International Journal of Learning Reformation in Elementary Education
Vol. 5, No. 03, pp. 940-964
journal.iistr.org/index.php/IJLREE
DOI: 10.56741/IISTR.ijlree.002543

Environmental Education in Elementary Schools (2015–2025): Scopus-Based Bibliometric Mapping and Thematic Evolution

[1]Vera Yuli Erviana, [1]Sabriyandi*
Corresponding Author: * 2200005228@webmail.uad.ac.id
[1] Universitas Ahmad Dahlan, Yogyakarta, Indonesia

ARTICLE INFO

Article history
Received 31 July 2026
Revised 17 September 2026
Accepted 24 September 2026

ABSTRACT

Environmental education in elementary schools has received significant attention over the past decade amid growing global sustainability challenges, such as climate change and biodiversity loss. This study provides a comprehensive bibliometric analysis of environmental education research published between 2015 and 2025, focusing on dominant and emerging themes, leading contributors, and global collaboration patterns. The findings reveal a substantial increase in research output, particularly after 2019, with prominent themes including curriculum integration, sustainability, climate change, and environmental protection. Emerging themes such as digital integration, STEAM education, and environmental attitudes reflect growing interest in interdisciplinary and technology-enhanced approaches. Spain recorded the highest national publication output, contributing 23 of the 113 publications (approximately 20.4%), while contributions from Europe, Asia, the Americas, and other regions indicate broad international participation. The analysis also identifies weakly connected thematic areas, uneven international collaboration patterns, and opportunities for stronger interdisciplinary and cross-country research linkages. The findings suggest that integrating digital tools, strengthening international collaboration, and incorporating diverse perspectives into sustainability education may support the field's continued development. This review provides policymakers, educators, and researchers with an evidence base to strengthen sustainable learning practices and advance environmental education in elementary schools.

Keywords
Bibliometric Analysis
Digital Integration
Environmental Education
STEAM Education
Sustainability

This is an open-access article under the CC–BY-SA license.

Introduction

Over the last decade, primary education has increasingly been expected to address global sustainability challenges, including biodiversity loss, climate change, and unsustainable resource use [1]–[3]. These pressures have strengthened the view that schooling should not only transmit academic content but also cultivate environmental literacy, values, and dispositions that support responsible decision-making for society and the planet [4]. In line with this shift, UNESCO positions Education for Sustainable Development (ESD) as a strategic pathway to equip learners with the knowledge, skills, and attitudes needed for sustainable living [5]–[6]. At the same time, SDG 4, particularly Target 4.7, calls for inclusive, quality education that integrates sustainability into curricula and educational practices [7]–[10].

Within this agenda, elementary school is a critical stage because children's habits, beliefs, and social-emotional competencies are actively forming, creating an early foundation for long-term environmental stewardship [11]–[13]. Nevertheless, curriculum reviews and policy discussions suggest that environmental education is unevenly embedded across educational systems, and classroom practice often remains indoor and textbook-centered, approaches that may be insufficient for developing sustainability competencies that require experiential, contextual, and meaningful engagement [14], [15]. This tension raises a practical and research-relevant question: how can schools design developmentally appropriate learning experiences that effectively foster environmental awareness and pro-environmental attitudes from an early age?

Reflecting this urgency, environmental education in elementary schools has become an increasingly visible research area, spanning classroom instruction, curriculum integration, and applied learning experiences that connect ecological concepts to children's everyday lives [16], [17]. Empirical studies indicate that well-designed environmental education can enhance student engagement, social interaction, and responsible dispositions, outcomes closely aligned with ESD priorities and SDG 4.7 [18], [19]. Accordingly, research outputs expanded during 2015–2025, positioning elementary environmental education as a key strand within sustainability-oriented educational scholarship.

Despite this growth, the literature remains difficult to interpret holistically [20]–[23]. Studies are dispersed across disciplines and publication venues, and many are context-specific, complicating efforts to identify field-level trends, intellectual structures, thematic priorities,

and collaboration patterns. Consequently, it remains unclear how the field has evolved during the SDG era, which themes are consolidating or emerging, who the most influential contributors are, and where substantive knowledge gaps persist. Addressing these issues requires a systematic, quantitative mapping approach that can synthesize large-scale publication data into interpretable patterns.



Fig. 1. Conceptual Framework for Mapping the Intellectual Structure of Environmental Education Research in Elementary Schools (2015–2025)

As depicted in Figure 1, global sustainability challenges have elevated Education for Sustainable Development (ESD) and SDG 4.7 as normative mandates, positioning environmental education in elementary schools as a strategic pathway for nurturing sustainability competencies and responsible dispositions from an early age. Although research outputs in this area expanded during 2015–2025, the literature remains fragmented across disciplines and publication outlets, limiting a holistic understanding of the field's intellectual structure, thematic evolution, and key contributors.

To address this gap, this study applies a bibliometric approach to systematically map the development of environmental education research in elementary schools during the SDG era, drawing on Scopus-indexed publications (2015–2025), PRISMA-guided selection procedures, and science mapping tools (VOSviewer and Biblioshiny) to examine publication growth and impact, conceptual and intellectual structures, and collaboration networks. By synthesizing dispersed evidence into an integrated knowledge map, the study identifies dominant and emerging themes, low-density clusters, and underexplored research areas, providing an evidence base to inform curriculum development, sustainability-oriented education policy, and future research agendas aligned with ESD and SDG 4.7. Accordingly, the study is guided by the following research questions:

RQ1. How have the volume and impact of environmental education research in elementary schools evolved from 2015 to 2025?

RQ2. Who are the leading contributors in this field (top authors, institutions, and countries), and what are their productivity and influence patterns?

RQ3. What are the dominant and emerging research themes in environmental education for elementary schools, based on keyword co-occurrence and thematic evolution analyses?

RQ4. What challenges and opportunities characterize the development of environmental education research in elementary schools, as reflected in publication patterns, thematic structures, and collaboration dynamics?

RQ5. What underexplored areas, implications, and future research directions can be identified from thematic gaps and low-density clusters?

By answering these questions, this study contributes in three ways: (1) theoretically, by providing a consolidated knowledge map that clarifies the field's intellectual structure and thematic development; (2) methodologically, by offering a replicable workflow that integrates PRISMA-guided screening with bibliometric science mapping; and (3) practically, by generating evidence that can support curriculum design, sustainability-oriented educational policy, and future research priorities aligned with ESD and SDG 4.7.

Methods

A. Research Design

This study used a bibliometric analysis design to map the evolution of environmental education research in elementary schools during 2015–2025. Bibliometric analysis is suitable for examining research development at scale because it quantitatively summarizes scientific production (publication growth and citations) and reveals the field's intellectual structure, conceptual themes, and collaboration networks through science mapping and network visualization.

To ensure transparency and replicability in data selection, this study followed the PRISMA 2020 framework for documenting identification, screening, eligibility assessment, and inclusion decisions [24]. The overall workflow consisted of four stages: (1) identification, (2) screening, (3) eligibility assessment, and (4) inclusion, culminating in a final dataset used for descriptive and network-based bibliometric analyses [25].

B. Data Sources and Search Strategy (Identification)

We retrieved the bibliographic data from Scopus on 2 June 2026. Scopus was selected for its broad coverage of peer-reviewed literature across education and interdisciplinary sustainability-related fields. A Boolean search strategy was developed to identify studies explicitly addressing environmental education within elementary or primary education contexts [26]–[28]. The search was conducted in the title, abstract, and keyword fields (TITLE-ABS-KEY) to balance topical relevance and search sensitivity. Table 1 presents the complete search string and predefined database limits.

Table 1. Scopus Search Strategy and Predefined Study Limits

Search Component	String / Filter
Keywords	TITLE-ABS-KEY ("environmental education") AND TITLE-ABS-KEY("primary education" OR "elementary education" OR "primary school*" OR "elementary school" OR "grade school*")
Document Type	Research Articles
Language	English
Timeframe	2015-2025
Additional Filters	Subject Areas: Social Sciences; Environmental Science; (Education-related scope)

The search strategy was intentionally focused on the established term *environmental education* while incorporating several descriptors commonly used for elementary-level education, including *primary education*, *elementary education*, *primary school*, *elementary school*, and *grade school*. To support search sensitivity, we searched titles, abstracts, and keywords rather than titles alone. In addition, we examined the relevance of retrieved records during title-and-abstract screening and re-checked it during data preprocessing to ensure the final dataset retained a clear elementary/primary education context.

This approach prioritized topical precision while allowing variation in terminology used to describe the educational level. Nevertheless, studies framed exclusively under broader or related concepts, such as *sustainability education*, *education for sustainable development*, or *outdoor education*, without explicitly using the term *environmental education*, may not have been retrieved. This limitation is acknowledged when interpreting the dataset's coverage.

The retrieved records were exported from Scopus in CSV format with complete available bibliographic metadata, including authors, affiliations, titles, abstracts, author keywords, index keywords, sources, cited references, citation counts, and publication years. The exported dataset was subsequently used for descriptive performance analysis and bibliometric science mapping.

C. Duplicate Removal and Title (Screening)

After retrieval, records were cleaned to remove duplicates using Scopus export identifiers and metadata matching (title, DOI, and author–year combinations). Next, we conducted title-and-abstract screening to remove studies clearly outside the scope of environmental education in elementary/primary education, consistent with PRISMA 2020 procedures [24]. We documented the process and decisions in a PRISMA flow diagram (Figure 1).

