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Science Teacher Identity in Environmental Chemistry Education Using the STEM Approach: A Bibliometric Analysis of Scopus Journals (2015–2024)

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A B S T R A C T

This study aims to investigate how Environmental Chemistry education contributes to shaping the science teacher identity of prospective chemistry teachers through a STEM approach. The bibliometric analysis method was conducted using Scopus data (2015–2024), analyzed with Biblioshiny and VOS Viewer. From an initial 483 documents, 418 relevant works comprising articles, books, and reviews were selected based on keywords such as "Science Identity", "Science Teacher Identity", "STEM Education Approach", and "Environmental Science Chemistry". Biblioshiny was used to identify trends over the decade, including annual publication rates, key journals, influential authors, productive affiliations and countries, globally cited articles, and frequently occurring keywords. VOS Viewer further enhanced the analysis by offering three types of visualizations network, overlay, and density to illustrate the relationships and research trends among the selected publications. These visual tools reveal the interconnectedness of topics and highlight emerging areas in the field. The findings offer valuable insights into the global development of research at the intersection of science identity, STEM education, and environmental chemistry. This bibliometric exploration provides a foundation for researchers to identify current trends, understand the research landscape, and recognize gaps that can inform future studies.

1. Introduction

Science teacher identity is essential for active participation in the rapidly changing world. Science identity, on the other hand, reflects the extent to which younger generations feel connected to and recognized in science, as well as their ability to engage as critical consumers and decision-makers (Hottecke & Allchin, 2020). Science identity encompasses perceptions, dispositions, values, and attitudes toward science (Wieselmann et al., 2020). Many prospective teachers experience a

lack of confidence in conducting experiments, analyzing data, and solving complex chemistry problems (Wahyuditi et al., 2020). This involves self-concept, self-efficacy, learner agency, motivation, epistemological beliefs, and science capital sociological capital related to knowledge, attitudes, and engagement in science.

Thus, strengthening teacher identity among prospective chemistry teachers becomes a key strategy in preparing educators who are competent in understanding, teaching, and applying chemistry concepts comprehensively (Zotos et al., 2020). In PISA 2025, science identity includes various elements that demonstrate competencies relevant to 21st-century learning. Its primary focus is on students' ability to use scientific information for decision making and action, measured through cognitive and non-cognitive tools. With pressing environmental issues becoming increasingly evident in daily life, students must understand and respond to these challenges with scientific knowledge, making informed decisions and taking action to address environmental concerns (Fang et al., 2019).

The concept of science teacher identity aims to meet both present and future needs, ensuring that sustainable development can be applied across all aspects of life, including education (Burbules et al., 2020). The values of sustainable development can be instilled in younger generations through education (Zguir et al., 2021). Chemistry education is one of the fields that can contribute positively to sustainable development by integrating environmentally friendly concepts and applications through practice (Boca & Saraçli, 2019). Environmental chemistry requires students to be sensitive to surrounding environmental issues, take responsibility for maintaining ecological balance, and understand the factors affecting populations and ecosystems. This learning approach necessitates teaching methods that provide more opportunities for investigation, measurement of simple environmental aspects, and collaborative group work to enhance students' skill development (Asadollah et al., 2021).

Environmental chemistry education must also encompass a broad understanding of science-based technology and scientific practices, as well as the interaction between science and technology. While chemistry as a science aims to explain natural phenomena, technology focuses on finding optimal solutions to problem-solving (Zindly et al., 2021). To integrate this learning effectively, an appropriate and relevant approach is required. One such approach is STEM, which offers a suitable framework for addressing the needs of this research. Previous studies have shown that the STEM approach is useful for demonstrating to students the concepts, principles, and techniques of science, technology, engineering, and mathematics, which are integrated into the development of products, processes, and systems in everyday life (Fajrina et al., 2020).

According to research by Hebebci & Usta (2022), the STEM approach in education can increase student engagement, develop critical thinking skills, foster creativity, and improve problem-solving abilities. According to Tytler (2020), the main focus on STEM education in schools is driven by major changes anticipated in the world of work in the future. STEM competencies are important to equip students to be more productive and think creatively. In addition, the STEM approach is

increasingly aligned with interdisciplinary teaching and learning methods. And according to Habig et al (2020), the interviews identified four program design principles that contribute to persistence in STEM fields: (1) providing multiple opportunities to become science practitioners; (2) providing exposure and experiences with STEM professionals such as scientists, educators, and graduate students to build social networks; (3) providing opportunities for participants to develop a shared science identity with like-minded individuals; and (4) offering exposure and preparation for a range of potential STEM majors and careers. However, research specifically exploring science identity in environmental chemistry education through the STEM approach remains very limited. In this context, science identity refers to how students perceive themselves in relation to science and how they connect science learning to everyday life and future careers. Given this gap, further research has the potential to be developed. As an initial step, we conducted a bibliometric analysis.

Bibliometric analysis has been widely applied across various disciplines to identify research trends, productive authors, countries, and affiliations, as well as to visualize keyword network mapping and overlays (Lrhoul et al., 2023). Therefore, this study aims to provide a comprehensive review by analysing literature related to science identity in chemistry education through the STEM approach using bibliometric analysis. We will explore how research in this field has evolved over the past decades, identify productive authors, countries, and affiliations, and evaluate emerging research focuses and priorities. By understanding these developments, we aim to provide valuable insights for researchers, educators, and policymakers in guiding the development of curricula and effective teaching methods related to science teacher identity. Through this analysis, we seek to highlight research gaps, identify opportunities and limitations, and offer guidance for future research directions and educational practices in this field.

2. Methodology

This study presents a bibliometric analysis based on data from the Scopus database, processed using R Studio with the Biblioshiny analysis program. Biblioshiny is a crucial tool for bibliometric analysis, providing a user-friendly platform for analysing and visualizing bibliographic data. Additionally, VOS Viewer is used to visualize data mapping. An illustration of the methodological design stages related to bibliometric analysis and detailed information on the research experiment can be seen in Figure 1.

