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Mapping The Science, Technology, Engineering and Mathematics (STEM) Research Network in Science and Environmental Education: A Bibliometric Review

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Luki Yunita[1*], Salamah Agung[2], Nur Kholiq Majid[3], Rifqa Masliah Humairah[4]

[1,2,3,4]Department of Chemistry Education, Faculty of Tarbiya and Teaching Sciences,
Universitas Islam Negeri Syarif Hidayatullah Jakarta, South Tangerang, Indonesia
Corresponding Email: *luki.yunita@uinjkt.ac.id

Abstract

Research on Science, Technology, Engineering, and Mathematics (STEM) in science education and environmental education continues to grow as an effort to improve the quality of learning and support sustainable development. However, studies mapping research developments in these fields are still limited. This study aims to analyze STEM research trends in science education and environmental education using a bibliometric approach. Data were obtained through Publish or Perish (PoP) using the Google Scholar database using the keywords STEM Chemistry Education and Environmental Education. A total of 193 articles published between 2022 and 2026 were collected and then selected, resulting in 22 articles for analysis using VOSviewer through network visualization, overlay, density, and co-authorship. The results show that the keywords education, science, science education, learning, STEM, and environmental education are the most dominant themes. In addition, the topics of environmental awareness, artificial intelligence, application, and science teaching have potential as future research directions, while co-authorship analysis indicates that collaboration between authors is still relatively limited. This study provides an overview of the development of STEM research and opportunities for its future development.

Keywords: Bibliometrics, Science Education, Environmental Education, STEM, VOSviewer

INTRODUCTION

Developments in the field of education in the 21st century require us to adopt teaching methods that combine conceptual understanding, critical thinking skills, creativity, collaboration and the ability to tackle real-world problems (Strat et al., 2024). The STEM approach, which encompasses Science, Technology, Engineering and Mathematics, has become one of the most widely used innovations in science education, as it links various disciplines through contextual, problem-solving-focused learning (Alkair et al., 2023). Over time, this approach has come to be seen not only as a means of improving pupils' learning outcomes, but also as a tool for raising awareness of environmental issues and sustainable development. Various studies have shown that integrating STEM with environmental education can enhance science literacy, problem-solving skills and pupils' participation in finding solutions to environmental issues through real-world, project-based learning activities (Alcántara-Rubio et al., 2022; Alkair et al., 2023).

Growing interest in the application of STEM in science education has led to a range of studies linking learning to environmental issues. Various studies show that the application of STEM can enhance pupils' abilities in critical thinking, problem-solving, creativity and environmental literacy through project-based learning, scientific research and the use of technology (Matovu et al., 2023). Furthermore, STEM has been implemented in a variety of contexts, including teaching about climate change, the greenhouse effect, environmental conservation, and the development of skills relevant to the 21st century (Remmen & Iversen, 2023; Shagrayeva et al., 2025). This development shows that STEM is now no longer regarded merely as one approach to learning, but has evolved into a strategy for preparing pupils to face future environmental challenges and the challenges of sustainable development (Ichsan et al., 2023; Kumar et al., 2023).

In line with the increasing adoption of STEM, the number of scientific articles in the fields of science and environmental education has also shown significant growth. Published research not only evaluates the effectiveness of STEM implementation on learning outcomes but also designs various learning models, teaching media, teaching aids, the integration of Education for Sustainable Development, and the use of digital technology in the teaching and learning process. Indeed, advances in artificial intelligence technology are beginning to be utilised to support STEM-based science learning, thereby broadening the scope of research in this area (Lee & Zhai, 2023). The diversity of these research topics illustrates that the study of STEM is constantly evolving and attracting the attention of researchers in various countries (Alcántara-Rubio et al., 2022; Xu & Ouyang, 2022).

Although research on STEM in science education and environmental education continues to grow, the majority of published articles focus more on the application of learning models, the creation of teaching materials, the improvement of learning outcomes, and the development of 21st-century skills (Zikargae et al., 2022). On the other hand, research specifically aimed at mapping research progress, patterns of author collaboration, frequently recurring topics, and the direction of research themes remains limited. Consequently, information on STEM research trends in science education and environmental education is not yet fully documented, and further studies are therefore needed to provide a comprehensive overview of developments in these fields (Çürük & Yildirim, 2025; Istiana et al., 2023; Kumar et al., 2023).