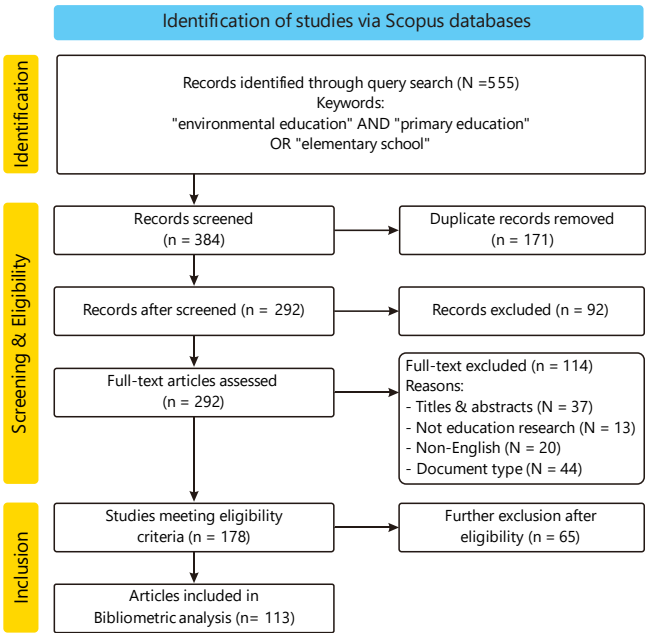


Fig. 2. PRISMA Flowchart of Study Selection

As shown in Fig. 2, global sustainability challenges have elevated Education for Sustainable Development (ESD) and SDG 4.7 as key policy and educational frameworks, positioning environmental education in elementary schools as a pathway to developing sustainability knowledge, competencies, and responsible dispositions from an early age. Although research outputs expanded during 2015–2025, the literature remains distributed across disciplines and publication outlets, limiting a consolidated understanding of its intellectual structure, thematic evolution, and key contributors. Theoretically, the framework clarifies how sustainability, curriculum, pedagogy, and emerging technological themes connect in the field's development. Practically, the evidence can help teachers and curriculum designers identify areas for stronger interdisciplinary, experiential, place-based, and technology-supported environmental learning, while providing policymakers with evidence to align elementary education with ESD and SDG 4.7.

D. Inclusion and Exclusion Criteria (Eligibility)

Eligibility was determined using predefined criteria to ensure included publications directly addressed environmental education in elementary or primary education contexts [29]–[30]. Table 2 summarizes the inclusion and exclusion criteria applied during the eligibility stage.

We excluded conference papers to maintain a more homogeneous bibliographic corpus of final research articles with relatively consistent reporting completeness, metadata structure, and citation characteristics. This decision does not imply that conference proceedings lack scientific or empirical value; rather, it reflects a predefined scope intended to improve comparability across publications included in the bibliometric analysis.

Table 2. Inclusion and Exclusion Criteria

Criteria Type	Inclusion Criteria	Exclusion Criteria
Document Type	Final publication of research articles	Conference papers, review articles, book chapters, editorials, notes, letters.
Publication Timeframe	Published 2015–2025	Published outside 2015–2025
Language and Accessibility	English	Non-English
Research Methodology	Explicitly addresses environmental education in relation to learning/teaching experiences	Does not relate to learning/ teaching (e.g., purely ecological/ technical without educational context)
Educational Stage	Focused on primary/elementary learners, teachers, curriculum, or school setting	Secondary/ higher education, informal adult education (unless primary clearly separable)

Accordingly, potentially relevant evidence reported exclusively in conference proceedings falls outside the scope of the present review.

The final dataset consisted of 113 research articles that met all eligibility criteria and was subsequently used for performance analysis, including productivity and citation indicators, and for science mapping of conceptual, intellectual, and social structures.

E. Data Preprocessing

Before conducting science mapping, the dataset was cleaned to improve the accuracy of bibliometric results. Keywords were standardized by merging synonyms and variants (e.g., "EE" with "environmental education" and harmonizing primary/elementary school terms), harmonizing spelling, and removing overly general terms that could distort thematic networks. We also normalized author names to reduce split identities caused by initials or spelling differences. In addition, we performed a relevance re-check to exclude records that lacked a clear elementary/primary education context. We documented all preprocessing decisions and aligned them with the PRISMA selection process to ensure transparency and replicability.

F. Bibliometric Analysis Procedures and Tools

This study employed complementary bibliometric tools to examine research performance, intellectual structure, thematic development, and collaboration patterns. Microsoft Excel was used for descriptive summaries and verification of annual publication outputs and citation counts [31]. Bibliometrix and its web-based interface, Biblioshiny, were used for performance analysis, bibliographic data exploration, and thematic mapping [32]–[33]. VOSviewer was used to construct, normalize, cluster, and visualize keyword co-occurrence, co-authorship, and co-citation networks [34]–[35]. Python supported reproducible preprocessing and workflow documentation [36].

For VOSviewer network analyses, we applied the full-counting method. In the keyword co-occurrence analysis, we used a minimum occurrence threshold of three to retain terms with sufficient representation in the 113-document dataset. Network relatedness was normalized

using the association-strength method, and clustering used a resolution parameter of 1.00, with a minimum cluster size of three nodes. We included only nodes that met the predefined occurrence or citation threshold and maintained at least one identifiable relationship with another node in the final networks. Before analysis, we standardized synonymous and variant terms during data preprocessing to reduce duplication and improve the interpretability of the resulting clusters.

Thematic interpretation combined structural and temporal indicators. We interpreted Biblioshiny thematic maps using Callon centrality and Callon density, which represent the external connectivity and internal development of thematic clusters, respectively. We examined these measures alongside keyword occurrence frequency and network connectivity in VOSviewer. Temporal patterns were further interpreted through the VOSviewer overlay visualization based on the relative average publication year of keywords. Accordingly, themes with relatively high occurrence and strong network connectivity were interpreted as prominent, whereas topics with more recent temporal positioning and developing network relationships were interpreted as emerging. Themes located at the periphery of the network with comparatively weaker connectivity were described as less central, rather than automatically classified as declining. This combined approach reduced reliance on subjective visual interpretation and provided a more systematic basis for examining thematic evolution across 2015–2025.

Results

A. Evolution of Environmental Education Research (RQ1)

The volume and impact of environmental education research in elementary schools from 2015 to 2025 evolved significantly, reflecting both increased publication output and a growing emphasis on sustainability education [37]–[40]. As illustrated in Figure 2, the number of published documents was low in 2015, with only 3 papers. After brief dips in 2016 and 2017, publication output rose sharply in 2019, peaking at 16 documents and continuing steadily, culminating in 21 publications in 2025. This upward trajectory suggests a clear trend in increasing research focus on environmental education in elementary schools.

Fig. 3 illustrates that this surge in publications aligns closely with the global emphasis on sustainability education, as highlighted by frameworks such as SDG 4.7, which advocates integrating sustainability principles into education systems worldwide [41]–[43]. Post-2020, publication volume has reflected a deeper commitment to addressing pressing global challenges such as climate change and resource depletion, indicating the growing relevance of environmental education within the broader educational agenda [44]–[46].

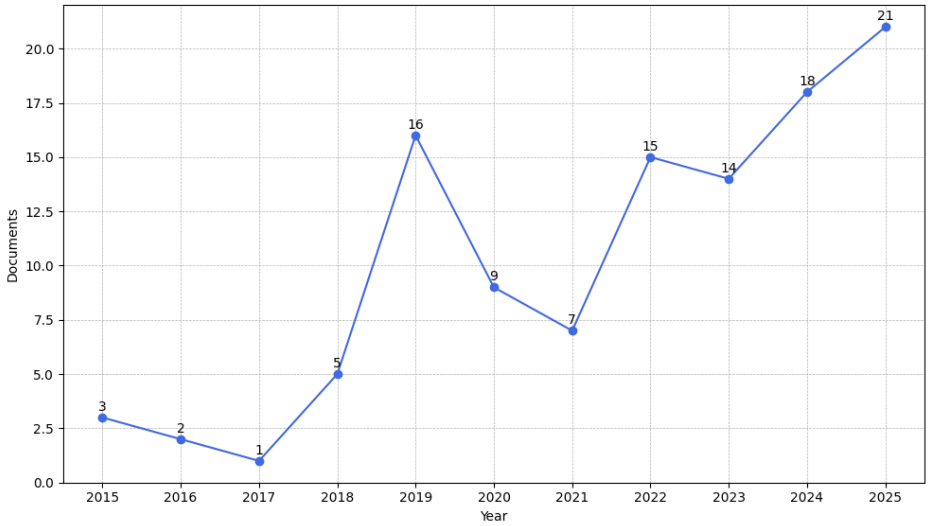


Fig. 3. Yearly Publication Trend of Environmental Education Research in Elementary Schools (2015-2025)

The growing volume of publications over the years clearly indicates that environmental education research in elementary schools has expanded both in quantity and strategic importance, meeting an increasing global demand for sustainability-focused education. This evolution reflects heightened academic interest and responds to the global call for sustainable practices across educational frameworks.

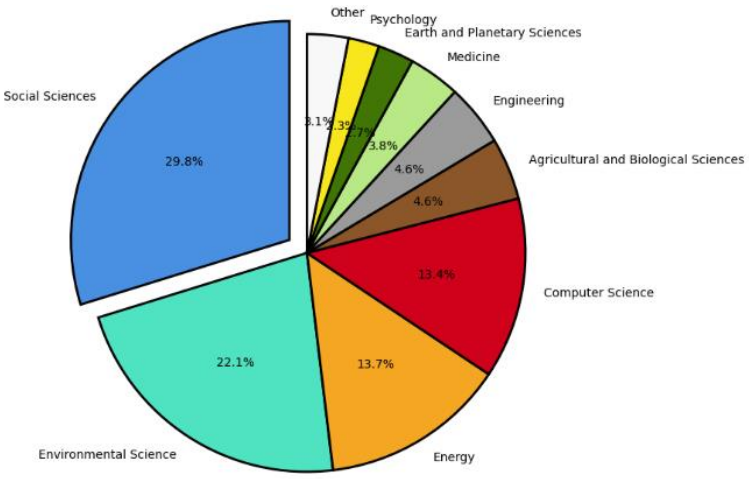


Fig. 4. Distribution of Research Documents by Subject Area

Fig. 4 further demonstrates the diverse range of topics explored within this research field. Social Sciences and Environmental Science account for the largest share of publications, at 29.8% and 22.1%, respectively. These disciplines underscore the interdisciplinary nature of environmental education, where understanding social behaviors and values is essential for promoting sustainable environmental actions in schools [44]–[46]. Fields such as Computer Science and Energy also play a significant role, reflecting the growing integration of technological solutions and energy management in sustainability education. These trends

highlight how the academic field is expanding and embracing interdisciplinary perspectives, particularly in line with Education for Sustainable Development (ESD) and the global push to achieve sustainability goals.