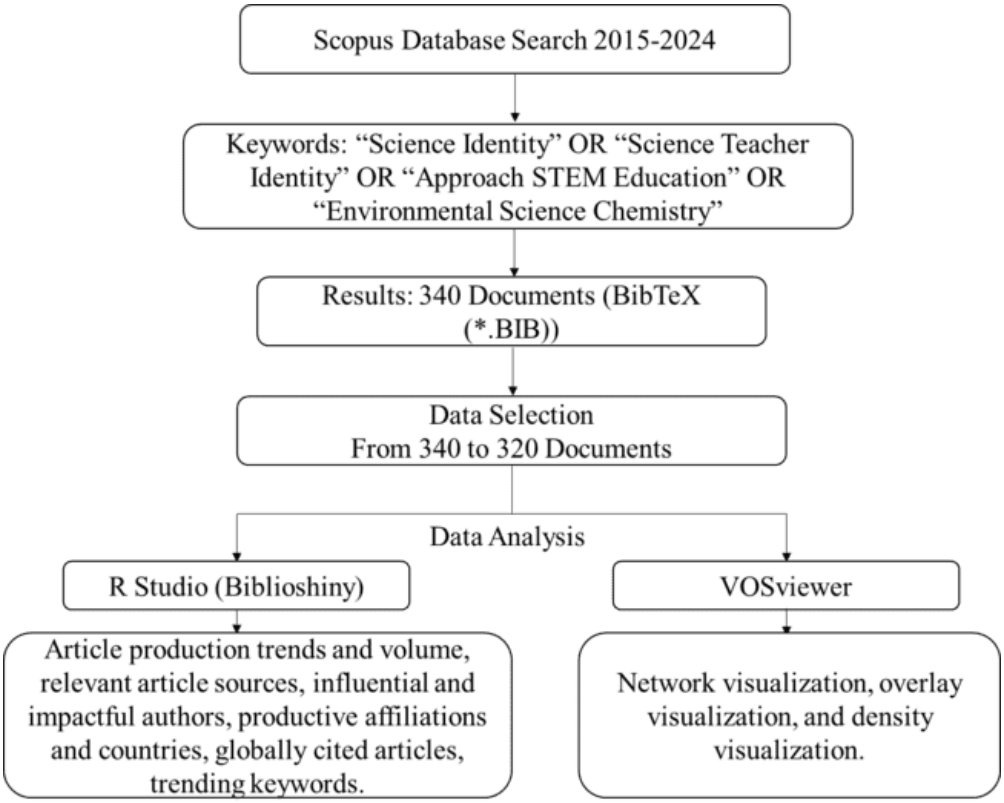

Figure 1. Data Analysis Flowchart.

3. Results and Conclusion

Development of Research Articles on Science Teacher Identity in Environmental Chemistry Learning Using the STEM Approach

The data analysis using R Studio with the Biblioshiny package serves as a valuable tool for researchers to explore and gain deeper insights into scientific literature. The database retrieved from Scopus, based on predefined keywords over the past ten years (2015–2024), initially yielded 340 documents. These documents comprised various types, including articles, books, book chapters, book chapter articles, conference papers, conference paper articles, conference reviews, editorials, errata, notes, and reviews, with a total of 931 authors. To refine the dataset for a more targeted analysis, a filtration process was conducted to focus on relevant articles and books. Consequently, document types such as editorials, errata, notes, and reviews were excluded. After filtering, the dataset was narrowed down to 320 documents, involving 899 authors.

A general overview of the obtained data is presented in (Table 1), while the annual research article trends can be observed in (Figure 2). Based on (Figure 2), the line graph illustrates a significant increase in the number of published articles each year over the past decade, except for 2024, as data collection was conducted mid-year. This trend is influenced by the annual rise in published articles, with a sequential

increase from 2015 to 2023, followed by a decline in 2024 (13, 14, 13, 21, 35, 39, 30, 55, 69, and 31 articles, respectively).

Table 1. Key Research Data Information Using the Keywords "Science Identity" OR "Science Teacher Identity" OR "Approach STEM Education" OR "Environmental Science Chemistry"

Description	Result
Key Information About Data	
Time Range	2015:2024
Sources (Journals, Books, etc.)	158
Documents	320
Annual Growth Rate (%)	8.125
Average Document Age	3.27
Document Content	
Keywords Plus (ID)	552
Author Keywords (DE)	836
Authors	
Authors	899
Authors of Single-Author Documents	41
Author Collaboration	
International Co-Authorship (%)	10.14
Document Type	
Article	244
Book	8
Book Chapter	1
Book Chapter Article	27
Conference paper	37
Conference Paper article	2
Conference review	1

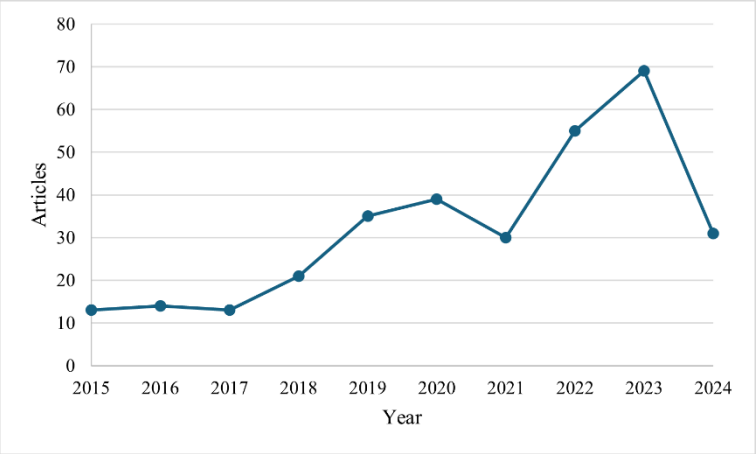

Figure 2. Graph of Research Article Development on Science Identity in Environmental Chemistry Learning Using the STEM Approach (2015–2024).

The annual trend in research development related to science identity and environmental chemistry learning using the STEM approach indicates continuous growth and expansion. As the number of researchers involved in this field increases, the volume of published articles is also expected to rise. This reflects a growing awareness of the importance of holistic and relevant education, along with strong support from various stakeholders (Yanez et al., 2019). The continuous advancement of research in this domain presents opportunities for scholars to make significant contributions to enhancing the quality of education and students' understanding of environmental science issues. Additionally, it may lead to new discoveries and innovations that can further improve research quality and help prevent plagiarism.