This study on STEM in science and environmental education aims to provide a more structured overview of developments in STEM research within science and environmental education, thereby serving as a foundation for researchers in determining the focus of future research (Jamali et al., 2023; Maryanti et al., 2022). A study on STEM in science and environmental education using a bibliometric approach. This review analysis was conducted to map publication trends, identify dominant research themes, examine relationships between keywords, and uncover research opportunities that could be further explored (Maryanti et al., 2022). It is hoped that the findings of this study will provide a comprehensive overview of developments in STEM studies within science and environmental education, whilst also serving as a reference for researchers wishing to undertake future research in these fields (Almasri, 2024; Wahyudi et al., 2025). The review to be discussed is not limited to the results obtained, but may also offer useful recommendations to stakeholders and researchers for improving STEM research in science education and environmental education. Consequently, the following research questions have been formulated: 1) what are the trends in publications relating to STEM in science education and environmental education; 2) how do collaborative networks between authors function, and which authors are productive and influential; 3) how can the impact of research be measured through citations; and 4) how can the relationships within these networks and the dominant research themes be visualised.

METHOD

This study employed a bibliometric analysis using a quantitative descriptive approach to analyse developments in research on Science, Technology, Engineering and Mathematics (STEM) within the fields of Science Education and Environmental Education (Koculu & Girgin, 2022). Bibliometric analysis is used to identify publication trends, developments in research topics, publication productivity, and relationships between keywords based on published scientific documents. Researchers can evaluate scientific productivity, collaboration patterns and citation networks within the academic literature through quantitative analysis of the academic literature (Donthu et al., 2021). Bibliometric analysis helps researchers understand research trends, emerging topics and research prospects. Software commonly used in bibliometric analysis includes Publish or Perish and VOSviewer. This software is designed to construct and visualise bibliometric networks based on scientific publication data; VOSviewer is a highly popular programme for bibliometric analysis, designed to construct and visualise bibliometric networks based on scientific publication data, including relationships between authors, keywords, institutions and citations. (Van Eck & Waltman, 2010). As a result, Vosviewer's ability to display network maps visually makes it easier for researchers to interpret the relationships between the elements being analysed.

The research data consists of scientific articles drawn from a body of literature that has been collected and selected in accordance with the research topic. All the articles analysed discuss the application of STEM in science education and environmental education, including studies on Education for Sustainable Development (ESD), the Sustainable Development Goals (SDGs), environmental literacy, project-based learning, and the development of 21st-century skills. These articles serve as the primary data source in the bibliometric analysis process. (Jamali et al., 2023). Data analysis during the research phase began with the collection of relevant articles; followed by a process of identification and selection based on their relevance to the research topic; the data obtained are then organised in RIS format and analysed using VOSviewer software to produce network visualisations, overlay visualisations, and density visualisations of co-occurring keywords.

RESULTS AND DISCUSSION

Literature Search Results Using Publish or Perish

The literature search was conducted using the Publish or Perish (PoP) application, utilising the Google Scholar database. A search using the keywords 'STEM Chemistry Education' and 'Environmental Education' for publications from 2022 to 2026 yielded a total of 200 articles. A selection process was then carried out based on topic relevance, duplication of articles, and completeness of information, resulting in 22 articles being selected for use as data in this study. This selection process aimed to ensure that the analysed articles were relevant to the research topic concerning STEM in science education and environmental education. The results are shown in Table 1.

Tabel 1. Publication Citation Matrix STEM Chemistry Education and Environmental Education

No	Indicator	Search Result
1	Keywords	STEM Education Chemistry and Environmental Education
2	Publication years	2022-2026
3	Papers	193
4	Citations	57814
5	Cites/year	14453.5
6	Cites/paper	299.55
7	Authors/paper	70.47
8	h-index	148
9	g-index	193
10	hI,annual	20.25
11	hA-index	83

Based on the results of the citation analysis in Table 1, a total of 193 articles published during the period 2022–2026 were identified using the keywords 'education', 'science', 'science education', 'learning', 'STEM' and 'environmental education'. This number of publications indicates that research on the assessment and evaluation of chemistry learning remains an actively developed topic and is relevant to current educational needs. All articles received a total of 57,814 citations, with an average of 299.5 citations per article or 14,453.5 citations per year. This indicates that the development of STEM in science education and environmental education remains a key focus in chemistry education research (W. Y. Lestari

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& Purnamasari, 2023). Trends in the annual number of publications on the topic of assessment and evaluation in chemistry education are presented in Table 2 and Figure 1.