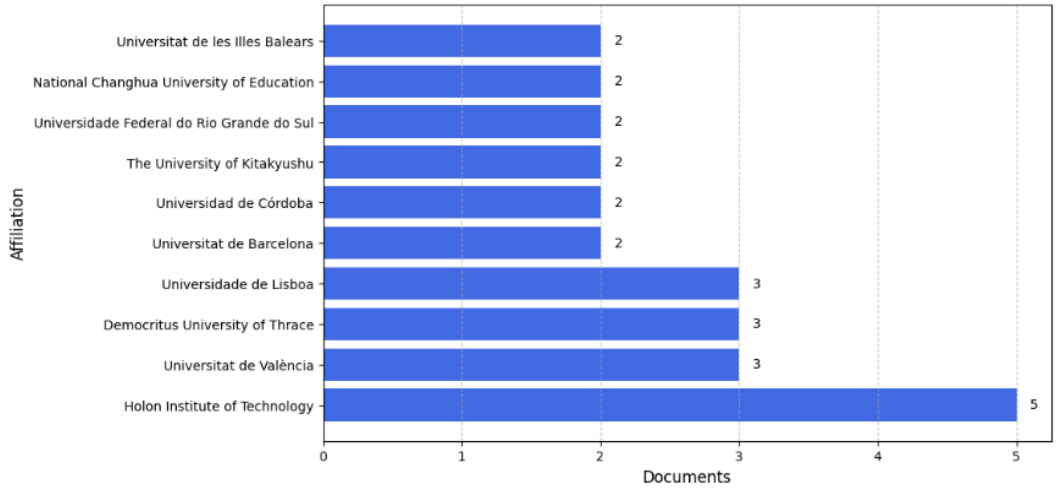


Fig. 5. Documents by Affiliation

Fig. 5 shows the distribution of research contributions by institution, revealing a concentration of publications from the Holon Institute of Technology, followed by other institutions with 2-3 papers. This concentration may suggest centralized research efforts in certain regions or institutions, pointing to a potential area for expansion and inclusivity in sustainability-focused research. The growing volume of research and its impact, as evidenced by institutional contributions, indicate a positive trend toward more structured and widely recognized research in this domain.

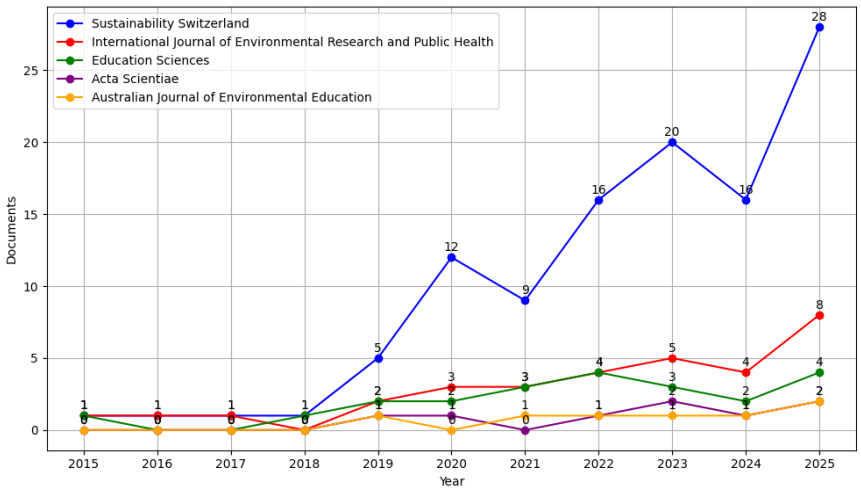


Fig. 6. Documents by Journal (2015–2025)

Additionally, Fig. 6 emphasizes the growing dominance of specific journals in the field. *"Sustainability Switzerland"* is particularly noteworthy, as it saw a significant increase in publications, peaking at 28 documents in 2025. The consistent, modest growth in journals such as the "International Journal of Environmental Research and Public Health" further

underscores the growing attention to sustainability in educational frameworks. However, the concentration of publications in a few prominent journals suggests the field could benefit from more diverse publication outlets to build a more balanced and robust intellectual structure in the future [47]–[49].

In conclusion, the volume of environmental education research in elementary schools has risen steadily from 2015 to 2025, with a marked acceleration after 2019, reflecting the growing global emphasis on sustainability education in answering RQ1. The interdisciplinary nature of the research, along with growing contributions from fields such as the social sciences, environmental sciences, and technology, highlights the field's broadening scope and impact. As publications continue to increase, future research should expand institutional and journal contributions to ensure sustainability education in elementary schools remains diverse, inclusive, and responsive to global challenges**.**

B. Leading Contributors and Influential Networks (RQ2)

The bibliometric analysis of environmental education research in elementary schools identifies influential contributions and geographic patterns of research productivity during 2015–2025. Table 3 presents the dataset's highly cited documents, along with their regional affiliations, publication sources, and Scopus citation counts, providing an overview of influential contributions in the field.

Table 3. Highly Cited Documents in Environmental Education in Elementary Schools (2015–2025)

Ref. No.	Region	Journal & Publisher	Cited by Scopus
[50]	Japan	Sustainable Environment Research	65
[51]	China	International Journal of Environmental Research and Public Health	50
[52]	Spain	International Journal of Environmental Research and Public Health	41
[53]	Germany	Sustainability Switzerland	41
[54]	Indonesia	International Journal of Interactive Mobile Technologies	39
[55]	Turkey	International Research in Geographical and Environmental Education	35
[56]	Spain	International Journal of Environmental Research and Public Health	28
[57]	Lithuania	Sustainability Switzerland	27
[58]	Germany	Sustainability Switzerland	26
[59]	Spain	Sustainability Switzerland	23
[60]	Greece	Sustainability Switzerland	23
[61]	Greece	Education Sciences	22
[62]	Spain	Internet of Things Netherlands	20
[63]	Spain	Sustainability Switzerland	16
[64]	Italy	International Journal of Environmental Research and Public Health	16
[65]	Spain	International Journal of Environmental Research and Public Health	16
[66]	Uganda	ORYX	15

[67]	Portugal	Sustainability Switzerland	15
[68]	Israel	EURASIA Journal of Mathematics, Science and Technology Education	15
[69]	Serbia	Sustainability Switzerland	14

The document represented by [50] from Japan, published in *Sustainable Environment Research*, received the highest Scopus citation count in the dataset (65 citations), followed by [51], from China with 50 citations, [52] from Spain, and [53], from Germany, with 41 citations each. These results indicate that influential contributions originate from several geographic regions and publication outlets rather than from a single national research context.

Spain is nevertheless well represented among the highly cited documents, including contributions represented by [52], [56], [64]. These publications appear across journals such as the *International Journal of Environmental Research and Public Health*, *Sustainability Switzerland*, and *Internet of Things Netherlands*. Rather than indicating dominance of the field as a whole, this pattern shows Spain's comparatively strong representation in the dataset and among its highly cited publications.

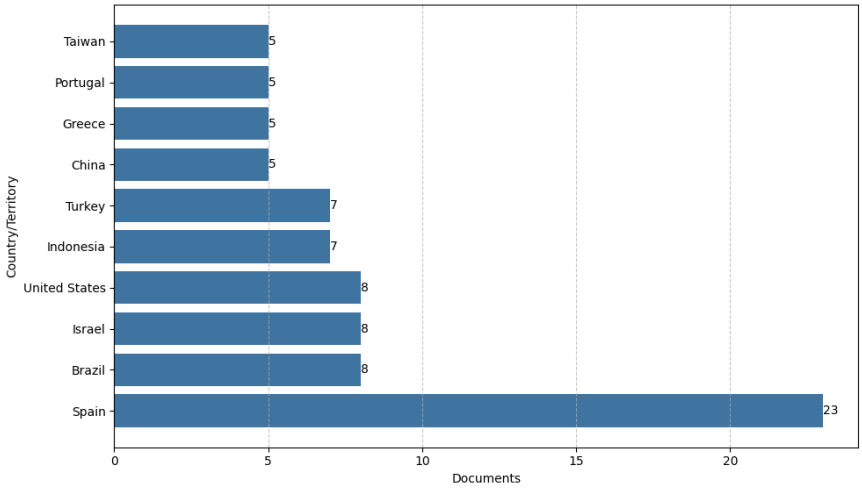


Fig. 7. Documents per Country or Territory

Fig. 7 presents the geographic distribution of publications included in the analysis. Spain recorded the highest publication output, with 23 of the 113 publications in the final dataset, representing approximately 20.4% of the total. Brazil, Israel, the United States, and Indonesia each contributed eight publications, followed by Turkey with seven, while Taiwan, Portugal, Greece, and China each contributed five publications. These results indicate an uneven geographic distribution of research output, with Spain accounting for the largest single-country contribution while substantial participation is also evident across Europe, Asia, the Americas, and other regions. Rather than demonstrating dominance by one country, the distribution reflects different levels of national research participation and highlights opportunities to broaden contributions from less-represented regions [70]–[71].