Relevant Article Sources on Science Teacher Identity in Environmental Chemistry Learning Using the STEM Approach

The analysis of article sources from the database over the past 10 years identified 10 relevant articles, with keyword relationships illustrated in (Figure 3). The findings indicate that the journal with the highest number of publications is Cultural Studies of Science Education, with 17 publications, followed by the International Journal of Science Education with 15 publications, Contributions from Science Education Research with 11 publications, and the Journal of Microbiology and Biology Education with 7 publications. Other sources have fewer publications, ranging between 4 and 6. This suggests that these four journals focus on themes such as cultural studies in science education, science education and teaching strategies, science curriculum development, assessment and evaluation in science education, research and innovation in science education, the impact of technology on science learning, and laboratory instruction with environmental experiment practices. Other article sources also play a significant role in publishing research on the proposed topic, albeit in smaller numbers.

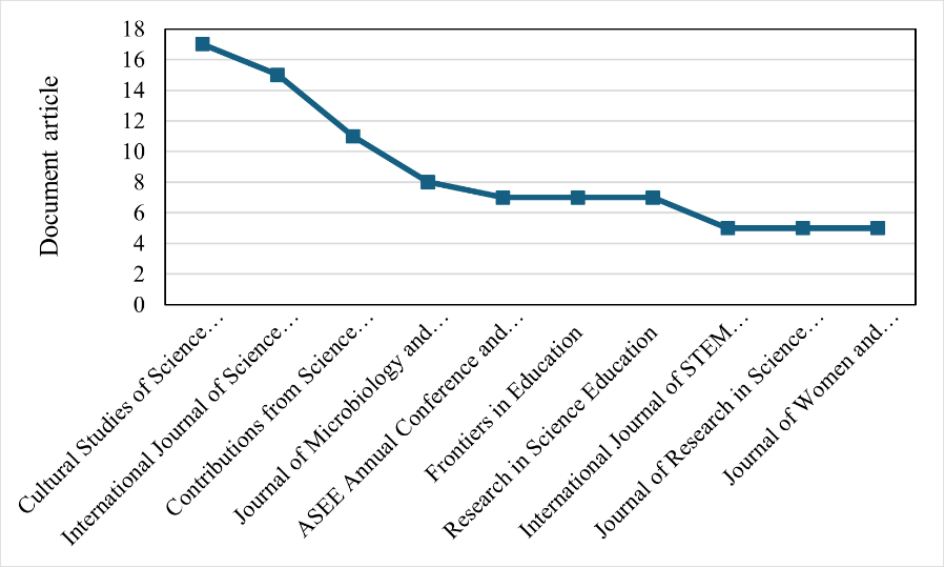

Figure 3. The Most Relevant Article Sources on Science Identity in Environmental Chemistry Learning Using the STEM Approach

The analysis results indicate that Cultural Studies of Science Education is one of the most relevant, impactful (7 article citations), and productive sources (with a total of 17 published articles) from 2015 to 2024. Impactful articles, as measured by the H-Index, serve as an indicator of research influence, demonstrating the number of publications citing a particular research article. The more citations an article receives, the greater its impact (Khurana & Sharma, 2022). In addition to this journal, several other sources also contribute impactful articles related to our research theme, albeit in smaller numbers.

This implies that the 10 most relevant and impactful articles can generally serve as reference sources and potential publication venues for further research. Productive sources that consistently publish research findings over the years exhibit a commitment to increasing publication trends (Bornmann et al., 2021), particularly on topics related to Science Identity, Environmental Chemistry Learning, and the STEM Approach. However, the more varied publication trends from other sources suggest that these articles may have a more specific research focus or experience fluctuations in available resources.

Influential and Impactful Authors on Science Teacher Identity in Environmental Chemistry Learning Using the STEM Approach

Interpretation (Table 2), obtained from Biblioshiny's analysis of 320 documents filtered as relevant to the study, shows the ten most influential and impactful authors in their respective fields, as determined by the H-Index metric, which we will analyze in depth. This index is typically calculated based on the number of citations an author's work receives from other researchers. The most cited author is Eric D. Deemer, who has published several articles with significant citation impact. Considering the impact of an author's research, it is important to note that relevance does not necessarily equate to influence on other studies (Zafrullah et al., 2023). For instance, an author who has published a few highly cited papers may be more relevant to a specific topic than an author who has produced numerous papers with fewer citations (Rusydiana, 2021).

Based on our search related to the research topic to be further investigated, Eric D. Deemer is identified as a highly influential author due to his primary research focus on academic and career development, particularly on motivational and socio-psychological factors affecting career exploration in STEM fields. The second most impactful author, Christopher D. Thompson, specializes in moral theology, rural life, and environmental management. Identifying the most relevant and impactful authors within this analysis, in alignment with our research theme, can serve as a reference for conducting a literature review and establishing future research collaborations. However, among these ten authors, the identity of science teachers is not included, indicating that research on the identity of science teachers remains underexplored. This presents an opportunity for novel research in the field.

Table 2. The 10 Most Influential and Impactful Authors Based on H-Index Related to Science Identity in Environmental Chemistry Learning

No	Author Name	Number of Article Topics	Related Topics	Analysis Results
1	Eric D. Deemer	4	STEM Approach	The results that institutional context, such as student racial diversity, plays an important role in reducing stereotype threat. Universities with more inclusive representation create a more supportive environment for students of color in STEM fields, thus increasing their sense of scientific identity and academic perseverance.
				The main objective of the study was to examine the role of Summer Science Program (SSP) in enhancing high school students' research motivation and identity through Self-Determination Theory (SDT) framework. Results showed significant increases in intrinsic motivation, research identity, and psychological need fulfillment. In addition, the need for autonomy and competence were shown to predict intrinsic motivation. Implications of the intervention are that precollege authentic research experiences can be effective in building motivation and scientific identity, and increase students' chances of persisting in STEM fields.
				The importance of research identity as a determining factor in sustaining students' interest and participation in science career pathways. The research method used a quantitative approach with adolescent student participants involved in an enrichment-based science program. The results showed that social bonds with both mentors and peers contributed significantly to the strengthening of research identity. Emotional support, a sense of community, and the presence of role models from mentors accelerate the process of internalizing science values in students.
				This research extends the application of Social Cognitive Career Theory (SCCT) in the context of science education by emphasizing the importance of building research experiences and mentoring support from the undergraduate level. This has implications for higher education institutions' strategies to strengthen the pipeline to science careers, particularly by providing meaningful research opportunities and mentor support.

