



Where is Environmental Issue Integration in Science Education Heading? Bibliometric Evidence on Emerging Research Frontiers

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Abstract: This study aims to analyze the integration of environmental issues in science education by systematically mapping research evolution and identifying emerging trends between 2015 and 2025. Employing a Systematic Literature Network Analysis (SLNA), the study combines a PRISMA-guided systematic literature review with bibliometric network analysis using Biblioshiny and VOSviewer. Data were retrieved from Scopus through a refined search strategy limited to peer-reviewed, open-access journal articles in the social sciences domain. Following PRISMA-based screening, 63 articles were analyzed to identify publication trends, influential contributors, thematic structures, and emerging research directions. The results reveal a notable increase in publication output after 2019 and the formation of five dominant thematic clusters: science education and literacy, sustainability education, socio-scientific reasoning, teacher professional development, and STEM integration. Keyword co-occurrence and density analyses indicate growing convergence around sustainability, inquiry-based learning, and ethical reasoning, highlighting these areas as key research frontiers. These findings emphasize the importance of integrating sustainability competencies into science curricula and strengthening teacher professional development to address environmental socio-scientific issues. Future pedagogical approaches should focus on inquiry-based STEM learning, socio-scientific issues (SSI)-based instruction, and ethics-oriented environmental reasoning to enhance students' critical thinking and responsible decision-making regarding environmental challenges.

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Introduction

Global environmental crises, including climate change, biodiversity loss, and pollution, present urgent challenges that demand scientifically literate and civically engaged citizens (Baltikian et al., 2025; Gally et al., 2025). Education plays a pivotal role in cultivating the knowledge, skills, and dispositions necessary to confront these crises (Kaukko et al., 2021). Consequently, integrating environmental issues into science education has gained increasing attention within both policy and research domains (Kimmerer, 2012; Littledyke, 2008). The study by Brundiers et al. (2010) emphasizes that integrating real-world environmental issues into academic curricula can effectively enhance learners' problem-solving abilities, connect theoretical knowledge with practical action, and cultivate collaborative and sustainability-oriented competencies through project-based, service, and community-engaged learning approaches. Likewise, international frameworks such as the Sustainable Development Goals underscore the global commitment to embedding sustainability competencies across educational systems, emphasizing the importance of



reorienting science education toward environmental and societal relevance (Kioupi & Voulvoulis, 2019).

Building on this pedagogical orientation, Sinakou et al. (2019) conducted a conceptual analysis that highlights how holistic, pluralistic, and action-oriented frameworks can enhance Education for Sustainable Development (ESD). Expanding on these principles, place-based and culturally responsive pedagogies connect local ecological knowledge with scientific concepts, enriching students' contextual understanding and engagement (Cicchino et al., 2023; Ibnu Fitrianto & Muhammad Farisi, 2025). Likewise, inquiry- and project-based learning models strengthen scientific reasoning and socio-scientific decision-making when grounded in authentic environmental problems (Arifin et al., 2025). While these pedagogical innovations have advanced environmental integration, several gaps remain in the literature. Empirical studies often focus on specific regions, educational levels, or age groups, limiting the generalizability of findings (Tsang, 2014). Moreover, most assessments of learning outcomes emphasize cognitive gains while underrepresenting affective and behavioural dimensions of environmental literacy. Although conceptual syntheses and narrative reviews have outlined pedagogical and theoretical developments, few studies have systematically examined the field's evolution using large-scale, data-driven approaches (Ncube & Ngulube, 2025). This lack of bibliometric evidence leaves unanswered questions about how research on environmental issue integration in science education has developed over time, who its leading contributors are, and what thematic trajectories shape its intellectual structure.

To address these gaps, a bibliometric network approach offers a powerful means of capturing publication trends, thematic structures, and collaboration networks that define the landscape of research on environmental issue integration in science education. While similar analyses have provided valuable insights in related areas of sustainability and science education, there has been no comprehensive bibliometric mapping dedicated specifically to this topic. The period between 2015 and 2025 is particularly significant, as 2015 marks a global turning point with the adoption of the United Nations Agenda 2030 for Sustainable Development, which strengthened international commitments to sustainability-oriented education. Extending the analysis to 2025 provides a full decade of scholarly development, allowing a more comprehensive evaluation of how research on environmental issue integration in science education has evolved in relation to global education and sustainability targets. The present study therefore aims to provide a systematic, quantitative, and network-based analysis of the research landscape on environmental issue integration in science education. This study combines bibliometric indicators and visualization techniques to map the evolution, structure, and intellectual dynamics of the field. It also identifies emerging directions for future research and policy engagement.