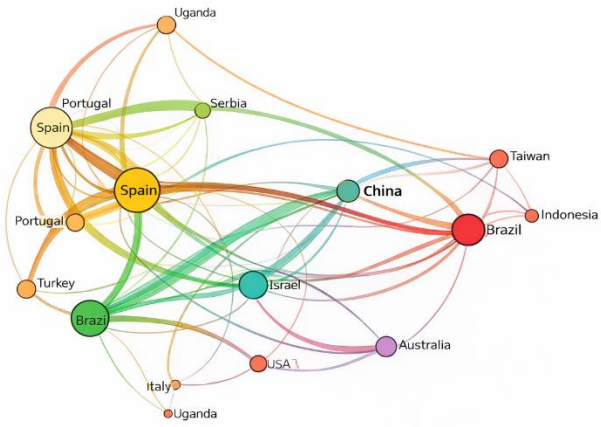


Fig. 8. Global Collaboration in Environmental Education Research in Elementary Schools

Fig. 8 illustrates the international collaboration patterns represented in the dataset. Cross-country research links are visible among contributors from several regions, including Europe, Asia, the Americas, and other parts of the world. However, these relationships are unevenly distributed, with some countries showing international connections while other contributions remain more nationally concentrated. Spain has a comparatively high publication presence in the dataset, but the collaboration map also demonstrates participation from countries such as Brazil, Israel, Indonesia, and other national contexts [72]–[74].

Because formal network-density and centrality statistics were not calculated for this comparison, the collaboration structure is interpreted descriptively rather than characterized as having quantitatively "low collaboration density." The observed pattern instead suggests an uneven distribution of international research linkages, with opportunities to strengthen cross-country knowledge exchange and broaden participation across regions [75]–[76]. Greater involvement of countries and regions with lower publication representation could further diversify perspectives on environmental education and strengthen the international knowledge base supporting sustainability-oriented education [77]–[79].

Overall, the findings address RQ2 by showing that research influence and productivity are distributed across multiple geographic contexts, although national contributions remain uneven. Spain recorded the highest publication output, contributing 23 of the 113 publications (approximately 20.4%), while highly cited studies also originated from Japan, China, Germany, Indonesia, Turkey, and other countries. International collaboration is evident across several regions, although cross-country linkages remain uneven. These patterns highlight opportunities to strengthen international research networks, broaden geographic participation, and facilitate knowledge exchange across different educational and sustainability contexts.

C. Dominant and Emerging Themes in Environmental Education (RQ3)

The thematic analysis of environmental education research in elementary schools reveals significant trends in both dominant and emerging themes. As depicted in Figure 8, the keyword co-occurrence analysis highlights how various concepts within the field are interconnected. The central node, "environmental education," links to core themes such as "primary education," "sustainability," and "education," underscoring the field's interdisciplinary nature. Surrounding clusters such as "climate change," "students," "teaching," and "environmental protection" reflect the diverse and complex issues addressed in environmental education, underscoring the broader goals of fostering environmental awareness and sustainability.

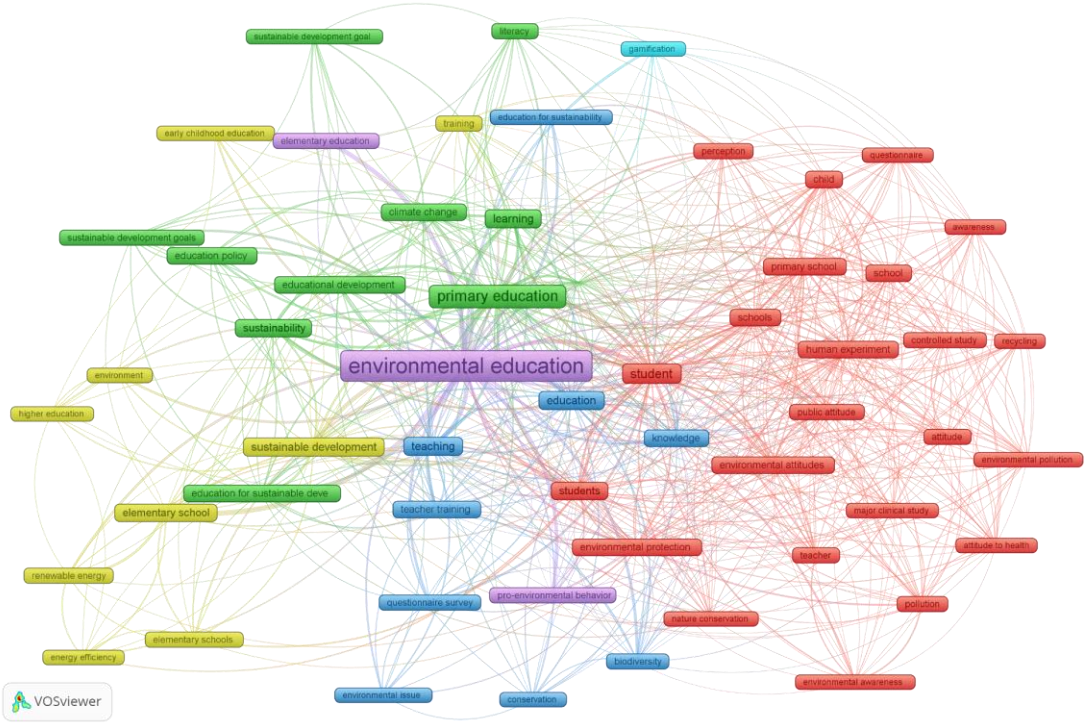


Fig. 9. Network Visualization of Environmental Education Research in Elementary Education

Fig. 9 further illustrates the evolution of research over time. The color gradient in the overlay visualization highlights a shift from foundational themes to more specific, emerging topics. Notably, the focus is increasingly on sustainability-related themes such as "environmental protection," "biodiversity," and "energy efficiency." This shift reflects growing attention to practical environmental issues and sustainable behaviors, suggesting a deeper integration of sustainability frameworks into educational practices.

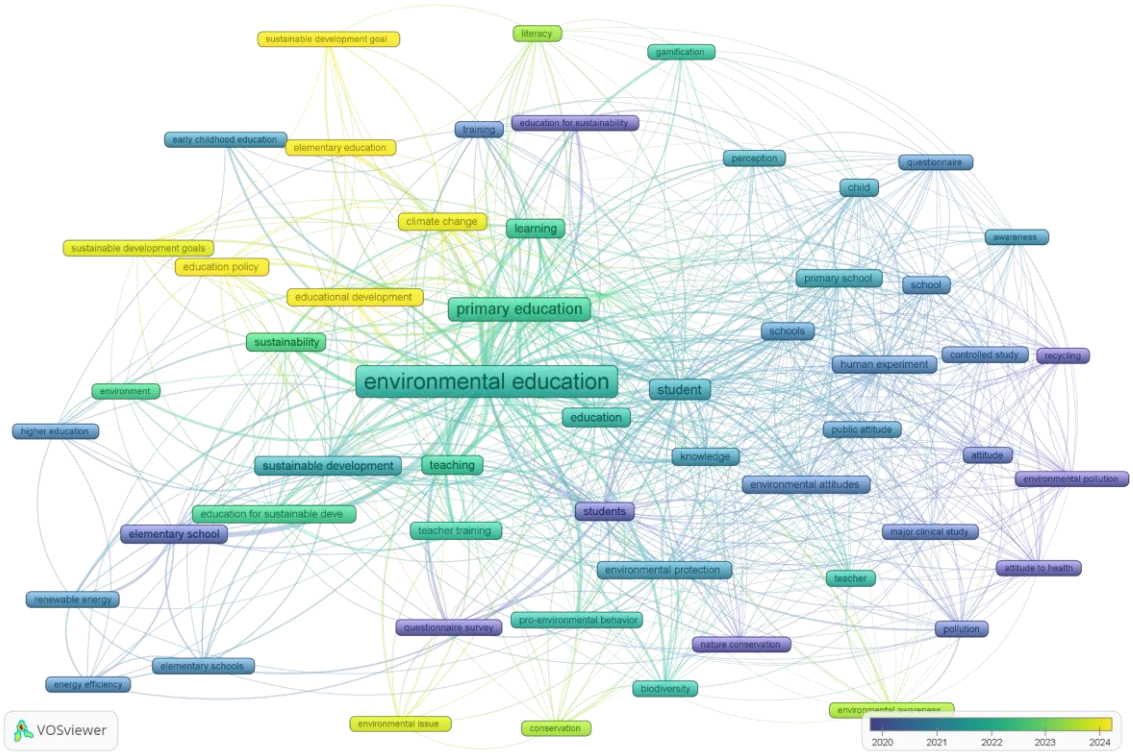


Fig. 10. Overlay Visualization

In addition to these visualizations in Fig. 9 and Fig. 10, Table 4 summarizes the motor, basic, and emerging themes identified through Biblioshiny's thematic map analysis. Dominant themes such as "curriculum integration" and "sustainability" reflect well-established areas of focus in environmental education, with an increasing emphasis on more innovative approaches. Emerging themes such as "digital integration" and "STEAM education" reflect a shift towards interdisciplinary, technology-enhanced learning models. The table also highlights the declining focus on traditional methods such as "textbook-based learning" and "top-down approaches," underscoring the ongoing transition to more student-centered, experiential learning.

Table 4. Dominant, Emerging, and Declining Themes in Environmental Education for Elementary Schools (2015–2025)

Theme Category	Themes	Description	Implication for Practice
Dominant Themes	Curriculum Integration	Integrating environmental education across subjects to promote sustainability.	Supports holistic environmental literacy across various disciplines.
	Sustainability	Emphasizing resource conservation, energy efficiency, and waste management.	Encourages sustainable behaviors in students' daily lives.
	Climate Change	Addresses the global impact of climate change on communities and ecosystems.	Prepares students to respond to climate-related challenges.
	Environmental Protection	Promoting ecological stewardship through education.	Strengthens environmental responsibility and action-oriented learning.