				Research Potential Operational Delineations (PODs) as a spatial framework for land and wildfire management. As a result, PODs were shown to help integrate science, technology and social values, improve inter-agency coordination and support adaptive risk mitigation strategies. The research contributed to a paradigm shift from reactive response to proactive prevention, although it still faced constraints, collaboration and local adaptation.
2	Christopher D. Thompson	4	Environmental	The effectiveness of online learning resources for first-year chemistry students using the Universal Design for Learning (UDL) framework. The research findings show that the diversity of digital resources can improve students' accessibility, motivation, and understanding. Flexible and accessible resources proved helpful for students with different backgrounds and learning styles. However, the authors also highlight the need for a more integrated design UDL strategies can be optimized in online chemistry learning.
				The results showed that female students often face structural and cultural barriers, such as gender stereotypes, lack of representation of female role models, and learning environments that are not always inclusive. This impacts their confidence, academic engagement and decision to pursue a career in STEM. Male students, on the other hand, tend to benefit more from supportive institutional norms in the STEM domain.
				The research focuses on the development and validation of instruments to measure the critical thinking skills of undergraduate chemistry students. The results showed that the developed instrument has good internal consistency and can be used as a reliable tool to measure the critical thinking skills of chemistry students. The main contribution is to provide a standardized instrument that can help educators evaluate the effectiveness of learning in developing critical thinking skills.
3	Lucy Avraamidou	2	Science Identity	The concept of science identity with a landscape of becoming approach, where identity is seen as a dynamic process that continues to develop, not something static. Avraamidou emphasizes the importance of recognition and emotions in the formation of science identity, especially for individuals from marginalized groups. Through the lens of intersectionality, this

				research shows how gender, ethnicity, social class, and personal experience interact to shape one's opportunities and barriers to identifying as a scientist.
				Science identity as a lens to understand the political dimension of the nature of science (NOS). The main objective is to rethink the NOS, not only as a set of epistemologies and scientific practices, but also as a political arena. The research emphasizes the importance of the social justice dimension in science education. The main contribution lies in merging the concept of science identity with the political perspective of NOS, thus expanding the understanding of how science education can be more inclusive. Thus, recommending the need for science education reform to pay more attention to aspects of representation, recognition, and diversity of learners.
				STEM doctoral student agency in terms of study funding. Students with a better understanding of funding mechanisms tend to have more control over their academic and career paths. Conversely, limited information or reliance on advisors may limit their autonomy. Using a qualitative approach, it is shown that students' experiences are strongly influenced by institutional structures, relationships with advisors, and access to information.
4	Maura Borrego	2	STEM Approach	The author highlights those critical methods rooted in critical theory, feminism, and decolonial approaches are used to explore issues of injustice, exclusion, and marginalization in STEM fields. The review showed although the number of publications using critical approaches is increasing, the proportion is still very small compared to traditional methods. Critical research often highlights the experiences of marginalized groups (e.g. women, students of colour, and other minority groups) and opens up space for structural change in the STEM education system.
5	Rowan H. Brookes	2	STEM Education	Results showed the decision to continue or leave is influenced by academic, affective and environmental factors. Many students leave physics not because of ability, but rather negative perceptions, lack of career relevance, and lack of support. The authors emphasize the need for institutional interventions to improve teaching, support and an inclusive learning climate.

6	Charles R. Fisher			Research on science identity, sense of belonging, and experiences of discrimination in new science students in Australia through a quantitative survey. Results show that a strong science identity increases a sense of belonging, while discrimination based on gender, ethnicity or background decreases belonging and motivation. This study emphasizes the importance of creating a more inclusive STEM higher education environment.
7	Remy Dou	2	STEM Identity	The results that STEM identity is formed through complex interactions between cognitive, affective and social dimensions. Recognition from others, a sense of belonging to the STEM community, and future aspirations play an important role in strengthening identity. This article makes a significant contribution by expanding conceptual understanding and offering a more comprehensive analytical framework for STEM identity research.
				The results showed childhood science talk serves as an important indicator of future STEM engagement. Students who had more frequent science conversations with their families or neighborhoods as children tended to have stronger STEM identities in college. These findings emphasize the importance of social and cultural interactions in shaping interest in and ownership of STEM, particularly for Latinx students at Hispanic Serving Institutions (HSIs).
8	Claudia Fracchiolla	2	Physics Identity	This research uses the community of practice (CoP) framework to explain how physics identities develop in informal programs. Social interactions, shared practices, and community connectedness prove important in building competence, recognition, and a sense of belonging to physics, which is often not achieved in formal education. Using qualitative methods (interviews and observations), this study confirms that science identity is formed not only from knowledge, but also from social experiences and community recognition.
9	Kathleen Hinko			Highlights how informal physics programs function as communities of practice (CoPs) that support students' scientific identity formation through social interaction, shared practice, and a sense of community. Engagement in such programs not only deepens academic understanding, but also provides recognition, builds confidence, and strengthens connectedness to the

				physics discipline, confirming the importance of informal programs as a complement to formal education by emphasizing the social, collaborative, and emotional aspects of science identity formation.
				The results showed science capital and STEM identity approach play a significant role in influencing students' decision to pursue STEM studies at university. However, these factors are not the only determinants, as socio-economic background, gender and ethnicity are also influential. The findings emphasize the importance of understanding STEM identity as an interrelated dimension of science capital and broader social structures.
10	Spela Godec	2	STEM Approach	Youth engagement in informal STEM education (such as clubs, museums, community-based science activities) by highlighting aspects of equity and inclusion. The results show that while many adolescents have an interest in STEM, not all have equal opportunities to participate. Participants from lower socio-economic groups, women and ethnic minorities tend to have more limited access. This suggests a structural gap in the distribution of informal STEM education opportunities.

Affiliations and Countries Productive in Research on Science Teacher Identity in Environmental Chemistry Learning Using a STEM Approach

In this Biblioshiny analysis, we can also identify the five most productive affiliations and countries each year over the past ten years. Based on (Figure 4), the graph shows that Purdue University has the highest article production, with 68 articles, followed by Florida International University with 54 articles, University of California with 46 articles, California State University with 29 articles, Duke University with 28 articles, and Texas A&M University with 25 articles. Meanwhile, based on (Figure 5), the graph shows the results of the analysis, highlighting the top five most productive countries year by year. The United States (USA) ranks first with the highest number of articles, followed by Australia, China, the United Kingdom, and Canada. From these results, we can identify affiliations and countries that can be used as references for future research collaborations.