The primary aim of this study is to systematically map and analyse the evolution, structure, and intellectual landscape of research on the integration of environmental issues within science education from 2015 to 2025. By employing bibliometric and network analysis, this study seeks to reveal how the field has evolved, who its most influential contributors are, and what conceptual and thematic trajectories define its development. This mapping contributes to a deeper understanding of environmental integration as a growing domain in science education and offers an empirical foundation for future theoretical and practical innovations.



Research Method

This study employs the Systematic Literature Network Analysis (SLNA) method, which combines a Systematic Literature Review (SLR) based on the PRISMA protocol with bibliometric network analysis using Biblioshiny and VOSviewer. The SLNA procedure applied in this research was adapted from previous studies, particularly from Kurdiati et al. (2025), while the SLR process strictly followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. In this study, the Scopus database was used to retrieve publications from 2015 to 2025 concerning the integration of environmental issues in science education within the social sciences domain. The search query applied was: TITLE-ABS-KEY (environmental AND issue AND science AND education) AND PUBYEAR > 2014 AND PUBYEAR < 2027 AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (OA, "all")). This search was limited to peer-reviewed journal articles written in English, available as open access, and categorized under the social sciences subject area. Additional inclusion and exclusion criteria were applied to ensure the relevance of the data, including the exclusion of conference papers, book chapters, reviews, and non-research notes.

The Scopus search covered the period from 2015 to October 2025 and initially retrieved 3,333 records. Following the PRISMA stages of identification, screening, eligibility, and inclusion, several filtering procedures were applied to ensure the relevance and quality of the dataset. At the screening stage, records that did not meet the predefined criteria such as publication year, subject area classification, document type, language, and accessibility were removed using Scopus database filters. The remaining articles were then assessed at the eligibility stage through title and abstract review to determine their relevance to environmental issue integration in science education. Studies addressing environmental topics in broader contexts without a clear connection to science education were excluded. After this process, 63 articles met all inclusion criteria and were retained for the final analysis, as presented in Figure 1.

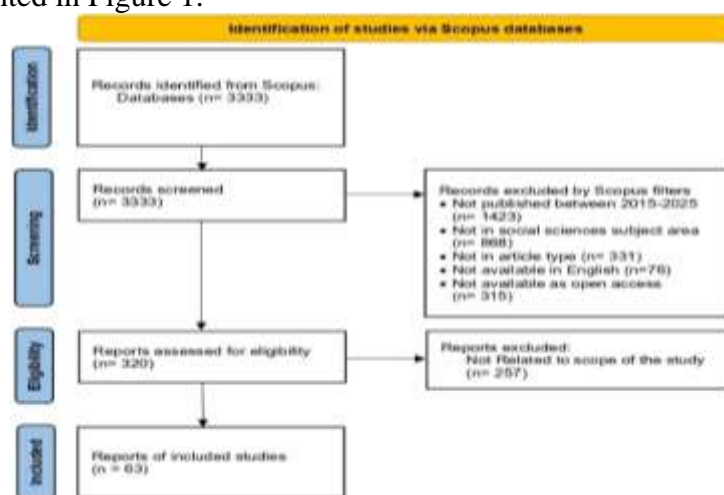


Figure 1. PRISMA Flow Diagram

The metadata obtained from the selected publications were exported in RIS format and subsequently analysed using VOSviewer to identify patterns, interconnections, and structural relationships among the articles. Furthermore, research trends were examined through Biblioshiny by utilizing BibTeX data, allowing for the generation of network and cluster visualizations that illustrate dominant research themes, author collaborations, citation linkages, and thematic evolutions over time. This analytical approach facilitated



comprehensive statistical examinations, including keyword frequency analysis, comparative assessments across publication groups, and the identification of longitudinal trends within the field.

