to investigate further mentoring in STEM research.

In addition, future research should investigate how mentoring can be utilized in STEM subjects to improve teachers' professional development and pedagogical knowledge. In addition, considering how mentoring can be enhanced for the professional development of teachers in STEM fields is critical. Improving the quality of instruction in STEM classrooms requires researchers to collaborate to foster teachers' professional development.

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Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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