



Environmental Literacy Shaping Educational Research: Trends, Knowledge Networks, and Future Pathways

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Abstract

Global environmental crises, including climate change and biodiversity loss, underscore the urgent need for ecological awareness and sustainable practices, with education serving as a key driver of environmental literacy. This study maps the development of environmental literacy research in education from 2015 to 2025. Using the Scopus database and PRISMA guidelines, 6,355 records were refined to 59 eligible publications. Bibliometric and science-mapping analyses with Biblioshiny, VOSviewer, and Excel generated descriptive statistics and network visualizations. Findings indicate steady growth in publications. The most cited studies focus on large-scale surveys, eco-school programs, and problem-based pedagogies. Thematic mapping and keyword co-occurrence reveal dominant clusters on environmental education, curriculum innovation, sustainability, and teacher development, alongside emerging topics such as climate change and indigenous knowledge integration. These results highlight both consolidated research areas and new directions, offering guidance for educators, policymakers, and researchers to strengthen environmental competencies and inform curriculum development.

INTRODUCTION

The accelerating pace of global environmental crises, including climate change, biodiversity loss, land degradation, and pollution, places societies at a critical juncture where enhanced ecological awareness and sustainable practices are imperative (Das et al., 2024; Kundariati et al., 2025; Lockie, 2023; Pörtner et al., 2023; Wagner, 2023). Education is widely recognized as a primary lever for cultivating that awareness and for translating knowledge into collective action (Alméstár et al., 2022; Kohl et al., 2022; Neloy & Rahman Shahin, 2025; Sliwka et al., 2024). Consequently, strengthening environmental competencies across formal and non-formal learning contexts has become central to policy debates on sustainable development (Caldana et al., 2023; Essomba et al., 2022). At the conceptual level, environmental literacy has come to denote a multidimensional competence that integrates factual knowledge, systems thinking, affective dispositions, practical skills, and the capacity for informed decision-making (Liu & Tobias, 2024; López-Alcarria et al., 2021). Framing environmental literacy as more than content knowledge underscores its role in fostering agency, critical reflection, and behavior that supports long-term sustainability (Israilova et al., 2023).

Empirical findings illustrate both progress and limitations in advancing environmental literacy through education. As demonstrated by Liang et al. (2018), a nationwide survey in Taiwan revealed that undergraduate students possessed only moderate levels of environmental literacy, with significant gaps in applied problem-solving skills. Evidence from program-based interventions also indicates positive impacts, though with contextual variations. For instance, Nurwidodo et al. (2020) reported that the Adiwiyata eco-school program in Indonesia significantly enhanced high school students' environmental literacy. Collectively, these findings underscore the importance of curriculum innovation and pedagogical

strategies in fostering environmental literacy, while also revealing uneven outcomes across different educational contexts and assessment measures.

Despite these advances, significant gaps remain that limit cumulative knowledge and policy translation. Much of the evidence comes from single-country studies or program evaluations with little cross-national comparability, while existing reviews are mostly narrative in nature. Specifically, there is a lack of bibliometric and network analyses that systematically map global and regional trends in environmental literacy research, identify influential contributors, and reveal thematic patterns. In particular, contributions from Indonesia are underrepresented in international journals, despite emerging evidence of impactful program-based interventions. Without such macroscopic mapping, stakeholders lack a coherent understanding of research concentrations, blind spots, and collaborative networks, which is crucial for guiding investments, curriculum reform, and international cooperation.

To address this gap, this study aims to conduct a comprehensive bibliometric and network analysis of environmental literacy research in education from 2015 to 2025. Drawing on the Scopus database and combining descriptive statistics with science-mapping methods (co-authorship, co-citation, bibliographic coupling, and keyword co-occurrence), the study examines publication growth, influential authors and institutions, the most impactful documents, thematic structures, and keyword networks, and concludes with a forward-looking research agenda. Based on these objectives, the study is guided by the following research questions:

- RQ1: What is the growth pattern of environmental literacy research in the field of education from 2015 to 2025?
- RQ2: Who are the most influential authors, institutions, and countries contributing to environmental literacy research in education?
- RQ3: Which documents have had the greatest impact on the development of

environmental literacy research in education?