Result and Discussion

Publication Volume (2015–2025)

Examining the temporal distribution of publications provides insight into how scholarly attention to environmental issue integration in science education has developed over time. Understanding these trends helps identify periods of increasing research interest and highlights the momentum of the field in response to global environmental and educational priorities. To further examine how research output has evolved during the study period, Figure 2 illustrates the yearly distribution of publications from 2015 to 2025.

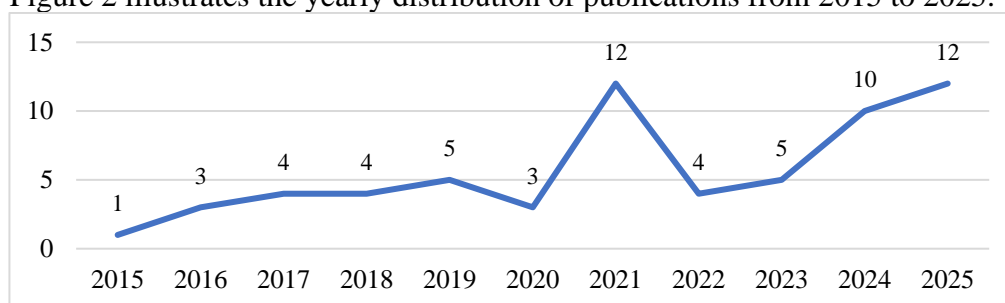


Figure 2. Number of Relevant Publications per year

As shown in Figure 2, the number of publications began to increase more noticeably after 2020, with significant peaks in 2021 and 2025, each reaching 12 publications. This trend reflects the growing scholarly attention to the integration of environmental issues within science education, particularly in response to the expanding global focus on sustainability and environmental challenges. Overall, the publication trajectory indicates a steady and accelerating growth of research in this area over the past decade, highlighting environmental issue integration as an increasingly important theme within contemporary science education research.

Most Prolific Contributors

To understand the key actors shaping research on environmental issue integration in science education, this section examines the geographical distribution of publications, leading institutional affiliations, and the most influential articles in the field. The global distribution of research productivity is illustrated in Figure 3, which shows the contribution of major countries over time.

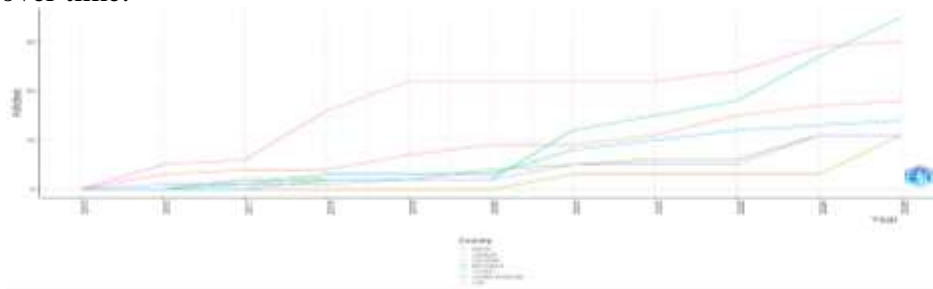


Figure 3. Countries' Production over Time

Figure 3 indicates that research activity in this field is geographically diverse and has expanded across multiple regions. The United States and Indonesia emerge as the most active contributors, both showing substantial increases in publication output during the later years of



the study period. Several other countries, including Brazil, Turkey, Germany, and the United Kingdom, also demonstrate consistent participation, while Canada shows a gradual increase in research activity. These patterns suggest that the integration of environmental issues in science education has become a globally shared research agenda, involving both established research systems and emerging contributors. At the institutional level, the most productive affiliations contributing to this research area are presented in Table 1.

Table 1. Most prolific affiliation

Affiliation	Articles
Universitas Pendidikan Ganesha	7
University of Alberta	7
Ilia State University (ISU)	6
University of York	6
Universidad Autónoma De Madrid	5
Universitas Negeri Malang	5
Universitas Negeri Yogyakarta	5
Universität Bremen	5
Shaanxi Normal University	4
Thai Nguyen University of Education	4

Table 1 shows that leading contributions originate from institutions located across Asia, Europe, and North America, indicating a geographically distributed research network. Universities such as Universitas Pendidikan Ganesha and the University of Alberta appear among the most productive institutions, alongside several other universities that consistently contribute to the development of this research field. To highlight the intellectual foundations of the field, Table 2 presents the most cited articles that have significantly influenced research on environmental integration in science education.