Theme Category	Themes	Description	Implication for Practice
	Biodiversity	Focusing on the conservation of biodiversity and ecosystems.	Enhances students' understanding of species and ecosystem interconnections.
Emerging Themes	Digital Integration	Incorporating digital tools like virtual learning and data analytics.	Enhances interactive and personalized environmental education.
	STEAM Education	Combining science, technology, engineering, arts, and mathematics with education.	Fosters creative problem-solving and critical thinking in environmental contexts.
	Environmental Attitudes	Promoting eco-conscious behaviors and participation in environmental causes.	Encourages the internalization of sustainable values.
	Place-Based Education	Focusing on local environmental issues and ecosystems.	Connects students with their local environment, enhancing real-world relevance.
	Technology and Innovation	Exploring technological solutions for sustainability challenges.	Prepares students for future innovations in sustainability.
Declining Themes	Traditional, Textbook-Based Learning	Reliance on reading and memorization with minimal field-based learning.	Shifting toward more engaging and hands-on learning experiences.
	Top-Down Approaches	Teacher-directed learning with limited student involvement.	Encourages more student-centered learning.
	Single-Subject Focus	Environmental education is an isolated subject.	Promotes interdisciplinary integration across various subjects.
	Passive Learning Approaches	Focus on lectures, reading, and rote memorization.	Moving towards more interactive and experiential learning methods.

These findings answer RQ3 by showing a shift in environmental education research from core topics such as climate change and biodiversity to more interdisciplinary, technology-driven approaches. As shown in Figures 8 and 9 and Table 4, the integration of digital tools and innovative pedagogies is becoming increasingly prominent, indicating a growing trend toward dynamic, modern educational practices. The decline of traditional, passive learning methods and the rise of student-centered, experiential approaches reflect a broader shift in educational paradigms that aligns with contemporary sustainability goals. Thus, this thematic evolution suggests a promising future for environmental education, with ongoing innovations that will likely continue to adapt to students' and the environment's needs.

D. Challenges and Opportunities in Environmental Education Research (RQ4)

The bibliometric analysis reveals several key challenges in environmental education research for elementary schools. A significant issue is the fragmented nature of research topics, which hinders the field's development and interdisciplinary collaboration. Clusters such as curriculum design and environmental literacy are weakly connected, reflecting the literature's isolated treatment of sustainability and education. For instance, "climate change" appears on

the periphery of the research network, while themes like sustainability have yet to be effectively integrated into fields like engineering or economics [80]–[83]. This fragmentation slows the field's evolution and diminishes its capacity to foster meaningful interdisciplinary exchange.

Moreover, the co-authorship network displays low collaboration density, with many studies being single-country publications. This lack of international partnerships weakens global knowledge sharing and limits the impact of environmental education research. The concentration of research in specific countries restricts the diversity of perspectives and regional expertise that could enrich the global sustainability education agenda [84]–[85].

Despite these challenges, the field offers notable opportunities for growth. Emerging clusters are forming around themes such as digital technology, STEAM education, and learner attitudes, indicating a shift toward more dynamic, interdisciplinary approaches. Integrating digital tools such as augmented reality (AR), virtual reality (VR), and mobile applications has been shown to enhance student engagement and environmental awareness [86]–[87]. These technological innovations present an opportunity to create more interactive, engaging, and impactful educational experiences that resonate with today's learners. Furthermore, the growing integration of keywords like "technology" and "innovation" reflects the increasing crossover between environmental education and technological disciplines [88]–[89].

Another key opportunity is to broaden the geographic diversity of contributions. While the global collaboration map shows increasing participation from regions such as Asia and Africa, the predominance of research from Western countries suggests an imbalance. Including more diverse perspectives from underrepresented regions could lead to a more equitable approach to sustainability education, ensuring that global challenges are addressed from multiple cultural and environmental contexts [43], [90]. Strengthening international collaboration, particularly between underrepresented countries and established research hubs, would enhance the overall quality and innovation in the field.

Finally, integrating indigenous and local knowledge into environmental education, particularly through digital tools, holds significant potential. Research in this area could foster more inclusive, locally relevant sustainability education by bridging traditional ecological knowledge with modern environmental challenges [91]–[93]. This integration could deepen students' understanding of global sustainability challenges while connecting them to their local environments. In summary, while challenges such as fragmented research, low collaboration, and regional concentration persist, the emerging themes and opportunities highlighted in this analysis point to a promising future for environmental education research in elementary schools.

E. Underexplored Areas and Future Research Directions (RQ5)

The thematic analysis of environmental education for elementary schools has identified several key underexplored areas that present opportunities for future research. One significant gap is the limited focus on community involvement in environmental education (EE). Although much existing research focuses on classroom integration, it places less emphasis on how communities can actively foster sustainability education [94]–[96]. Incorporating community-based initiatives could enhance the real-world relevance of environmental concepts and engage students more deeply in local environmental challenges [97]–[98]. This direction offers considerable potential to strengthen the connection between education and environmental action across diverse contexts, making it a crucial area for future exploration.

Another notable underexplored area is the lack of cross-cultural approaches to sustainability education. While global interest in sustainability is growing, much of the research remains concentrated in Europe and North America. Regions like the Global South remain underrepresented in the literature [99]. Cross-cultural studies could provide valuable insights into how environmental education is adapted to diverse socio-economic and cultural contexts, leading to more inclusive educational strategies. Future research should bridge these gaps to ensure environmental education is globally relevant and culturally sensitive [69].

There is also a clear need for more robust research designs. Many existing studies are cross-sectional, limiting the understanding of the long-term impacts of environmental education on students' attitudes and behaviors. Longitudinal studies, mixed-methods approaches, and classroom intervention studies would provide a deeper understanding of how environmental education influences students over time [100]–[101]. Such designs could generate more comprehensive insights into the effectiveness of different teaching strategies, curriculum integration, and technology's role in promoting sustainability education.

Further, strengthening the integration of policy, curriculum, and classroom practices is essential. While environmental education has gained recognition, its implementation remains fragmented [102]. Future research should explore how national and local sustainability policies align with curriculum development and classroom teaching practices. Investigating how teachers are supported in delivering sustainability education and how curricula are updated to reflect global sustainability goals, especially SDG 4.7, is critical for creating cohesive educational frameworks [8]–[9].

Finally, international collaboration remains a key area for improvement. The bibliometric analysis shows that many studies remain single-country publications, limiting knowledge exchange across borders [103]. Strengthening international networks, especially between underrepresented countries, would enhance the quality and innovation in environmental education research. This could be achieved by developing shared frameworks, standardizing

key terms, and fostering interdisciplinary collaborations across environmental science, education, and technology [103]. In conclusion, addressing these underexplored areas and pursuing these future research directions would significantly advance environmental education in elementary schools, aligning with RQ5 and supporting global sustainability challenges while fostering sustainable practices in future generations.

Limitations of the Review

The review presented here has several limitations that must be acknowledged when interpreting its findings. First, the data scope is limited to publications indexed in Scopus between 2015 and 2025. As a result, the review excludes studies from other databases, gray literature, and non-English language publications, potentially omitting important contributions, particularly from regions with limited access to international databases. Second, the review's timeframe is limited to publications from 2015 to 2025, excluding longer-term historical trends that may have shaped environmental education research before 2015. Consequently, this analysis may not fully capture the impact of global policy changes or the complete implementation of the Sustainable Development Goals (SDGs).

Furthermore, geographic and thematic limitations remain, with research predominantly concentrated in certain countries, such as Spain. This concentration could introduce biases, particularly by underrepresenting research from regions of the Global South. Finally, the study primarily focuses on academic contributions, potentially overlooking valuable insights from practitioners and community-based projects in environmental education.

Conclusion

This study mapped the development of environmental education research in elementary schools from 2015 to 2025, highlighting publication growth, thematic development, geographic contributions, and collaboration patterns. The field expanded substantially during the study period, particularly after 2019, with prominent attention to sustainability, climate change, biodiversity, curriculum integration, and environmental protection. More recent research attention also extends toward digital integration, STEAM education, environmental attitudes, and other interdisciplinary approaches. Spain recorded the highest national publication output, contributing 23 of the 113 publications, while contributions from multiple regions show the field's increasingly international character. Nevertheless, the thematic and collaboration networks remain unevenly connected, indicating opportunities for stronger interdisciplinary and cross-country knowledge exchange.

The findings also identify several gaps relevant to developing sustainable learning environments in elementary schools, particularly in community-connected learning, cross-

cultural perspectives, longitudinal and classroom-based evidence, and stronger alignment among sustainability policy, curriculum, and teaching practice. Sustainable learning environments may therefore be strengthened through participatory, context-responsive, interdisciplinary, and appropriately technology-supported approaches that connect environmental knowledge with students' everyday experiences. Addressing these gaps can contribute directly to SDG 4.7 by strengthening the knowledge, competencies, values, and educational practices required for sustainable development. Accordingly, this bibliometric map provides an evidence base for researchers, educators, curriculum developers, and policymakers to prioritize future research and strengthen sustainability-oriented elementary education.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] P. Glavič, "Identifying key issues of education for sustainable development," *Sustain.*, vol. 12, no. 16, pp. 1–18, 2020, doi: 10.3390/su12166500.

[2] H. Kopnina, Education for the future? Critical evaluation of education for sustainable development goals," *J. Environ. Educ.*, vol. 51, no. 4, pp. 280–291, 2020, doi: 10.1080/00958964.2019.1710444.

[3] C. Bangay, "Education, anthropogenic environmental change, and sustainable development: A rudimentary framework and reflections on proposed causal pathways for positive change in low- and lower-middle income countries," *Dev. Policy Rev.*, vol. 40, no. 6, pp. 1–19, 2022, doi: 10.1111/dpr.12615.

[4] R. Lee and S. Al-Adeimi, "Supporting literacy through the Justice and Dialogic Education (JADE) framework," *Read. Res. Q.*, vol. 60, no. 4, pp. 1–14, 2025, doi: 10.1002/rrq.70062.

[5] H. Oe and Y. Yamaoka, "A qualitative assessment of community learning initiatives for environmental awareness and behaviour change: Applying UNESCO Education for Sustainable Development (ESD) framework," *Int. J. Environ. Res. Public Health*, pp. 1–21, 2022, doi: 10.3390/ijerph19063528.