RQ4: What thematic structures emerge in the field of environmental literacy research in education during the 2015–2025 period?

RQ5: How does the co-occurrence analysis of keywords provide insights into environmental literacy research in education?

RQ6: What future research directions and agendas can be identified from the trends and gaps in environmental literacy research in education?

METHOD

Research Design and Data Sources

This study adopted a systematic bibliometric review approach, integrating a systematic literature review (SLR) procedure guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol with bibliometric and science mapping analysis. This combined approach was selected because it enables both the systematic identification and selection of relevant literature and the quantitative mapping of research trends, thematic structures, and relationships among publications within a research field. Compared with conventional narrative reviews, bibliometric approaches provide a more objective and data-driven method for examining the development and intellectual structure of a research domain.

The Scopus database was selected as the primary data source due to its extensive coverage of high-quality peer-reviewed journals across multiple academic disciplines. In addition, Scopus provides well-structured bibliographic metadata and advanced search functions that support bibliometric analysis. Its comprehensive indexing and frequent updates also ensure the inclusion of recent scholarly publications related to environmental literacy.

To identify relevant publications, a structured search strategy was implemented using the advanced search feature in Scopus. The search incorporated key terms associated with environmental literacy and applied several filtering criteria to ensure the

relevance and quality of the dataset. The following search query was used:

TITLE-ABS-KEY (environmental AND literacy) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOC"))

The search was conducted on 35 February 2026 and initially retrieved 6,355 records. These publications consisted of journal articles published between 2015 and 2025, categorized within the social sciences subject area, written in English, and available as open-access publications. To ensure transparency and methodological rigor, the subsequent filtering and selection stages followed the PRISMA framework, which organizes the literature selection process into the stages of identification, screening, eligibility assessment, and final inclusion.

The complete selection process is illustrated in the PRISMA flow diagram presented in Figure 1, which summarizes how the initial dataset was systematically refined to obtain the final corpus of relevant studies.

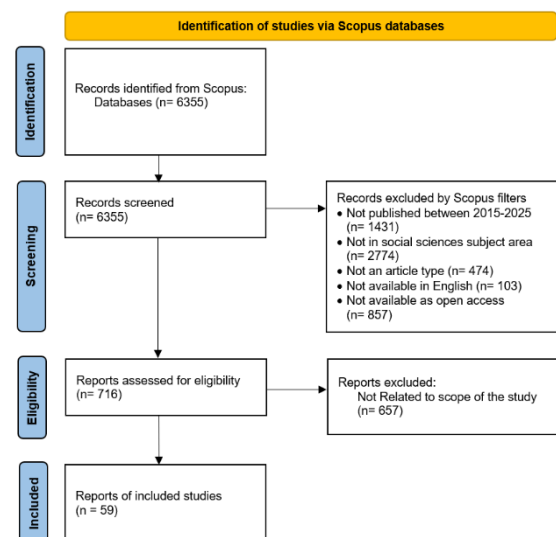


Figure 1. PRISMA flow diagram

As shown in Figure 1, the 6,355 records identified from the Scopus database were subjected to a structured screening process. During this stage, several filtering criteria were applied to remove publications that did not meet the predefined requirements. Studies were excluded if they were not published

within the specified time range (2015–2025), did not belong to the social sciences subject area, were not categorized as journal articles, were not written in English, or were not available as open-access publications. After applying these filters, 716 articles remained and were further assessed for eligibility.

During the eligibility stage, the remaining articles were examined to determine their relevance to the scope of the study. Publications that did not directly address environmental literacy or were outside the thematic focus of this research were excluded. Through this evaluation process, 657 articles were removed, resulting in a final dataset of 59 studies that met all inclusion criteria and were used for further analysis.