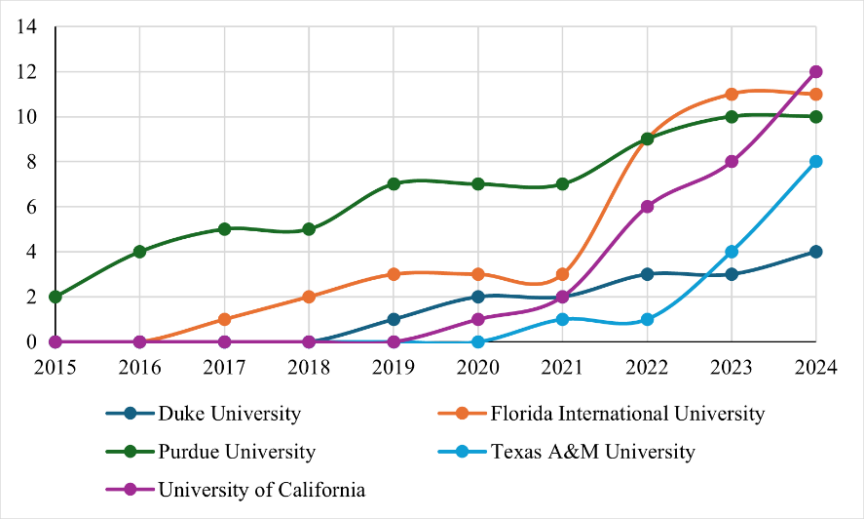

Figure 4. Development of Affiliations in Article Production Related to Science Identity in Environmental Chemistry Learning Using a STEM Approach from 2015 to 2024

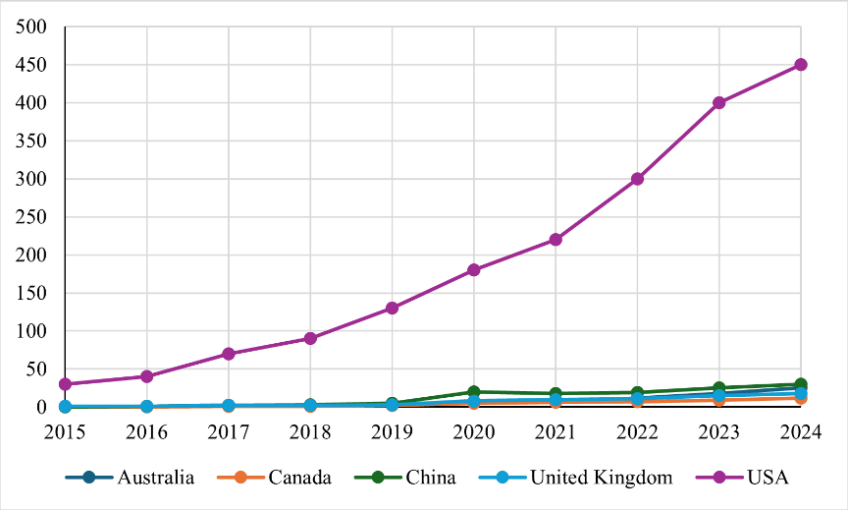

Figure 5. Development of Countries in the Production of Articles Related to Science Teacher Identity in Environmental Chemistry Learning Using the STEM Approach from 2015 to 2024

Quote from a Research Article Related to the Science Teacher Identity in Environmental Chemistry Learning Using the STEM Approach

Specifically, the quote from the research article related to the research theme on the identity of science in environmental chemistry learning with the STEM approach is shown in (Figure 6), which is a graph illustrating the number of frequently cited documents worldwide.

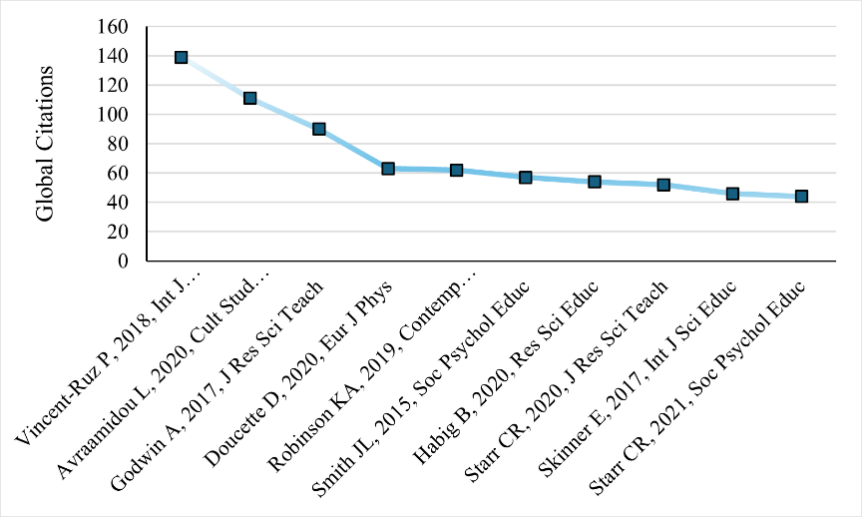

Figure 6. Most-Cited Relevant Articles Worldwide

Based on Figure 6, it is stated that the most cited relevant article sources by researchers are from the International Journal of STEM Education, with 139 citations, authored by Paulette Vincent-Ruz in 2018, available at the following article link: https://doi.org/10.1186/s40594-018-0140-5. This is followed by the article from the journal *Cultural Studies of Science Education*, authored by Lucy Avraamidou in 2020, with 111 citations, and the article link: https://doi.org/10.1007/s11422-019-09954-7. Other article sources have citations below 100, but are still relevant to the research theme. The global citation trend for these top 10 articles generally shows an increase over time, indicating that the research described in these articles has a significant impact on the field of education. Therefore, this data can be further examined for a literature review on the research theme, which focuses on science teacher identity in environmental chemistry learning using the STEM approach.

Development of Keyword Emergence

The analysis of the development of keyword emergence related to the keyword search "Science Identity" OR "Science Teacher Identity" OR "STEM Education Approach" OR "Environmental Science Chemistry" can be seen in (Table 3), which shows the top 10 most frequently used keywords by researchers in the last 10 years. The results indicate a correlation and relevance with the keywords of the planned research, such as Science Identity (7 occurrences) and Environmental Science (6 occurrences), while the keyword specification for STEM Education appears less frequently, presenting an opportunity for further research. The analysis results in (Figure 7) show a Word Cloud that focuses on related and frequently used keyword combinations (Kulakli & Shubina, 2020). This analysis highlights various aspects of engineering education, including professional aspects, aspects for students, and other related fields. The words and phrases in this word cloud provide a snapshot of the breadth and complexity of the field of education.