[6] S. Jangde and M. A. Ahmad, "Integrating sustainability into equal education opportunities," in *Environ. Landscape and Sustain. Biodiversity for Healthy Green Growth*, pp. 97–103, 2025, doi: 10.1007/978-3-031-75405-0_10.

[7] R. P. Xuan and M. H. Lindqvist, "Exploring sustainable development goals and curriculum adoption: A scoping review from 2020–2025," *Societies*, vol. 15, no. 8, pp. 1–25, 2025, doi: 10.3390/soc15080212.

[8] D. Pérez-Jorge and M. C. Martínez-Murciano, "Quality education for sustainability: A systematic review of primary education initiatives aligned with SDG 4," *Pedagog. Soc. Rev. Interuniv.*, vol. 48, pp. 183–197, 2025, doi: 10.7179/PSRI_2026.48.11.

[9] J. Holst, M. Singer-Brodowski, A. Brock, and G. de Haan, "Monitoring SDG 4.7: Assessing education for sustainable development in policies, curricula, training of educators and student assessment (input-indicator)," *Sustain. Dev.*, vol. 32, no. 4, pp. 3908–3923, 2024, doi: 10.1002/sd.2865.

[10] M. Gawlik-Kobylińska, "Four-dimensional instructional design as a framework for immersive learning to advance inclusive education (SDG 4)," *Int. J. Sustain. High. Educ.*, no. 2019, pp. 1–29, 2026, doi: 10.1108/ijshe-08-2025-0920.

[11] Y. Lin, M. A. A. Kadir, and D. Kaur, "Preschool educators' perceptions on values education," *Educ. Sci.*, vol. 15, no. 2, pp. 1–17, 2025, doi: 10.3390/educsci15020140.

[12] R. AlAli, A. Al-Barakat, T. Alrosaa, S. Alotaibi, A. Abdullatif, and S. Almughyirah, "Science education and environmental identity: An integrative approach to fostering sustainability practices in primary school students," *Sustain.*, vol. 17, no. 19, pp. 1–30, 2025, doi: 10.3390/su17198883.

[13] N. Z. Abiddin, R. Omar, and M. Saroni, "Cultivating empathy and environmental stewardship: Harnessing the partnerships of parents, teachers and communities for sustainable moral

development and social cohesion," *Rev. Gest. Soc. e Ambient.*, vol. 18, no. 8, pp. 1–20, 2024, doi: 10.24857/rgsa.v18n8-052.
[14] X. Zhang, W. Jung, and M. Asari, "Systematic review of environmental education teaching practices in schools: Trends and gaps (2015–2024)," *Sustain.*, vol. 17, no. 19, pp. 1–18, 2025, doi: 10.3390/su17198561.
[15] I. Guevara-Herrero, B. Bravo-Torija, and J. M. Pérez-Martín, "Educational practice in education for environmental justice: A systematic review of the literature," *Sustain.*, vol. 16, no. 7, pp. 1–17, 2024, doi: 10.3390/su16072805.
[16] I. Maryani, S. Latifah, L. Fatmawati, V. Y. Erviana, and F. N. Mahmudah, "Technology readiness and learning outcomes of elementary school students during online learning in the new normal era," *Pegem Egit. ve Ogr. Derg.*, vol. 13, no. 2, pp. 45–49, 2023, doi: 10.47750/pegegog.13.02.06.
[17] V. Y. Erviana and Y. Sepriansyah, "The effectiveness of virtual reality media on primary school students' learning outcomes," *Int. J. Elem. Educ.*, vol. 8, no. 1, pp. 141–149, 2024, doi: 10.23887/ijee.v8i1.67734.
[18] K. Velempini, "Assessing the role of environmental education practices towards the attainment of the 2030 sustainable development goals," *Sustain.*, vol. 17, no. 5, pp. 1–20, 2025, doi: 10.3390/su17052043.
[19] I. M. Gunamantha and I. N. Dantes, "Cultivating environmental literacy in the classroom: A study of knowledge, attitudes, and behavior toward 3R in Indonesian elementary education in support of SDG 4.7," *J. Lifestyle SDGs Rev.*, vol. 5, no. 6, e06779, 2025, doi: 10.47172/2965-730X.SDGsReview.v5.n06.pe06779.
[20] B. Miseliunaite, I. Kliziene, and G. Cibulskas, "Can holistic education solve the world's problems: A systematic literature review," *Sustain.*, vol. 14, no. 15, pp. 1–20, 2022, doi: 10.3390/su14159737.
[21] N. C. Miller *et al.*, "The outcomes of nature-based learning for primary school aged children: A systematic review of quantitative research," *Environ. Educ. Res.*, vol. 27, no. 8, pp. 1115–1140, 2021, doi: 10.1080/13504622.2021.1921117.
[22] S. Koul and B. Nayar, "The holistic learning educational ecosystem: A classroom 4.0 perspective," *High. Educ. Q.*, vol. 75, no. 1, pp. 98–112, 2021, doi: 10.1111/hequ.12271.
[23] J. E. van Dijk-Wesselius, A. E. van den Berg, J. Maas, and D. Hovinga, "Green schoolyards as outdoor learning environments: Barriers and solutions as experienced by primary school teachers," *Front. Psychol.*, vol. 10, pp. 1–16, 2020, doi: 10.3389/fpsyg.2019.02919.
[24] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *BMJ*, vol. 372, pp. 1–9, 2021, doi: 10.1136/bmj.n71.
[25] R. F. A. Saputra, M. Ridha, and J. T. Sulaimon, "Deep learning applications in primary education: A systematic literature review of emerging trends, challenges, and opportunities," *J. Pendidik. Progresif*, vol. 15, no. 3, pp. 1785–1810, 2025, doi: 10.23960/jpp.v15i3.pp1785-1810.
[26] M. Pourreza and F. Ensan, "Towards semantic-driven boolean query formalization for biomedical systematic literature reviews," *Int. J. Med. Inform.*, vol. 170, e104928, 2023, doi: 10.1016/j.ijmedinf.2022.104928.
[27] M. Gusenbauer and N. R. Haddaway, "Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources," *Res. Synth. Methods*, vol. 11, no. 2, pp. 181–217, 2020, doi: 10.1002/jrsm.1378.
[28] H. Scells, G. Zuccon, and B. Koopman, "A comparison of automatic Boolean query formulation for systematic reviews," *Inf. Retr. J.*, vol. 24, no. 1, pp. 3–28, 2021, doi: 10.1007/s10791-020-09381-1.
[29] Y. Jing, C. Wang, Y. Chen, H. Wang, T. Yu, and R. Shadiev, "Bibliometric mapping techniques in educational technology research: A systematic literature review," *Educ. Inf. Technol.*, vol. 29, no. 8, pp. 9283–9311, 2024, doi: 10.1007/s10639-023-12178-6.
[30] A. Heirali *et al.*, "Eligibility criteria of randomized clinical trials in critical care medicine," *JAMA Netw. Open*, vol. 8, no. 1, pp. 1–14, 2025, doi: 10.1001/jamanetworkopen.2024.54944.
[31] G. S. Miñan, J. A. Moreno, and X. D. Fernández, "LIA method for the application of Microsoft Excel in data tabulation in systematic reviews," in *CEUR Workshop Proceedings*, 2023, pp. 44–55.
[32] H. Mondal, "A technical note on bibliometric analysis by Biblioshiny and VOSviewer," *Indian J. Radiol. Imaging*, vol. 36, no. 2, pp. 167-174, 2025, doi: 10.1055/s-0045-1810060.
[33] B. D. Ghorbani, "Bibliometrix: Science mapping analysis with R Biblioshiny based on Web of Science in applied linguistics," in *A Scientometrics Res. Perspective in Appl. Ling.*, 2024, pp. 197–234. doi: 10.1007/978-3-031-51726-6_8.
[34] A. Kirby, "Exploratory bibliometrics: Using VOSviewer as a preliminary research tool," *Publications*, vol. 11, no. 1, pp. 1–14, 2023, doi: 10.3390/publications11010010.
[35] A. Kemeç and A. T. Altınay, "Sustainable energy research trend: A bibliometric analysis using

VOSviewer, RStudio Bibliometrix, and CiteSpace Software Tools," *Sustain.*, vol. 15, no. 4, pp. 1–21, 2023, doi: 10.3390/su15043618.

[36] A. Lavanya *et al.*, "Assessing the performance of Python data visualization libraries: A eview," *Int. J. Comput. Eng. Res. Trends*, vol. 10, no. 1, pp. 28–39, 2023, doi: 10.22362/ijcert/2023/v10/i01/v10i0104.

[37] N. M. Ardoin, A. W. Bowers, N. W. Roth, and N. Holthuis, "Environmental education and K-12 student outcomes: A review and analysis of research," *J. Environ. Educ.*, vol. 49, no. 1, pp. 1–17, 2018, doi: 10.1080/00958964.2017.1366155.

[38] J. O'Flaherty and M. Liddy, "The impact of development education and education for sustainable development interventions: A synthesis of the research," *Environ. Educ. Res.*, vol. 24, no. 7, pp. 1031–1049, 2018, doi: 10.1080/13504622.2017.1392484.

[39] Z. Yan, Mohd H. Mohd Yasin, Mohd S. O. Fauzee, and W. WanNik, "The research landscape of environmental education for sustainable development in basic education: A bibliometric analysis," *Eastasouth J. Learn. Educ.*, vol. 3, no. 02, pp. 104–122, 2025, doi: 10.58812/esle.v3i02.581.

[40] Z. Arifin, S. Sukarmin, and S. Saputro, "Trends and research frontiers in socioscientific issues for sustainable science education: A systematic and bibliometric analysis from 2014 – 2024," *J. Pedagog. Res.*, vol. 9, no. 1, pp. 407–434, 2025, doi: 10.33902/JPR.202530575.