Table 2. Data on The Most Frequently Cited Articles

No	Author	Year of Publication	Article Title	Article Source	Number of Citations
1	DL Sparks, B Singh, MG Siebecker	2022	Environmental soil chemistry	https://books.google.com	5996
2	LI González-Pérez, MS Ramírez-Montoya	2022	Components of Education 4.0 in 21st century skills frameworks: systematic review	https://mdpi.com	1402
3	P Reiser, M Neubert, A Eberhard, L Torresi…	2022	Graph neural networks for materials science and chemistry	https://nature.com	1094
4	J Willard, X Jia, S Xu, M Steinbach, V Kumar	2022	Integrating scientific knowledge with machine learning for engineering and environmental systems	https://dl.acm.org	1039
5	RM Felder, R Brent	2024	Teaching and learning STEM: A practical guide	https://books.google.com	1037
6	W Xu, F Ouyang	2022	The application of AI technologies in STEM education: a systematic review from 2011 to 2021	https://springer.com	812
7	F Wang, L Xiang, KSY Leung, M Elsner, Y Zhang…	2024	Emerging contaminants: a one health perspective	https://cell.com	804
8	G Tom, SP Schmid, SG	2024	Self-driving laboratories for	ACS Publications	786

No	Author	Year of Publication	Article Title	Article Source	Number of Citations
	Baird, Y Cao, K Darvish…		chemistry and materials science		
9	EA Alasadi, CR Baiz	2023	Generative AI in education and research: Opportunities, concerns, and solutions	ACS Publications	747
10	SHPW Gamage, JR Ayres, MB Behrend	2022	A systematic review on trends in using Moodle for teaching and learning	Springer	704

Based on Table 2, the results of the analysis using Publish or Perish show that the articles with the highest number of citations indicate that the research in question has made a significant contribution to the development of STEM studies in science education and environmental education. The high number of citations suggests that these articles are frequently cited by other researchers, thereby exerting a significant influence on the development of research in this field. Research on STEM n Chemistry and Environmental Education can be seen in Table 3 and Figure 1.

Table 3. Trends in Google Scholar Database Publications

Year of Pulication	Result of Publication	Percentage
2026	1	1%
2025	17	9%
2024	31	16%
2023	70	36%
2022	74	38%
Total: 193 articels		

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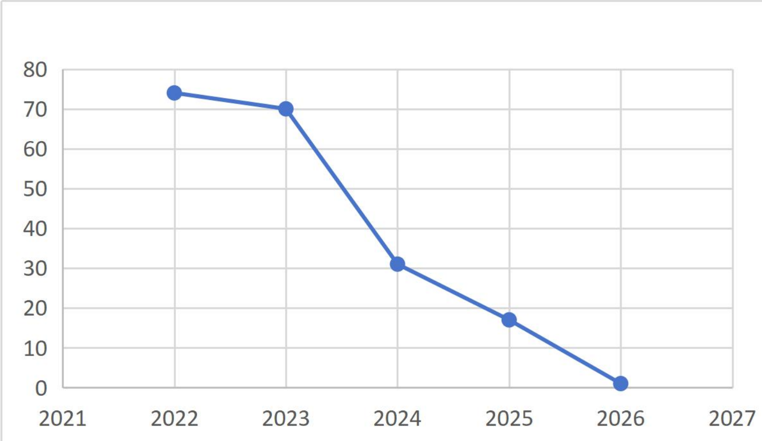

Figure 1. Research on STEM n Chemistry and Environmental Education

According to Table 3, the number of publications on STEM in science education and environmental education fluctuated during the period 2022–2026. The year 2022 saw the highest number of publications, totalling 74 articles (38 per cent). The high number of publications in 2022 indicates growing interest among researchers in the application of the STEM approach to support science learning and environmental education. However, the decline in the number of publications in subsequent years does not necessarily indicate a waning of research interest; rather, it may be influenced by the article selection process, the keywords used, or the limited scope of the databases analysed.

A literature search on STEM chemistry education and environmental education yielded 193 records from the Google Scholar database for the period 2022–2026 (see Table 4); of these articles, the sources that most frequently addressed STEM chemistry education and environmental education were classified, and the six most frequently cited sources were identified. Table 4 shows that Springer published the most articles (30), followed by ACS Publications (18), Taylor & Francis (13), MDPI (11), CELL (8) and https://books.google.com (6).