Table 3. Frequency of Words Used in the Top 10 Most Common Keywords

Keywords	Amount
Students	32
Engineering Education	14
Professional Aspects	13
Education Computing	10
Science Identity	7
Education	6
Environmental Science	6
Sense of Belonging	5
Computer Science Education	4
E-Learning	4

Figure 7. Word Cloud related to the keywords Science Identity, Science Teacher Identity, STEM Education Approach, and Environmental Science Chemistry.

The visualization of keyword occurrences was also performed using VOS Viewer. The visualization analysis of the Scopus database produced 8035 keyword terms found across all the articles; however, only 450 keywords met the criterion of appearing at least 5 times for each keyword, after which their relevance scores were calculated. Based on these scores, the most relevant keywords to the topic, representing 60%, were selected, resulting in 270 keywords. These were then re-selected to further enhance their relevance to the related topic, resulting in 74 keywords, which were classified into 6 clusters with 626 links. The visualization analysis mapping can be seen in (Figure 8), which illustrates a network visualization showing the relationships between the keywords as follows:

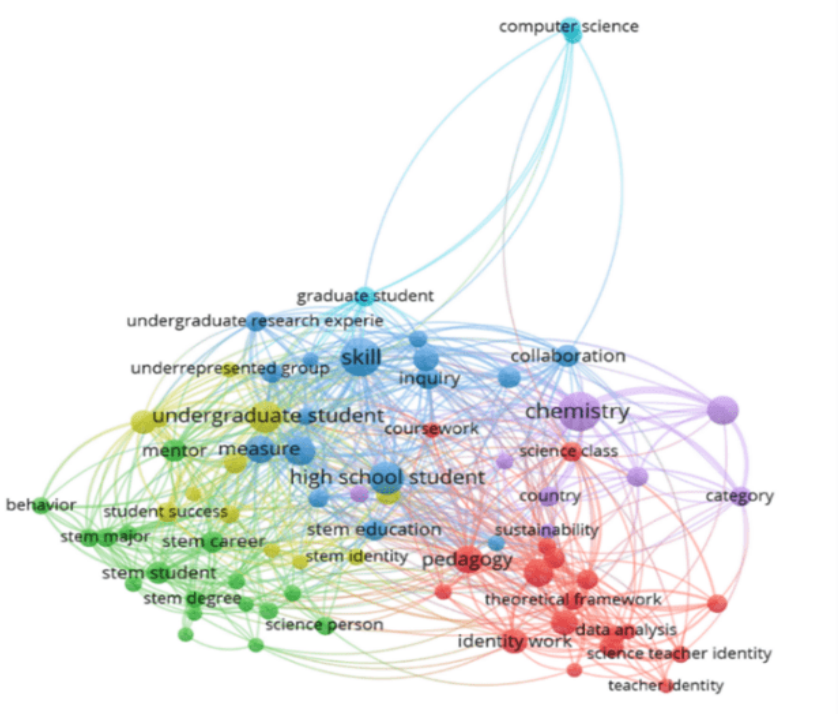

Figure 8. Network Visualization of the keywords Science Identity, Science Teacher Identity, STEM Education Approach, and Environmental Science Chemistry

Based on the network visualization in (Figure 8), six interconnected clusters were identified as follows:

- Cluster 1 (red) contains 18 keywords: coursework, data analysis, deeper understanding, identity construction, identity work, pedagogy, positive science identity, science class, science classroom, science content, science identity research, science learning, science teacher, science teacher identity, science teaching, teacher identity, science teaching, teaching, and theoretical framework. Interestingly, this cluster reflects a trend in research over the past 10 years that focuses more on science learning, including science identity.
- Cluster 2 (green) includes 17 keywords: behaviour, informal science education, mentor, next generation, practical implication, race ethnicity, science communication, science discipline, science educator, science identity theory, science person, STEM career, STEM degree, STEM discipline, STEM major, STEM student, and undergraduate STEM student. This cluster highlights the inseparable connection between science and STEM research. The interconnections between this cluster and others can also be observed.
- Cluster 3 (blue) consists of 16 keywords: assessment, collaboration, effectiveness, evaluation, experiment, exploratory factor analysis, high school student, inquiry, laboratory, measure, research experience, skill, STEM education, student science identity, and undergraduate research. This cluster reflects a comprehensive focus on improving and understanding STEM education across various educational levels, from high school research to undergraduate studies.
- Cluster 4 (yellow) contains 12 keywords: career choice, current study, professor, science achievement, science capital, science interest, science self-efficacy,

STEM identity, student success, undergraduate student, underrepresented group, and underrepresented minority. This indicates the relationship between educational experiences, personal and social factors, and student career outcomes, with an emphasis on inclusivity and support for underrepresented groups in STEM fields.

- Cluster 5 (purple) consists of 8 keywords: better understanding, category, chemistry, country, environmental science, science identity formation, scientific community, and sustainability. This cluster is related to enhancing the understanding of how science identity is formed and maintained in specific disciplines like chemistry and environmental science, influenced by sustainability practices and national contexts.
- Cluster 6 (light blue) contains 3 keywords: computer science, computer science identity, and graduate student. These items are less relevant to the associated keywords and can therefore be considered less significant.

Each keyword term that appears is labelled with a coloured circle, and the grouping represents the relationships between keywords. The frequency of keyword occurrences in article titles and abstracts influences the size of the label's circle the more frequently a keyword appears, the larger and more prominent its circle. This visualization highlights the grouping of frequently studied keywords and illustrates the connection between the topic of science identity and environmental chemistry learning using a STEM approach. To examine the interconnected links between keywords related to this research topic, refer to (Figure 9). The visualization refines the original four keywords into three more specific focus areas: science teacher identity, environmental science, and STEM education.