Study Selection and Data Analysis

The selected publications served as the dataset for bibliometric analysis and research trend mapping. Bibliographic metadata from the included articles were exported from Scopus in CSV format, which contained information such as authors, publication year, author keywords, sources, affiliations, and citation data. These metadata enabled comprehensive quantitative analysis of publication characteristics and relationships within the environmental literacy research field.

Bibliometric analysis was conducted using Biblioshiny (Bibliometrix package in R) and VOSviewer. Biblioshiny was employed to perform descriptive bibliometric analysis, including examination of publication growth trends, source distribution, author productivity, country contributions, and

citation patterns. It also enabled the identification of thematic evolution and emerging topics in environmental literacy research.

Meanwhile, VOSviewer was used for science mapping analysis, particularly to visualize relationships among publications through keyword co-occurrence networks and cluster analysis. These visualizations help identify dominant research themes, conceptual relationships among topics, and patterns of collaboration among researchers. In the network visualization, nodes represent items such as keywords or authors, while links indicate the strength of relationships between them.

Through this integrated analytical approach, the final dataset of 59 articles provides a systematic and data-driven foundation for exploring the development, thematic structure, and research trends of environmental literacy studies within the social sciences domain.

RESULT AND DISCUSSION

Literature growth pattern from year to year

The analysis of publication dynamics provides an overview of how research on environmental literacy in education has evolved over time. Examining the annual distribution of documents allows us to identify emerging interest, periods of rapid development, and potential shifts in scholarly attention. Figure 1 illustrates the number of relevant publications per year from 2017 to 2025.

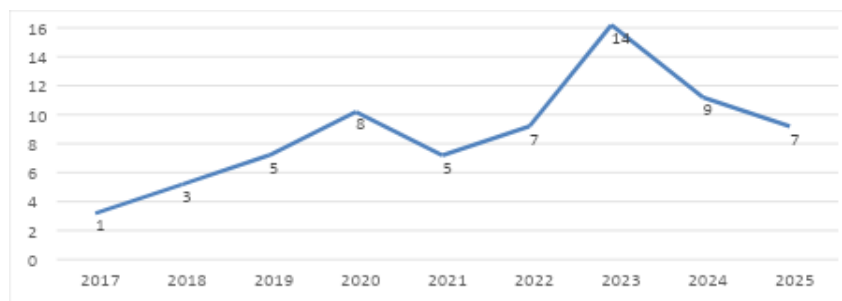


Figure 2. Number of relevant publications per year

The line graph in Figure 2 shows that publications on environmental literacy in education began modestly in 2017 with only

one article. The number of studies then gradually increased in the following years, reaching three publications in 2018 and five in

2019. A further rise occurred in 2020 with eight publications, indicating growing scholarly attention to environmental literacy within educational research. However, a slight decline was observed in 2021 with five publications, before the number increased again to seven publications in 2022.

A significant surge occurred in 2023, when the number of publications reached its highest point with 14 articles, marking the peak of research activity in this period. Although the number declined slightly in the following years, the level of scholarly output remained relatively strong with nine publications in 2024 and seven publications in 2025. Overall, this pattern demonstrates a general upward trend in research interest, suggesting that environmental literacy has increasingly

gained recognition as an important topic in educational research.

Most influential contributors

Understanding the most influential contributors provides insights into how knowledge production on environmental literacy is distributed globally and institutionally. By identifying the most active countries, affiliations, and patterns of collaboration, we can see which contexts have been driving the field and how international engagement has shaped its development. To better understand the temporal trajectory of these contributions, Figure 3 presents the annual publication growth of the top 10 contributing countries.