Table 4. Core Journal STEM Topics: Chemistry Education and Environmental Education

Article Resource	Number of Articles
Springer	30
ACS Publications	18
Taylor &Francis	13
MDPI	11
CELL	8
https://books.google.com	6

Visualisation STEM Chemistry Education and Environmental Education

VOSviewer displays a network visualisation of keywords that co-occur in the 193 articles analysed. Each node in the network represents a single keyword, with the size of the node reflecting the frequency of that keyword's occurrence, whilst the connecting lines

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indicate the strength of the relationship between keywords (Nisa & Ayu, 2023). The results of the network visualisation are presented in Figure 2.

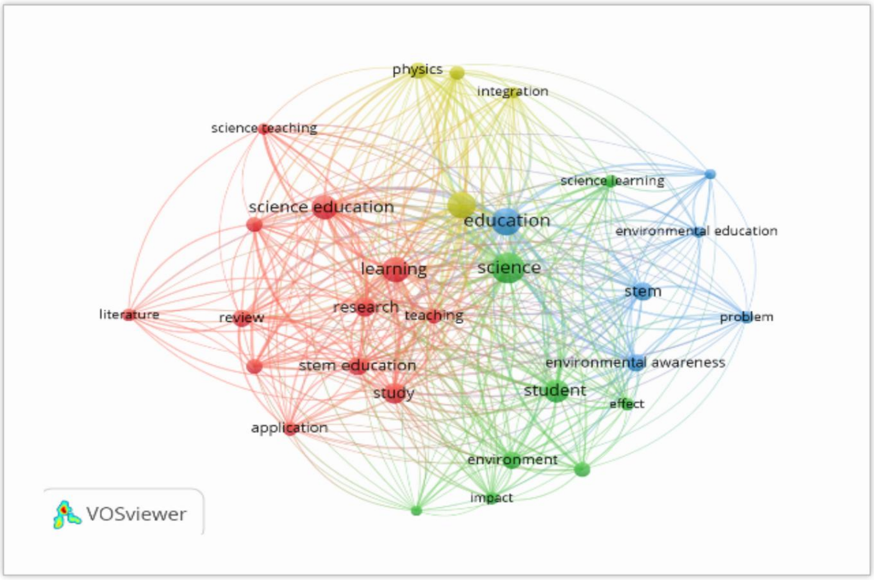

Figure 2. Network Visualization

Based on Figure 2, the results of the network visualisation analysis using VOSviewer software reveal a visualisation of the relationships between keywords (co-occurrence), showing that research on STEM in science education and environmental education is dominated by the keywords ‘STEM’, ‘science education’, ‘science’, ‘education’ and ‘environmental education’. The size of the nodes for these five keywords indicates their high frequency of occurrence across various publications, whilst the connecting lines illustrate the strong interrelationships between research topics. Furthermore, the appearance of the keywords ‘environmental awareness’, ‘science learning’, ‘environmental science’ and ‘Artificial Intelligence’ indicates that STEM research is beginning to evolve towards learning that focuses on raising environmental awareness and the use of digital technology in the learning process. These findings are consistent with research Shagrayeva et al., (2025) which states that the implementation of STEM can raise environmental awareness through problem-solving-based learning, and is supported by research Chistyakov et al., (2023) which explains that the integration of digital technology into science learning is one of the key directions for the development of STEM education in the era of digital transformation. STEM research needs to focus on comprehensive and integrated strategies, with an emphasis on advances in technology and pedagogy in the development of a curriculum that is relevant and aligned with 21st-century educational competencies, so as to have a meaningful and relevant impact (Umar, et al., 2026).

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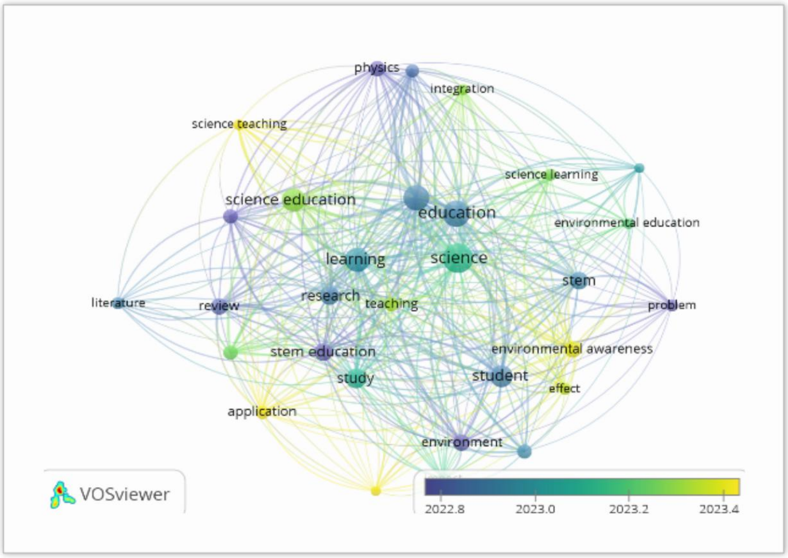