[41] A. Achmadi, M. Zulianto, I. Ruslianto, and M. Thoharudin, "Mapping global trends and emerging themes in learning evaluation for quality education (SDG 4): A bibliometric analysis," *Int. J. Sustain. Dev. Plan.*, vol. 20, no. 9, pp. 3717–3730, 2025, doi: 10.18280/ijsdp.200907.

[42] N. Giangrande *et al.*, "A competency framework to assess and activate education for sustainable development: Addressing the UN sustainable development goals 4.7 challenge," *Sustain.*, vol. 11, no. 10, pp. 1–16, 2019, doi: 10.3390/su11102832.

[43] M. B. Tafese and E. Kopp, "Embedding social sustainability in education: A thematic review of practices and trends across educational pathways from a global perspective," *Sustain.*, vol. 17, no. 10, pp. 1–21, 2025, doi: 10.3390/su17104342.

[44] D. A. Mosoh, O. Prakash, A. K. Khandel, and W. A. Vendrame, "Preserving earth's flora in the 21st century: Climate, biodiversity, and global change factors since the mid-1940s," *Front. Conserv. Sci.*, vol. 5, pp. 1–40, 2024, doi: 10.3389/fcosc.2024.1383370.

[45] A. Al-Maadid, M. S. Ben Ali, and K. Si Mohammed, "The effect of climate risk on the human development index using the panel time-varying interactive fixed effects," *Environ. Sustain. Indic.*, vol. 27, e100757, 2025, doi: 10.1016/j.indic.2025.100757.

[46] M. Senevirathne, H. A. C. Priyankara, D. Amaratunga, R. Haigh, N. Weerasinghe, and C. Nawaratne, "A capacity needs assessment to integrate MOOC-based climate change education with the higher education institutions in Europe and developing countries in Asia: Findings of the focused group survey in PCHEI under the BECK project," *Int. J. Disaster Resil. Built Environ.*, vol. 12, no. 5, pp. 515–527, 2021, doi: 10.1108/IJDRBE-07-2020-0074.

[47] Z. Lin and N. Li, "Global diversity of authors, editors, and journal ownership across subdisciplines of psychology: Current state and policy implications," *Perspect. Psychol. Sci.*, vol. 18, no. 2, pp. 358–377, 2023, doi: 10.1177/17456916221091831.

[48] D. Wu, X. Lu, J. Li, and J. Li, "Does the institutional diversity of editorial boards increase journal quality? The case economics field," *Scientometrics*, vol. 124, no. 2, pp. 1579–1597, 2020, doi: 10.1007/s11192-020-03505-6.

[49] S. van Bellen, J. P. Alperin, and V. Larivière, "Scholarly publishing's hidden diversity: How exclusive databases sustain the oligopoly of academic publishers," *PLoS One*, vol. 20, pp. 1–15, 2025, doi: 10.1371/journal.pone.0327015.

[50] T. T. P. Hoang and T. Kato, "Measuring the effect of environmental education for sustainable development at elementary schools: A case study in Da Nang city, Vietnam," *Sustain. Environ. Res.*, vol. 26, no. 6, pp. 274–286, 2016, doi: 10.1016/j.serj.2016.08.005.

[51] B. Yang, N. Wu, Z. Tong, and Y. Sun, "Narrative-based environmental education improves environmental awareness and environmental attitudes in children aged 6–8," *Int. J. Environ. Res. Public Health*, vol. 19, no. 11, pp. 1–19, 2022, doi: 10.3390/ijerph19116483.

[52] M. C. Ricoy and C. Sánchez-Martínez, "Raising ecological awareness and digital literacy in primary school children through gamification," *Int. J. Environ. Res. Public Health*, vol. 19, no. 3, pp. 1–19, 2022, doi: 10.3390/ijerph19031149.

[53] J. Holst, A. Brock, M. Singer-Brodowski, and G. de Haan, "Monitoring progress of change: Implementation of Education for Sustainable Development (ESD) within documents of the German education system," *Sustain.*, vol. 12, no. 10, pp. 1–19, 2020, doi: 10.3390/su12104306.

[54] D. Safitri *et al.*, "Web-based animation video for student environmental education at elementary schools," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 11, pp. 66–80, 2021, doi: 10.3991/ijim.v15i11.22023.

[55] M. Genc, T. Genc, and P. G. Rasgele, "Effects of nature-based environmental education on the attitudes of 7th grade students towards the environment and living organisms and affective tendency," *Int. Res. Geogr. Environ. Educ.*, vol. 27, no. 4, pp. 326–340, 2018, doi: 10.1080/10382046.2017.1382211.

[56] I. Aznar-Díaz, F. J. Hinojo-Lucena, M. P. Cáceres-Reche, J. M. Trujillo-Torres, and J. M. Romero-Rodríguez, "Environmental attitudes in trainee teachers in primary education. The future of biodiversity preservation and environmental pollution," *Int. J. Environ. Res. Public Health*, vol. 16, no. 3, pp. 1–11, 2019, doi: 10.3390/ijerph16030362.

[57] I. Kliziene, G. Taujanskiene, A. Augustiniene, B. Simonaitiene, and G. Cibulskas, "The impact of the virtual learning platform eduka on the academic performance of primary school children," *Sustain.*, vol. 13, no. 4, pp. 1–14, 2021, doi: 10.3390/su13042268.

[58] T. Richter, A. Rendigs, and C. P. Maminirina, "Conservation messages in speech bubbles-evaluation of an environmental education comic distributed in elementary schools in Madagascar," *Sustain.*, vol. 7, no. 7, pp. 8856–8880, 2015, doi: 10.3390/su7078855.

[59] O. Álvarez-García, L. Á. García-Escudero, F. Salvà-Mut, and A. Calvo-Sastre, "Variables influencing pre-service teacher training in education for sustainable development: A case study of two Spanish universities," *Sustain.*, vol. 11, no. 16, pp. 1–14, 2019, doi: 10.3390/su11164412.

[60] S. Lefkeli, E. Manolas, K. Ioannou, and G. Tsantopoulos, "Socio-cultural impact of energy saving: Studying the behaviour of elementary school students in Greece," *Sustain.*, vol. 10, no. 3, pp. 1–14, 2018, doi: 10.3390/su10030737.

[61] D. Petkou, V. Andrea, and K. Anthrakopoulou, "The impact of training environmental educators: Environmental perceptions and attitudes of pre-primary and primary school teachers in Greece," *Educ. Sci.*, vol. 11, no. 6, pp. 1–18, 2021, doi: 10.3390/educsci11060274.

[62] B. Tabuenca *et al.*, "Greening smart learning environments with Artificial Intelligence of Things," *Internet of Things (Netherlands)*, vol. 25, p. 101051, 2024, doi: 10.1016/j.iot.2023.101051.

[63] A. Torralba-Burrial and E. Dopico, "Promoting the sustainability of artisanal fishing through environmental education with game-based learning," *Sustain.*, vol. 15, no. 17, pp. 1–15, 2023, doi: 10.3390/su151712905.

[64] N. Favuzzi *et al.*, "Evaluation of an alimentary education intervention on school canteen waste at a primary school in Bari, Italy," *Int. J. Environ. Res. Public Health*, vol. 17, no. 7, pp. 1–15, 2020, doi: 10.3390/ijerph17072558.

[65] M. Á. Aguilar-Jurado, P. Gil-Madrona, J. F. Ortega-Dato, and D. Zamorano-García, "Effects of an educational glass recycling program against environmental pollution in Spain," *Int. J. Environ. Res. Public Health*, vol. 16, no. 24, pp. 1–16, 2019, doi: 10.3390/ijerph16245108.

[66] K. E. Lukas, A. Leeds, M. A. Slavin, J. Tinka, and C. J. Kendall, "Impact of teacher training in conservation education on student learning in primary schools adjacent to Kibale National Park, Uganda," *Oryx*, vol. 53, no. 3, pp. 497–504, 2019, doi: 10.1017/S0030605317000965.

[67] M. E. Ferreira, A. C. André, and R. Pitarma, "Potentialities of thermography in ecocentric education of children: An experience on training of future primary teachers," *Sustain.*, vol. 11, no. 9, 2019, doi: 10.3390/su11092668.

[68] S. Miedijensky and A. Abramovich, "Implementation of 'education for sustainability' in three elementary schools-what can we learn about a change process?," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 15, no. 10, p. em1754, 2019, doi: 10.29333/ejmste/109145.

[69] V. O. Lovren and M. M. Jablanovic, "Bridging the gap: The affective dimension of learning outcomes in environmental primary and secondary education," *Sustain.*, vol. 15, no. 8, pp. 1–12, 2023, doi: 10.3390/su15086370.

[70] K. Heng, Mo. Hamid, and A. Khan, "Factors influencing academics' research engagement and productivity: A developing countries perspective," *Issues Educ. Res.*, vol. 20, no. 3, pp. 965–987, 2020, doi: 10.3316/informit.465283943914964.

[71] M. Yuan, H. Lin, H. Wu, M. Yu, J. Tu, and Y. Lü, "Community engagement in public health: A bibliometric mapping of global research," *Arch. Public Heal.*, vol. 79, no. 1, pp. 1–17, 2021, doi: 10.1186/s13690-021-00525-3.

[72] J. Martínez-Aznar, Á. de Frutos, and G. Calvo, "Assessing environmental literacy in secondary education: The influence of mountain tourism and nature-based activities in Huesca, Spain," *Int. Res. Geogr. Environ. Educ.*, pp. 1–17, 2025, doi: 10.1080/10382046.2025.2570540.

[73] A. Cano-Ortiz, J. C. Piñar-Fuentes, C. M. Musarella, and J. Peña-Martínez, "Education for

environmental sustainability component: Innovative strategies for experiential learning in natural contexts," *Educ. Sci.*, vol. 15, no. 6, pp. 1–35, 2025, doi: 10.3390/educsci15060697.