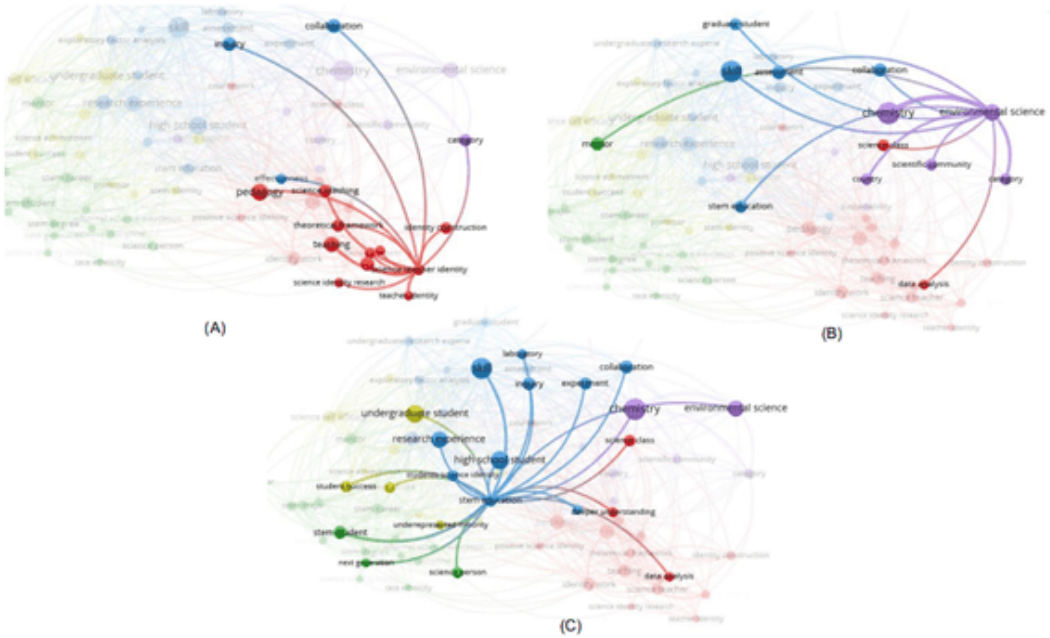

Figure 9. Network Visualization of the Keywords Science Teacher Identity (A), Environmental Science (B), and STEM Education (C)

Figure 9a presents a visualization of keywords related to the study of science teacher identity, showing its connections with other keywords. It includes 14 links, with a frequency of 7 occurrences and a total link strength of 20. This keyword is closely linked to science identity research and teacher identity, indicating potential opportunities for further development of science identity in prospective or current chemistry teachers.

Figure 9b illustrates the visualization of the environmental science keyword, which belongs to Cluster 5. It has 12 connected links, a frequency of 20 occurrences, and a total link strength of 39. The strongest connection in this keyword cluster is with chemistry, confirming that environmental science is associated with chemistry. However, based on the mapping, there has been limited research on environmental chemistry learning using a STEM approach to enhance science identity.
Figure 9c focuses on STEM education, which is located in Cluster 3. It has 21 connected links, a frequency of 11 occurrences, and a total link strength of 26. The visualization shows that STEM education is linked to chemistry and environmental science, but there is no direct connection to the enhancement of identity, particularly science identity or science teacher identity. From these three visualizations, the relationship between these keywords highlights a research gap, suggesting a novel direction for future studies.

The next visualization mapping analysis is the overlay visualization, as shown in (Figure 10). This visualization illustrates overlapping keywords, indicating the novelty of the research. Based on these findings, it is evident that the number of publications on this topic has increased significantly, with the highest concentration beginning in 2022 and continuing to rise through 2024, reflecting a growing research interest in this area.

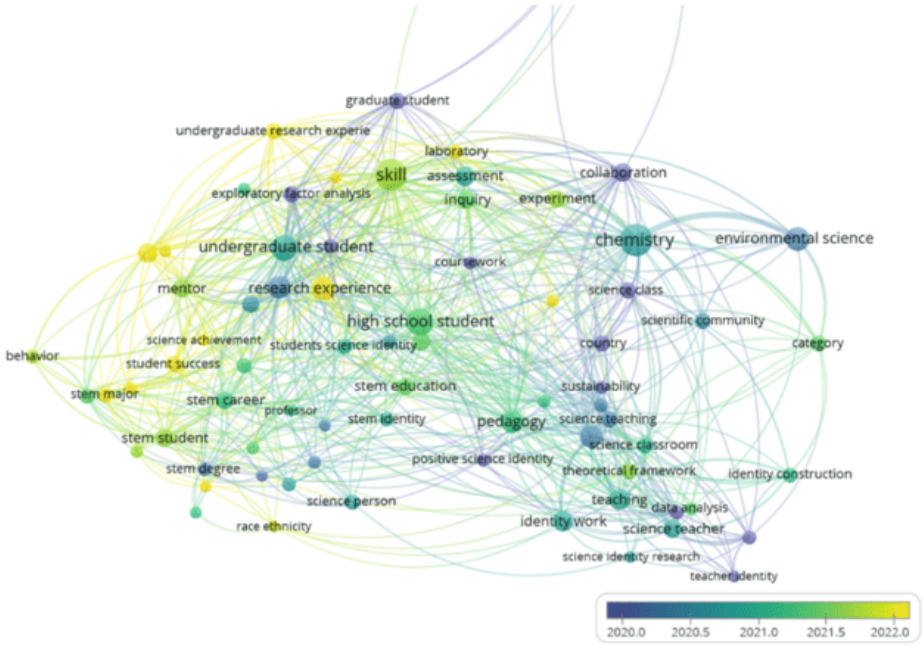

Figure 10. Overlay Visualization of the Keywords Science Identity, Science Teacher Identity, STEM Education Approach, and Environmental Science Chemistry.

The density visualization can be seen in (Figure 11), which illustrates the frequency of keyword occurrences across all article documents from 2015 to 2024. In the density map, the more yellow a keyword appears and the larger its circle diameter, the more frequently it occurs. Conversely, if the colour fades and blends into the green background, the keyword appears less frequently (Tupan, 2019). Based on the visualization results, the most prominent yellow-coloured keywords are Chemistry, Skill, Research Experience, and Undergraduate Student.