Figure 3. Overlay Visualization

Based on Figure 3, the results of the overlay visualisation show the development of research themes based on the average year of publication. Keywords such as ‘education’, ‘science’ and ‘physics’ are displayed in darker colours, indicating that these topics have been extensively researched for some time. Conversely, keywords such as ‘environmental awareness’, ‘environmental science’, ‘application’, ‘science teaching’ and ‘Artificial Intelligence’ are shown in lighter colours, indicating that these themes represent relatively new areas of research focus. This shift indicates that STEM research is no longer solely oriented towards improving learning outcomes, but is also beginning to emphasise the fostering of environmental awareness, the utilisation of technology, and learning innovations that support sustainable development. These findings are consistent with research Xu & Ouyang, (2022) which explains the importance of integrating STEM into environmental education to support the Sustainable Development Goals (SDGs), as well as research Wahyudi et al., (2025) which shows that environment-based STEM learning can improve pupils’ scientific literacy and their concern for environmental issues.

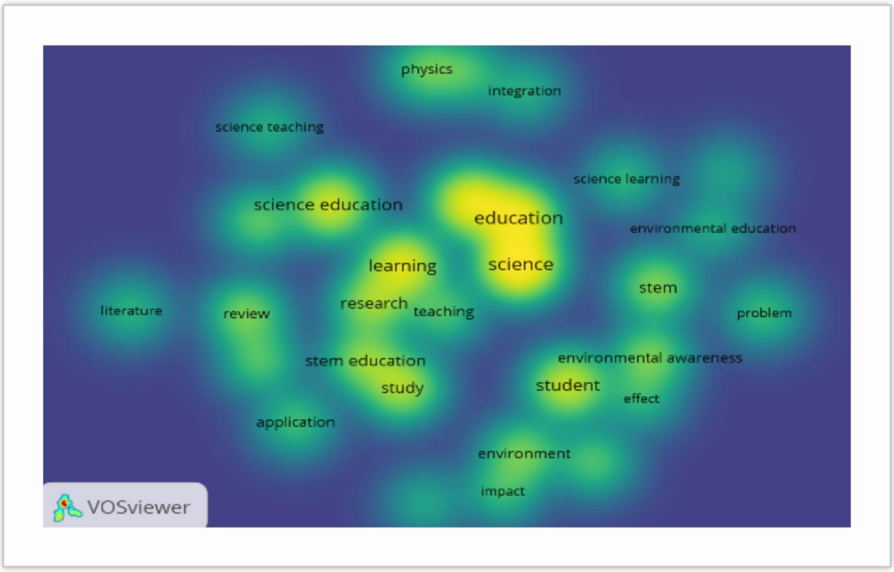

Figure 4. Density Visualization

Based on Figure 4, the results of the density visualisation show that the keywords ‘STEM’, ‘science education’, ‘science’, ‘education’ and ‘environmental education’ have the highest density levels, indicating that these themes have remained the primary focus of research over the past five years. Conversely, the keywords ‘Artificial Intelligence’, ‘environmental awareness’ and ‘science teaching’ have relatively low density levels, suggesting they still hold potential as future research directions. This situation indicates that the integration of artificial intelligence-based technology and the strengthening of environmental education within STEM learning still require further study. (Uralovich et al., 2023). These findings are consistent with research Rillig et al., (2023) which states that bibliometric analysis is capable of identifying both established themes and new themes that offer opportunities for further research, and is supported by research Yazidi & Rijal, (2024) which emphasises that the use of digital technology is one of the key trends in the development of STEM education.

Table 5. Keywords Representing Each Cluster

No	Cluster	Element
1	Cluster 1 (12 items)	Application. Artificial intelligence. Learning. Literature. Research. Review. Science education. Science teaching. STEM education. Study. Systematic review. Teaching
2	Cluster 2 (8 items)	Chemical. Effect. Environment. Environmental science. Impact. Science. Science learning. Student
3	Cluster 3 (6 items)	Education. Environmental awereness. Environmental education. Problem. STEM. Sustainable development
4	Cluster 4 (4 items)	Biology. Chemistry. Integration. Physics

Table 5 shows the results of the topic network analysis for STEM chemistry education and environmental education; the results reveal four clusters: cluster 1 (12 items), cluster 2 (8 items), cluster 3 (6 items) and cluster 4 (4 items). Figure 3 illustrates research trends in STEM chemistry education and environmental education based on an overlay of publication years, whilst Figure 4 visualises the depth of these research trends.