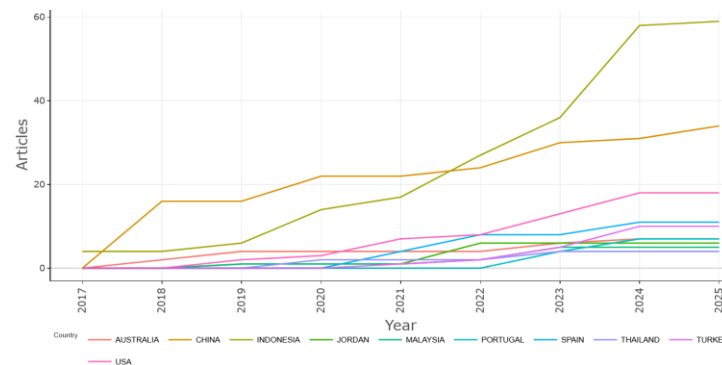


Figure 3. Production growth of the top 10 countries

The line chart in Figure 3 demonstrates a dramatic increase in Indonesia's output, especially from 2020 onward, culminating in 59 publications by 2025. China shows steady growth since 2018, reaching 34 publications, while the United States has gradually risen to 18. Other countries such as Spain, Turkey, Portugal, and Jordan display more recent but accelerating engagement, suggesting

expanding interest in environmental literacy beyond the early-leading regions. These patterns reflect both the consolidation of research capacity in Indonesia and China as well as the widening global participation in the field. Table 1 provides an overview of the leading institutional affiliations in terms of influence.

Table 1. Most influential affiliation

Affiliation	Articles
Universitas Negeri Malang	12
National Taiwan Normal University	8
Universitas Negeri Yogyakarta	7
Universitas Serambi Mekkah	6
Applied Science Private University	5
Universitas Islam Negeri Raden Intan Lampung	5
Universitas Sebelas Maret	5

Universitas Negeri Malang emerges as the leading institution, with 12 publications, followed by National Taiwan Normal University (8) and Universitas Negeri Yogyakarta (7). Other key institutions include Universitas Serambi Mekkah, Applied Science Private University, and Universitas Islam Negeri Raden Intan Lampung, each producing five or more articles. Notably, institutions from Indonesia dominate the list, supported by contributions from universities in Taiwan, the United States, and China. This demonstrates the prominent role of Indonesian higher education institutions in shaping global

scholarship on environmental literacy in education.

Most impactful articles

In bibliometric analysis, citation count is a key indicator of scholarly influence, as it reflects how often a publication has been recognized and used by other researchers. Identifying the most cited works provides insight into which studies have shaped the field of environmental literacy in education and which themes have generated the greatest academic attention. Table 2 lists the top five most cited articles within the dataset, including their total citations (TC) and average citations per year (C/Y).

Table 2. Most cited articles

Rank	Article	Authors	Journal	TC	C/Y
1	A Nationwide Survey Evaluating the Environmental Literacy of Undergraduate Students in Taiwan	Liang et al. (2018)	Sustainability	60	7,50
2	Environmental Literacy on Ecotourism : A Study on Student Knowledge , Attitude , and Behavioral Intentions in China and Taiwan	Fang et al. (2018)	Sustainability	56	7,00
3	Leveraging collective action and environmental literacy to address complex sustainability challenges	Ardoin et al. (2023)	Ambio	51	17,00
4	The role of eco-school program (Adiwiyata) towards environmental literacy of high school students	Nurwidodo et al. (2020)	European Journal of Educational Research	39	6,50
5	The implementation of local environmental problem-based learning student worksheets to strengthen environmental literacy	Suryawati et al. (2020)	Jurnal Pendidikan IPA Indonesia	35	5,83

The table 2 reveals that *A Nationwide Survey Evaluating the Environmental Literacy of Undergraduate Students in Taiwan* by Liang et al. (2018), published in *Sustainability*, is the most cited article with 60 citations (7.50 per year). This is closely followed by Fang et al. (2018), also in *Sustainability*, with 56 citations, focusing on environmental literacy in ecotourism contexts. Ardoin et al. (2023), with 51 citations and the highest annual citation rate (17.00), demonstrates the rapidly growing influence of recent scholarship that links collective action to environmental literacy in addressing sustainability challenges.