Table 2. Most Cited Articles

Rank	Article	Authors	TC	C/Y
1	Use of the concept of <i>Bildung</i> in the international science education literature, its potential, and implications for teaching and learning	Sjöström et al. (2017)	120	13,33
2	Exploring students' epistemological knowledge of models and modelling in science: results from a teaching/learning experience on climate change	Tasquier et al. (2016)	39	3,90
3	Research-Based Transformative Science/ STEM/ STES/ STESEP Education for "Sustainability Thinking": From Teaching to "Know" to Learning to "Think"	Zoller (2015)	38	3,45

As shown in Table 2, several highly cited studies have shaped the theoretical and pedagogical discourse in this area. The work by Sjöström et al. (2017) stands out as the most influential publication, emphasizing the role of philosophical perspectives such as *Bildung* in science education. Other influential studies, including those by Tasquier et al. (2016) and Zoller (2015), highlight the importance of modelling, sustainability thinking, and transformative approaches in science and STEM education. Collectively, these works have contributed to establishing the conceptual foundations for integrating environmental and sustainability perspectives into science education.



Thematic Map

This study analyses the thematic structure of research on environmental issue integration in science education using a thematic map, which classifies research themes based on their relevance (centrality) and development (density). The thematic distribution is presented in Figure 4.

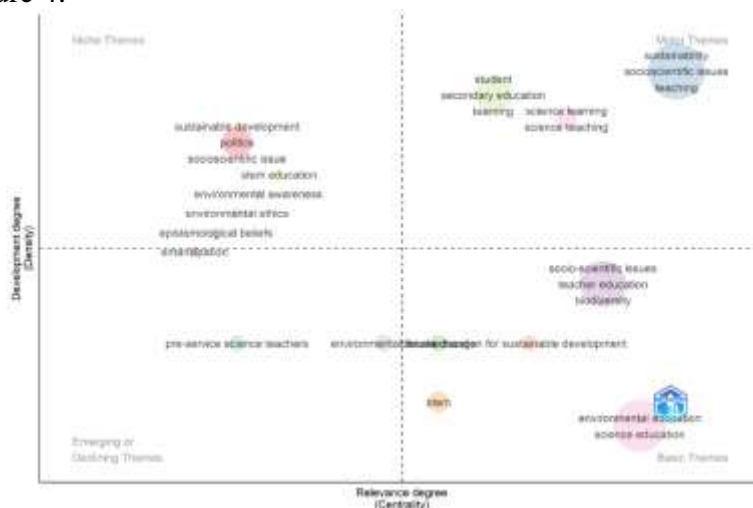


Figure 4. Thematic Map

Figure 4 indicates that sustainability, socio-scientific issues, teaching, and science learning function as Motor Themes, showing that current research strongly emphasizes the integration of environmental issues into science learning through sustainability-oriented and socio-scientific approaches. Themes such as environmental education, science education, biodiversity, and teacher education appear as Basic Themes, suggesting that they serve as the conceptual foundation supporting research on environmental integration in science education.

Meanwhile, topics including sustainable development, environmental ethics, STEM education, epistemological beliefs, and environmental awareness remain in the Niche Themes quadrant. Although conceptually developed, these themes tend to be more specialized and less integrated into the main research agenda. This condition may reflect pedagogical barriers, such as limited teacher preparedness for interdisciplinary instruction, curriculum constraints, and the lack of practical models for integrating sustainability perspectives into science learning.

Finally, pre-service science teachers and education for sustainable development appear as Emerging Themes, indicating that research on teacher preparation and long-term sustainability education is still developing and requires further attention. Overall, the thematic map shows that research is increasingly oriented toward sustainability-based science learning, while challenges related to pedagogy and teacher capacity continue to influence the integration of several important themes within mainstream science education research.