Visualisation of The Citation Network Structure of Publications

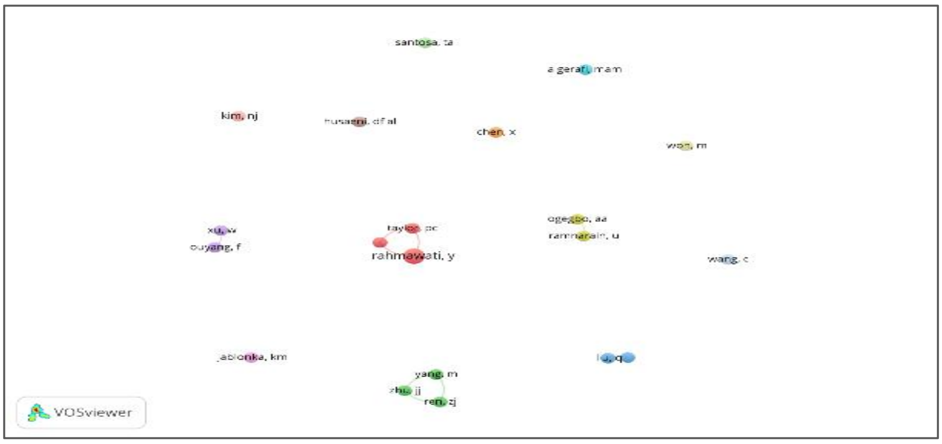

Figure 5 Visualization of the author network structure

Based on Figure 5, a co-authorship analysis using VOSviewer was conducted to identify patterns of collaboration amongst authors in publications discussing STEM in science education and environmental education. The visualisation revealed several clusters of authors; however, the majority of authors remained in single-author clusters, indicating that the level of collaboration amongst researchers on this topic remains relatively low. Only a few authors have direct collaborative links, such as Rahmawati, Y. with Taylor, P.C., and Yang, M., Zhu, J.J., and Ren, Z.J., who form a collaborative network within a single cluster. These findings suggest that research on STEM in environmental education is still dominated by specific groups of researchers and that no extensive collaborative networks have yet been established between countries or institutions. Menurut Maryanti et al., (2022), Co-authorship analysis is one of the key indicators in bibliometrics for describing the level of scientific collaboration, whereby a greater number of links between authors indicates a stronger research network within a particular field. The findings of this study are also consistent with Alcántara-Rubio et al., (2022) which emphasises the importance of multidisciplinary collaboration in the development of STEM research in order to produce more comprehensive learning innovations that are relevant to the educational challenges of the 21st century. The low level of inter-author connections indicates that research on STEM in environmental education is still developing in isolation across various research groups. This situation presents an opportunity to enhance collaboration across institutions and across countries in order to strengthen research development in this field (Almasri, 2024).

CONCLUSION

Based on the results of a bibliometric analysis using Publish or Perish and VOSviewer, it can be seen that research on Science, Technology, Engineering, and Mathematics (STEM) in science education and environmental education has experienced rapid growth during research over the past five years. The results of the overlay visualisation indicate a shift in the direction of research towards the topics of environmental awareness, artificial intelligence, applications, and science teaching. This suggests that STEM research is no longer solely focused on improving learning outcomes, but is beginning to integrate issues of environmental sustainability and the development of digital technology into the learning process. Furthermore, environmental education and STEM-based learning innovations have not yet been widely implemented, presenting significant opportunities for development in future research. Collaboration amongst authors remains relatively limited and is dominated by specific groups of researchers. The majority of authors have not yet established extensive collaborative networks, indicating that research in this field is still developing in isolation. Therefore, enhancing collaboration across institutions and across countries represents an opportunity that needs to be developed to strengthen research on STEM in science education and environmental education.

SUGGESTIONS

The results of this study indicate that trends in STEM research have evolved from learning focused on the integration of science, technology, engineering and mathematics towards learning that also integrates environmental sustainability, digital technology and artificial intelligence. Consequently, it is hoped that the findings of this study will serve as a reference for researchers and policymakers in determining the direction of future STEM research development.

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