Overall, the most impactful documents demonstrate that environmental literacy research has developed along three primary

axes: (1) large-scale surveys and assessments (e.g., Liang et al., Fang et al.), (2) educational programs and pedagogical interventions (e.g., Adiwiyata, problem-based learning), and (3) conceptual and community-based approaches (e.g., Kaya & Elster, Ardoin et al.). The prominence of both regional case studies and broader theoretical discussions highlights a balance between local contextualization and global applicability.

Thematic map

To better understand the intellectual and conceptual structure of environmental literacy research in education, a thematic map was generated. This approach enables the identification of core, emerging, niche, and

peripheral themes that characterize the research landscape, as shown in Figure 4.

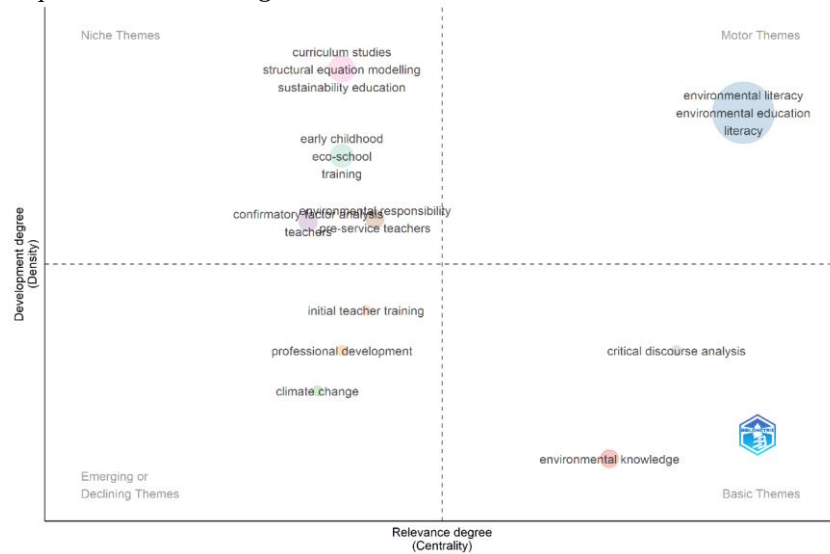


Figure 4. Thematic map

Figure 4 illustrates four clusters of research themes. The Motor Themes quadrant (upper-right) identifies environmental literacy and environmental education as mature, central drivers of the field, functioning as the intellectual engine that continues to shape future inquiries. The Niche Themes quadrant (upper-left) includes curriculum studies, sustainability education, eco-school training, and structural equation modeling, which are well developed internally but remain peripheral unless better linked to broader research conversations. The Emerging or Declining Themes quadrant (lower-left) highlights initial teacher training, professional development, and climate change, suggesting areas either in early development or losing momentum, requiring close monitoring to assess their trajectory. The Basic Themes quadrant (lower-right) points to foundational but underdeveloped concepts such as environmental knowledge and critical discourse analysis, which are central yet demand further theoretical and empirical elaboration.

Taken together, the thematic structure shows that environmental literacy remains the dominant and most established area, while the

field is diversifying toward educational strategies and socio-critical approaches. At the same time, emerging issues such as climate change education and teacher professional development require stronger integration into mainstream scholarship. Bridging foundational knowledge with applied educational practices will be critical to enhance the robustness and global relevance of environmental literacy research.

Co-occurrence Analysis

A co-occurrence analysis of keywords was conducted to capture the conceptual structure and thematic development of environmental literacy research. This analysis employed three complementary visualization techniques: network visualization, overlay visualization, and density visualization, which emphasizes the intensity and clustering of thematic foci. Together, these approaches provide a comprehensive view of the research landscape, enabling the identification of both core themes and emerging topics. The resulting patterns are displayed in Figure 5, which illustrates the network visualization of co-occurrence.