Network Visualization for Co-occurrence

To identify the main thematic relationships within the literature on environmental issue integration in science education, a keyword co-occurrence analysis was conducted. This analysis helps reveal the dominant research themes and how different concepts are interconnected within the field. The resulting keyword network is presented in Figure 5, which visualizes the relationships among frequently used author keywords.

Figure 6 illustrates the chronological development of major research themes in this field. Earlier studies were largely centred on foundational topics such as environmental education, teacher education, biodiversity, and scientific literacy, reflecting the initial efforts to integrate environmental perspectives into science curricula and educational practice. More recent studies increasingly focus on themes such as sustainability, climate change, socio-scientific issues, and education for sustainable development. These topics indicate a growing emphasis on interdisciplinary learning, ethical reasoning, and the role of science education in addressing complex environmental challenges.

Density Visualization for Co-occurrence

To identify the most prominent research themes within the literature, a density visualization of keyword co-occurrence was conducted. This analysis highlights areas where research activity is most concentrated in studies on environmental issue integration in science education. The results of this mapping are presented in Figure 7.

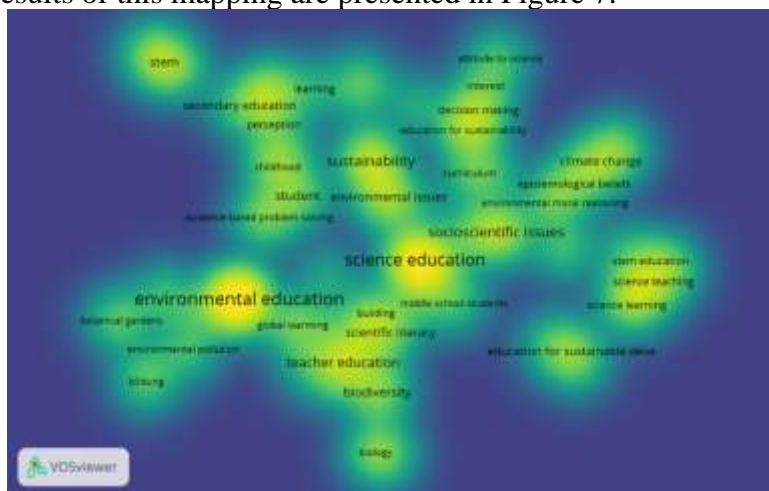


Figure 7. Density Visualization for Co-occurrence

Figure 7 shows that science education, environmental education, and sustainability form the core areas of research concentration in this field. These themes indicate a strong integration between environmental knowledge, pedagogical development, and sustainability-oriented learning. Several closely related themes, including teacher education, scientific literacy, and socio-scientific issues, also appear as important supporting areas, reflecting the emphasis on developing learners' critical thinking and ethical engagement with environmental challenges. In addition, topics such as climate change, STEM education, and education for sustainable development appear as emerging directions that expand the interdisciplinary scope of research.

Agenda for Future Research

The bibliometric findings indicate that research on environmental issue integration in science education continues to grow, yet several conceptual and practical gaps remain. The literature particularly highlights the need to strengthen the alignment between pedagogical innovation, contextualized environmental learning, and teacher collaboration in sustainability-oriented science education. Based on patterns identified through the bibliometric and thematic analyses, Table 3 summarizes several key directions that may guide future research, focusing on pedagogical approaches, contextual integration of environmental issues, and collaborative professional development among teachers.



Table 3. Future Research Questions

Focus Research	Future Research Questions
Innovative pedagogical models integrating environmental and scientific learning	<ul style="list-style-type: none"> • How can context-based and inquiry-oriented learning models effectively integrate environmental issues within science instruction? • What design principles can enhance conceptual understanding while fostering environmental awareness? • To what extent can hybrid or outdoor-based learning environments strengthen students' sustainability competencies?
Contextualizing environmental issues in local and global perspectives	<ul style="list-style-type: none"> • How can local ecological contexts be used to make global environmental issues more relevant for students? • What pedagogical approaches best connect indigenous and scientific knowledge systems in environmental learning?
Designing professional learning communities for sustainable teaching practices.	<ul style="list-style-type: none"> • How can teacher networks and communities of practice foster continuous improvement in environmental teaching? • What forms of collaboration between educators and researchers promote innovation in sustainability pedagogy?