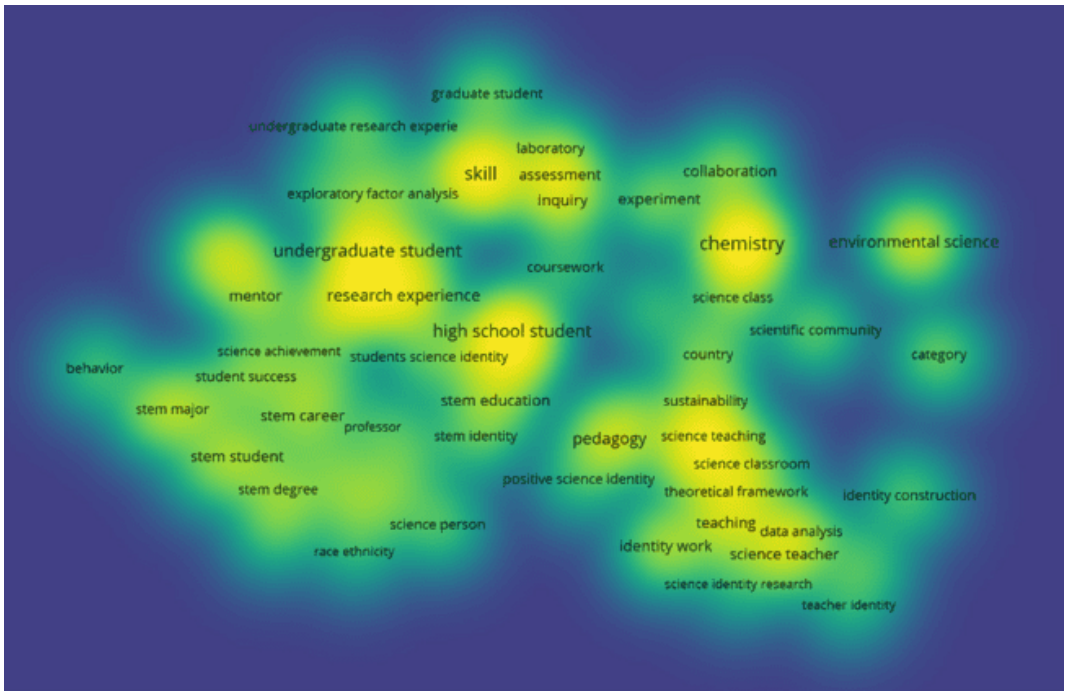

Figure 11. Density Visualization of the Keywords Science Identity, Science Teacher Identity, STEM Education Approach, and Environmental Science Chemistry

Future Research Directions on Science Teacher Identity in Environmental Chemistry Learning Using a STEM Approach

Another aspect in determining the direction of future research is to examine the trending research topics to date and the opportunities for novelty in upcoming studies, which can be seen through the thematic map. Several topics have shown an increasing trend over the past 10 years, including environmental science and science teacher identity, indicating that environmental issues are becoming increasingly important and receiving greater attention from researchers. To explore trending topics and future research opportunities, a literature review of articles serves as the foundation for the next research topic, as shown in (Figure 12).

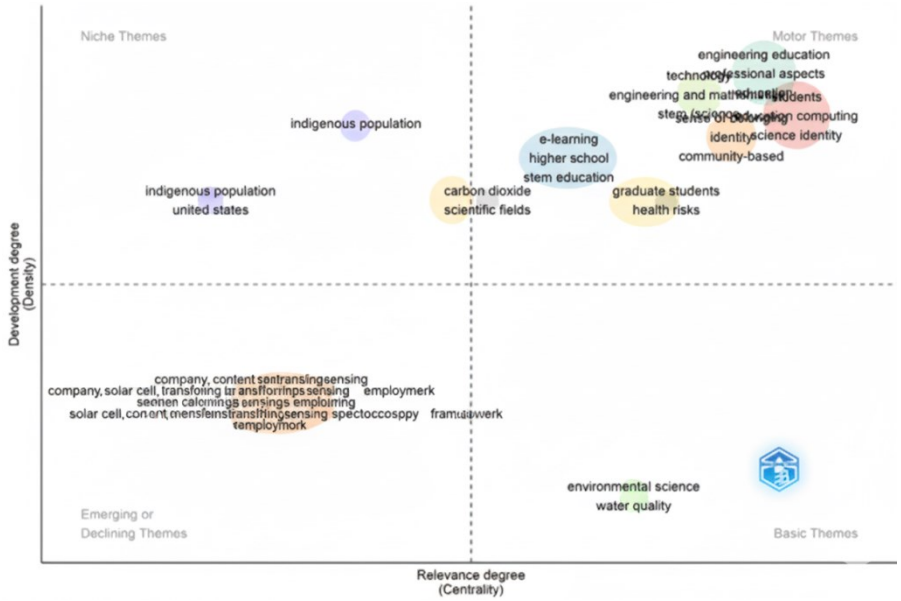

Figure 12. Thematic Map of the Keywords Science Identity, Science Teacher Identity, STEM Education Approach, and Environmental Science Chemistry

Based on (Figure 12), the thematic map in the bibliometric analysis of the large dataset of scientific publications in Scopus shows that the points on the map represent different research topics, while the edges between the points represent the strength of relationships between these topics. The size of the nodes represents the importance of the topic, and the colour of the nodes represents the theme of the topic. The map is divided into four main themes: basic themes, motor themes, niche themes, and emerging or declining themes. The basic themes, located in the lower-right section, include environmental science, water quality, and employment, which have had significant influence on extensively studied topics. The motor themes, which are key drivers of research, are located in the upper-right section. These include the most frequently appearing topics such as students, education computing, science identity, and sense of belonging. The niche themes, which are more specific and may be newly emerging, are located in the upper-left section, with topics such as indigenous population and United States. Lastly, the emerging or declining themes are found in the lower-left section, including higher education and heavy metals, with the lowest density.

Thus, the centrality of the map indicates that the further to the right a topic appears, the more influential it is in the research field. In contrast, the density suggests that the further up the map a topic is, the more articles related to that topic have been produced (Galeano-Barrera *et al.,* 2022). Therefore, researchers should pay attention to the lower-left section, as it indicates emerging or declining themes, meaning there has been less research in those specific areas. Based on these analyses, researchers can establish boundaries and key findings, especially regarding trending topics and thematic mapping, to inform further research. This analysis serves as a foundation for future studies. The next research step will involve a literature review of relevant articles on enhancing science identity in

environmental chemistry learning with a STEM approach. The ultimate goal is to produce a novel and impactful research study.

4. Conclusion

A Scopus database search from 2015 to 2024 using keywords related to science identity, STEM education, and environmental chemistry was analyzed with Biblioshiny in R Studio. The analysis revealed trends in publication output, key sources, influential authors, productive institutions and countries, highly cited articles, and keyword patterns. VOS Viewer visualizations network, overlay, and density were used to map relationships among articles. These findings provide valuable insights into global research developments and help identify emerging trends and research gaps. The study serves as a reference for future investigations within the scope of science identity and environmental STEM education.

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