[74] J. M. C. Castellanos, A. R. de Castro, and M. R. M. Girona, "Trends and perspectives in education for sustainable development in the teaching of geography in Spain," *Sustain.*, vol. 13, no. 23, pp. 1–15, 2021, doi: 10.3390/su132313118.

[75] H. Alderwick, A. Hutchings, A. Briggs, and N. Mays, "The impacts of collaboration between local health care and non-health care organizations and factors shaping how they work: A systematic review of reviews," *BMC Public Health*, vol. 21, no. 1, pp. 1–16, 2021, doi: 10.1186/s12889-021-10630-1.

[76] F. Marín-González, S. R. Moganadas, A. J. Paredes-Chacín, S. F. Yeo, and S. Subramaniam, "Sustainable local development: Consolidated framework for cross-sectoral cooperation via a systematic approach," *Sustain.*, vol. 14, no. 11, pp. 1–33, 2022, doi: 10.3390/su14116601.

[77] M. A. Ayanwale, R. R. Molefi, and S. Oyeniran, "Analyzing the evolution of machine learning integration in educational research: A bibliometric perspective," *Discov. Educ.*, vol. 3, no. 1, pp. 1–21, 2024, doi: 10.1007/s44217-024-00119-5.

[78] I. Irwanto, "Research trends on artificial intelligence in K-12 education in Asia: A bibliometric analysis using the Scopus database (1996–2025)," *Discov. Artif. Intell.*, vol. 5, no. 1, pp. 1–42, 2025, doi: 10.1007/s44163-025-00389-4.

[79] K. Mehmood, X. Qiu, and M. A. Khan, "Uncovering the path to sustainability: Knowledge evolution, global collaborations, and emerging research frontiers in environmental science," *Int. J. Environ. Sci. Technol.*, vol. 22, no. 15, pp. 16307–16324, 2025, doi: 10.1007/s13762-025-06666-0.

[80] P. Prihandoko, A. P. Windarto, M. Yanto, and M. H. Yuhandri, "Sectoral vulnerabilities and adaptations to climate change: Insights from a systematic literature review," *Int. J. Electr. Comput. Eng.*, vol. 14, no. 6, pp. 6944–6957, 2024, doi: 10.11591/ijece.v14i6.pp6944-6957.

[81] Z. Ni, W. Zhao, C. Yin, M. E. Meadows, and P. Pereira, "Mapping geography's engagement with the Sustainable Development Goals: Research foci, contributions, and future directions," *Geogr. Sustain.*, vol. 6, no. 6, p. 100376, 2025, doi: 10.1016/j.geosus.2025.100376.

[82] F. Romero-Perdomo, J. D. Carvajalino-Umaña, J. L. Moreno-Gallego, N. Ardila, and M. Á. González-Curbelo, "Research trends on climate change and circular economy from a knowledge mapping perspective," *Sustain.*, vol. 14, no. 1, pp. 1–17, 2022, doi: 10.3390/su14010521.

[83] S. Syed and F. Ashfaq, "Challenges in implementing environmental education for sustainability: Bibliometric analysis," *Int. J. Res. Econ. Commer.*, vol. 6, no. 1, 2025, doi: 10.56536/ijrec.v6i1.44.

[84] M. Bemke-Świtilnik, A. Drabek, A. M. Kamińska, and A. Smoliński, "Research collaboration patterns in sustainable mining-A co-authorship analysis of publications," *Sustain.*, vol. 12, no. 11, pp. 1–16, 2020, doi: 10.3390/su12114756.

[85] I. Mitrović, M. Mišić, and J. Protić, "Exploring high scientific productivity in international co-authorship of a small developing country based on collaboration patterns," *J. Big Data*, vol. 10, no. 1, pp. 1–28, 2023, doi: 10.1186/s40537-023-00744-1.

[86] H. C. K. Lin, L. W. Lu, and R. S. Lu, "Integrating digital technologies and alternate reality games for sustainable education: Enhancing cultural heritage awareness and learning engagement," *Sustain.*, vol. 16, no. 21, pp. 1–18, 2024, doi: 10.3390/su16219451.

[87] D. Safitri, A. Marini, P. Irwansyah, and A. Sudrajat, "Transforming environmental education with augmented reality: A model for learning outcome," *Soc. Sci. Humanit. Open*, vol. 12, no. December 2024, p. 101796, 2025, doi: 10.1016/j.ssaho.2025.101796.

[88] K. Rana, S. J. Aitken, and R. Chimoriya, "Interdisciplinary approaches in doctoral and higher research education: An integrative scoping review," *Educ. Sci.*, vol. 15, no. 1, pp. 1–20, 2025, doi: 10.3390/educsci15010072.

[89] A. Ibrahim, "Identifying gaps and contributions of project-based learning in vocational education and STEM fields: A comprehensive bibliometric analysis," *J. Scientometr. Res.*, vol. 14, no. 1, pp. 86–98, 2025, doi: 10.5530/jscires.20250763.

[90] I. Žalėnienė and P. Pereira, "Higher education for sustainability: A global perspective," *Geogr. Sustain.*, vol. 2, no. 2, pp. 99–106, 2021, doi: 10.1016/j.geosus.2021.05.001.

[91] N. C. G. Ribeiro and D. de M. G. Sant'Ana, "The entomological exhibition of a science museum and its contributions to non-formal education," *Acta Sci. - Biol. Sci.*, vol. 41, no. 1, pp. 1–7, 2019, doi: 10.4025/actascibiolsci.v41i1.43668.

[92] H. Friman, N. Matsliah, E. Dabbah, Y. Sitbon, I. Banner, and Y. Einav, "Ubiquitous learning of renewable energy and environmentalism to various israeli populations," in *Proceedings - 2020 International Symposium on Educational Technology, ISET 2020*, 2020, pp. 114–117. doi: 10.1109/ISET49818.2020.00033.

[93] D. das C. de Azevedo Ribeiro, C. G. Passos, and T. D. Miskinis Salgado, "The environmental issue of pesticides: The problem-solving methodology in elementary school," *Acta Sci.*, vol. 21, no. 4, pp. 97–114, 2019, doi: 10.17648/acta.scientiae.v21iss4id4961.
[94] I. Alkaher and D. Gan, "The role of school partnerships in promoting education for sustainability and social capital," *J. Environ. Educ.*, vol. 51, no. 6, pp. 416–433, 2020, doi: 10.1080/00958964.2020.1711499.
[95] C. Wamsler, "Education for sustainability: Fostering a more conscious society and transformation towards sustainability," *Int. J. Sustain. High. Educ.*, vol. 21, no. 1, pp. 112–130, 2020, doi: 10.1108/IJSHE-04-2019-0152.
[96] A. Altassan, "Sustainable integration of solar energy, behavior change, and recycling practices in educational institutions: A holistic framework for environmental conservation and quality education," *Sustain.*, vol. 15, no. 20, pp. 1–26, 2023, doi: 10.3390/su152015157.
[97] A. M. Nchaga, "Exploring community-based learning: Opportunities and challenges," *Res. Output J. Arts Manag.*, vol. 4, no. 1, pp. 46–52, 2025, doi: 10.59298/ROJAM/2025/414652.
[98] S. Chowdhury and A. Alzarrad, "Advancing community-based education: Strategies, challenges, and future directions for scaling impact in higher education," *Trends High. Educ.*, vol. 4, no. 2, pp. 1–30, 2025, doi: 10.3390/higheredu4020021.
[99] A. C. Hughes *et al.*, "Who is publishing in ecology and evolution? The underrepresentation of women and the Global South," *Front. Environ. Sci.*, vol. 11, pp. 1–10, 2023, doi: 10.3389/fenvs.2023.1211211.
[100] N. M. Ardoin, A. W. Bowers, and E. Gaillard, "Environmental education outcomes for conservation: A systematic review," *Biol. Conserv.*, vol. 241, e108224, 2020, doi: 10.1016/j.biocon.2019.108224.
[101] S. Collado, C. D. Rosa, and J. A. Corraliza, "The effect of a nature-based environmental education program on children's environmental attitudes and behaviors: A randomized experiment with primary schools," *Sustain.*, vol. 12, no. 17, pp. 1–12, 2020, doi: 10.3390/SU12176817.
[102] N. Sadan, "Overcoming organizational fragmentation in environmental education–the networking role of local education offices," *Environ. Educ. Res.*, vol. 31, no. 1, pp. 151–172, 2025, doi: 10.1080/13504622.2024.2376728.
[103] L. Wu, W. Madurapperuma, and R. Dissanayake, "The effects of country-of-origin research: A bibliometric analysis," *Inf. Res. Commun.*, vol. 1, no. 2, pp. 144–160, 2024, doi: 10.5530/irc.1.2.17.

Authors



Vera Yuli Erviana is a member of the teaching staff in the Department of Elementary Teacher Education, Faculty of Teacher Training and Education, Universitas Ahmad Dahlan, Yogyakarta. Her areas of expertise include innovation in elementary school learning and social studies education in elementary schools. She teaches several courses, including Lesson Planning in Elementary Schools, Curriculum Development in Elementary Schools, Classroom Action Research, Basic Social Studies, Advanced Social Studies, Social Studies Learning Materials for Elementary Schools, and Microteaching. She earned her bachelor's degree in Elementary Teacher Education, as well as her master's and doctoral degrees in Basic Education, from Universitas Negeri Yogyakarta. (email: vera.erviana@uad.ac.id).



Sabriyandi was born in Bekut on 27 September 2000. He is an undergraduate student in the Elementary School Teacher Education Program (PGSD), Faculty of Teacher Training and Education, Universitas Ahmad Dahlan, where she has been pursuing her bachelor's degree since 2022. In addition, Sabriyandi actively participates in seminars and training programs on soft skill development and instructional media, and is accustomed to working collaboratively and professionally. (email: 2200005228@webmail.uad.ac.id).