The directions outlined in Table 3 indicate that future studies should prioritize the development of innovative pedagogical models, the contextualization of environmental issues within both local and global perspectives, and the strengthening of collaborative professional communities for teachers. These areas are essential for supporting the effective integration of environmental issues in science education. Advancing research in these directions may contribute to more coherent instructional practices and better prepare students to understand and respond to sustainability challenges in real-world contexts.

The bibliometric results indicate that research on environmental issue integration in science education has grown substantially, particularly after 2019. This trend reflects increasing global attention to sustainability and is consistent with earlier reviews showing that sustainability-oriented science education research expanded following the institutionalization of the Sustainable Development Goals (SDGs) (Guo et al., 2024). The collaborative authorship pattern also indicates that this research domain is inherently interdisciplinary, involving connections among science education, environmental studies, and social sciences, as emphasized by Kimmerer (2012).

The thematic and keyword analyses reveal a clear conceptual transition from foundational themes such as environmental education and scientific literacy toward more integrative orientations, including sustainability, socio-scientific issues, and ethical reasoning. Similar developments were reported by Levy et al. (2021), who highlighted the increasing emphasis on value-based decision making and civic engagement in science learning. Tasquier et al. (2016) also noted that addressing environmental complexity requires learning environments that integrate scientific understanding with modelling, inquiry, and real-world problem contexts.

This shift from scientific literacy to socio-scientific reasoning has important practical implications for science teachers. Scientific literacy traditionally emphasizes understanding scientific concepts and principles, whereas socio-scientific reasoning requires students to interpret evidence, evaluate multiple perspectives, and make informed decisions about complex environmental problems. Consequently, science instruction needs to move beyond knowledge transmission toward learning environments that support discussion, argumentation, and critical evaluation of real-world environmental issues.

In practice, teachers need to incorporate classroom activities that engage students with authentic environmental contexts, such as analyzing local environmental problems, debating



climate-related decisions, and evaluating the societal impacts of scientific developments. Learning approaches such as inquiry-based learning, socio-scientific issue discussions, and community-based environmental projects can help students connect scientific knowledge with ethical reflection and responsible decision making. Through these practices, science classrooms can better prepare students not only to understand environmental problems but also to participate actively in addressing sustainability challenges.

Overall, the findings suggest that environmental issue integration in science education is evolving toward more contextual and participatory forms of learning. For science teachers, this transition implies a shift from teaching environmental knowledge as isolated content toward facilitating students' ability to reason about complex environmental issues and make responsible socio-scientific decisions.

Conclusion

This study provides a comprehensive bibliometric overview of how environmental issue integration in science education has evolved over the past decade and where the field is currently heading. By mapping publication trends, thematic structures, and research frontiers, the findings demonstrate that environmental integration has transitioned from a peripheral concern into a central and interdisciplinary research domain within science education. The steady growth in publications, increasing international collaboration, and consolidation of sustainability-oriented themes indicate a strengthening scholarly commitment to addressing complex environmental challenges through science learning. The intellectual structure of the field reveals a clear orientation toward sustainability, socio-scientific reasoning, and inquiry-based pedagogy, suggesting that environmental issues are increasingly framed as integral to scientific literacy, ethical reasoning, and responsible citizenship. Rather than functioning merely as contextual enrichment, environmental issue integration now represents a transformative paradigm that reshapes the goals, content, and pedagogical approaches of science education. Overall, this study positions environmental issue integration as a dynamic and forward-looking research area, with growing relevance for educational theory, practice, and policy in the context of global sustainability challenges.

Recommendation

Based on the findings of this review, several concise recommendations are proposed.

For Future Researchers

- Conduct longitudinal and context-based studies to examine how environmental issue integration influences students' sustainability awareness and decision-making.
- Explore the effectiveness of socio-scientific and sustainability-oriented pedagogies across diverse educational contexts.

For Practitioners (Science Teachers)

- Integrate real-world environmental and socio-scientific issues into science lessons to strengthen students' reasoning and environmental responsibility.
- Apply inquiry and context-based learning that connects scientific concepts with local environmental contexts.

For Policymakers

- Strengthen teacher professional development in sustainability-oriented science teaching.
- Support curriculum policies that embed environmental issues within science education frameworks.



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