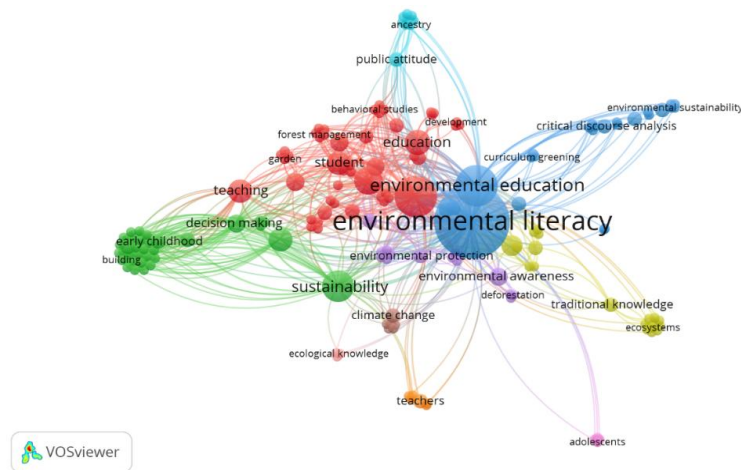


Figure 5. Network visualization for co-occurrence

The network visualization (Figure 5) reveals *environmental literacy* as the largest and most central node, underscoring its role as the core of the field. Closely linked are terms such as *environmental education*, *sustainability*, *students*, and *teaching*, indicating that much of the research focuses on the educational dimension of literacy development. The clusters also suggest specific thematic orientations:

1. The blue cluster centers on *environmental literacy* and *environmental education*, representing the conceptual heart of the field.
2. The red cluster groups keywords such as *students*, *education*, and *teaching*, reflecting studies on pedagogical practices and learning contexts.
3. The green cluster highlights *sustainability*, *decision making*, and *early childhood*, pointing to research on integrating literacy into sustainability education and early learning.
4. The yellow and purple clusters include themes like *environmental awareness*, *traditional knowledge*, *ecosystems*, and *climate change*, suggesting connections to ecological contexts and indigenous perspectives.
5. Smaller nodes such as *critical discourse analysis* and *public attitude* show

specialized but emerging research directions.

Overall, the co-occurrence network demonstrates that environmental literacy research is strongly anchored in education but increasingly interlinked with sustainability, ecological knowledge, and cultural contexts. The implications are twofold: first, the dense interconnections between *literacy* and *education* reflect the consolidation of this area as a central research domain; second, the growing ties to sustainability and indigenous knowledge point to an expanding interdisciplinary scope. Future research could deepen these connections by bridging classroom practices with broader social and ecological systems, thereby positioning environmental literacy as a transformative driver of sustainable education.

While the network visualization shows the structural connections between keywords, overlay visualization provides a temporal perspective. By assigning colors to keywords according to the average year of their appearance, this analysis illustrates how the thematic focus of environmental literacy research has evolved over time. This temporal distribution is further illustrated in Figure 6, which presents the overlay visualization of keyword co-occurrence.

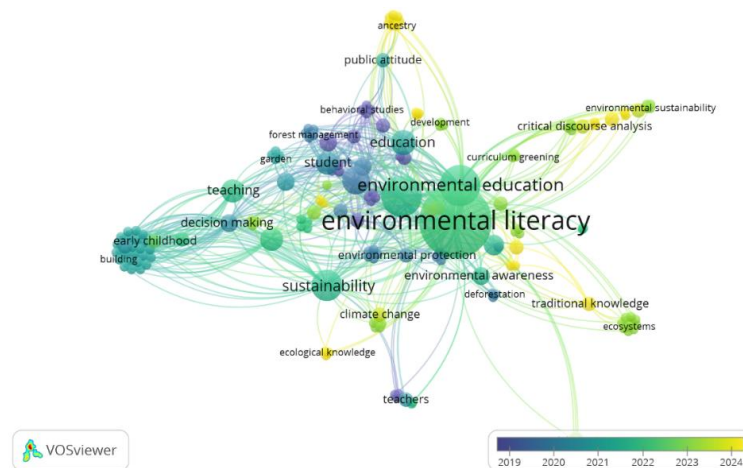


Figure 6. Overlay visualization for co-occurrence

As shown in Figure 6, *environmental literacy* and *environmental education* remain central themes across the period, appearing in green to indicate their continued relevance throughout 2019–2023. Earlier clusters, represented in blue, include *teaching*, *early childhood*, and *decision making*, reflecting foundational concerns that characterized the initial stage of research in this field. By contrast, newer keywords shown in yellow, such as *critical discourse analysis*, *curriculum greening*, *environmental sustainability*, *public attitude*, and *traditional knowledge*, indicate emerging areas of inquiry that have gained momentum in more recent years (2022–2024). These topics point to a shift in the research agenda, with greater emphasis on critical, social, and cultural dimensions of environmental literacy, as well as its integration with sustainability and indigenous knowledge systems.

To provide a deeper understanding of the thematic patterns emerging from the bibliometric mapping, a density visualization was generated. This approach highlights the intensity and frequency of co-occurrence among keywords, with brighter colors indicating stronger associations. The visualization enables the identification of dominant research focuses and peripheral yet relevant themes within the field of environmental literacy studies. By employing this perspective, it becomes possible to discern how the central concept interacts with adjacent constructs such as sustainability, environmental awareness, and education, thereby offering a more nuanced depiction of the research landscape. The detailed distribution of these keyword relationships is depicted in Figure 7, which illustrates the density visualization of co-occurrence.

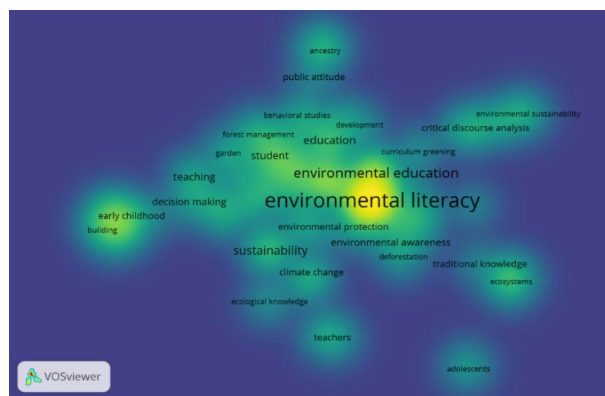


Figure 7. Density visualization for co-occurrence

As illustrated in Figure 7, *environmental literacy* emerges as the most prominent and densely connected theme, reflecting its

central role in the discourse. Closely related clusters such as *sustainability*, *environmental education*, *environmental awareness*, and

traditional knowledge further underscore the interdisciplinary orientation of the field. The prominence of terms like *students*, *teachers*, and *decision making* indicates a strong educational dimension, while the presence of concepts such as *climate change*, *ecosystems*, and *ecological knowledge* signifies the integration of scientific and ecological perspectives. This mapping suggests that current scholarship does not merely address knowledge acquisition but extends toward behavioral and attitudinal dimensions of environmental responsibility. The implication is that future research should consider

strengthening cross-disciplinary linkages, particularly between educational practices and ecological challenges, to foster a more holistic framework for advancing environmental literacy.

Agenda for Future Research

Building on the bibliometric findings, it is essential to identify gaps and emerging directions for future inquiry in environmental literacy research. Table 3 outlines these directions in the form of research streams, focal points, and guiding questions.

Table 3. Future research questions

Research Stream	Focus	Future Research Questions
Pedagogical Approaches	Integration of environmental literacy into teaching methods	How can innovative pedagogies (e.g., problem-based learning, eco-school programs, curriculum greening) be scaled across diverse educational contexts?
Teacher Education	Professional development and teacher preparation	In what ways can initial teacher training and continuous professional development better equip educators to foster environmental literacy among students?
Socio-cultural Dimensions	Role of cultural, traditional, and community knowledge	How can indigenous knowledge, traditional practices, and public attitudes be meaningfully integrated into environmental literacy education?
Critical Perspectives	Discourse and socio-political analysis	What insights can critical discourse analysis provide in reshaping environmental literacy education toward equity, justice, and transformative sustainability?
Early Childhood & Youth	Developmental perspectives on environmental literacy	How does environmental literacy evolve from early childhood through adolescence, and what interventions are most effective at each stage?

The agenda in Table 3 underscores that future research must move beyond measuring environmental knowledge and attitudes toward engaging with systemic, cultural, and critical dimensions of literacy. It highlights the need for stronger connections between teacher education, innovative pedagogy, and global collaboration. Importantly, the integration of indigenous knowledge and discourse analysis points to a broader and more inclusive understanding of environmental literacy. By addressing these questions, researchers can strengthen the theoretical foundations, broaden the practical applications, and enhance the transformative potential of environmental literacy in advancing sustainability goals worldwide.

Discussion

The bibliometric analysis reveals a consistent growth of environmental literacy research in education between 2015 and 2025, particularly from 2020 onward. This upward trajectory aligns with global priorities in Education for Sustainable Development, as shown by UNESCO (2020), and reflects research by Maritz et al. (2014), which emphasizes the role of institutional programs and policy frameworks in supporting educational innovation. The dominance of Indonesia, China, and the United States in publication output mirrors national research capacity and policy engagement, while emerging contributions from Spain, Turkey, and Portugal indicate the gradual

globalization of the field. Patterns of co-authorship reflect interdisciplinary collaboration, supporting Vygotsky (1978) socio-constructivist view that learning is enhanced through collective, contextually grounded efforts.

Thematic mapping and keyword co-occurrence analyses indicate a conceptual shift from foundational topics, such as environmental literacy and basic education, toward integrative areas including sustainability, curriculum greening, indigenous knowledge, and climate change education. This evolution reflects transformative learning theory, emphasizing critical reflection and perspective change to promote sustainable behavior, as shown by Ocak et al. (2025) in eco-school programs. The emergence of clusters on teacher professional development, early childhood interventions, and behavioral engagement suggests research is moving beyond knowledge acquisition to include attitudinal, systemic, and applied dimensions.

Overlay and density visualizations further reveal temporal shifts. Early studies focused on curriculum design and classroom-based interventions, which is consistent with Gök & Boncukçu (2023), who reported moderate environmental literacy among undergraduates and gaps in applied problem-solving skills. More recent research integrates ecological systems, sustainability, and socio-cultural perspectives, reflecting the growing emphasis on place-based and context-sensitive learning. However, uneven density in emerging themes, such as critical discourse analysis and indigenous knowledge, indicates persistent gaps in longitudinal and practice-oriented research, highlighting areas for future investigation.

Taken together, these findings suggest that environmental literacy research is maturing into a coherent but still evolving field, with increasing interdisciplinarity, global participation, and transformative potential. This study's novelty lies in systematically mapping contributions from Indonesia alongside global trends, positioning local initiatives within the

international research landscape, and providing a forward-looking agenda that integrates theory, empirical evidence, and policy relevance.

CONCLUSION

The results of this bibliometric study show that research on environmental literacy in education has experienced steady growth over the past decade, with a notable increase in publications after 2020. Indonesia has established itself as the leading hub of scholarship, supported by influential institutions and strong networks of collaboration, followed by China, the United States, and other emerging contributors. Influential publications highlight large-scale surveys, eco-school initiatives, problem-based pedagogies, and conceptual explorations that have significantly shaped the direction of the field. Thematic mapping further reveals environmental literacy and environmental education as the dominant research engines, complemented by niche areas such as curriculum studies, eco-school training, and sustainability education, alongside emerging interests in teacher development, climate change, and discourse analysis.

This study contributes to the field by providing a comprehensive, systematic bibliometric and science-mapping analysis that integrates both global and Indonesian research outputs. By identifying publication trends, influential authors, thematic structures, and emerging topics, the study offers actionable insights for policymakers, educators, and researchers. In particular, it highlights Indonesia's growing role in international scholarship, demonstrating how local initiatives, such as eco-school programs, contribute to the global understanding of environmental literacy. Overall, the study advances knowledge by bridging gaps in cross-national comparisons, offering a framework for future research, and positioning Indonesia's contributions within the international environmental education landscape.

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