Journal of Media Horizons
ISSN: 2710-4060 2710-4052 Volume 6, Issue 5, 2025

MAPPING FIVE DECADES OF ENVIRONMENTAL LITERACY RESEARCH: PATTERNS, GAPS, AND EMERGING FRONTIERS

Farahat Ali

Assistant Professor, School of Media and Mass Communication, Beaconhouse National University, Lahore, Pakistan.

farahat.ali@bnu.edu.pk

DOI:https://doi.org/10.5281/zenodo.17300291

Keywords
Environmental literacy, bibliometric analysis, sustainability education, environmental education, global research trends

Article History
Received: 17 June 2025
Accepted: 27 September 2025
Published: 08 October 2025

Copyright @Author
Corresponding Author: *
Farahat Ali

Abstract
Environmental literacy has become a central concept in education and sustainability debates, yet its research trajectory remains fragmented across disciplines and regions. This study applies a bibliometric approach to map five decades of environmental literacy scholarship, analyzing 660 documents indexed in the Web of Science (1971-2026). Using performance indicators and science mapping techniques, the study reconstructs the intellectual, conceptual, and social structures of the field. Results reveal that environmental literacy has evolved from limited pedagogical inquiries to an interdisciplinary research domain that engages with pressing issues such as climate change, sustainability, and public health. Intellectual foundations remain rooted in education and behavior theories, while thematic analyses highlight the growing prominence of student attitudes, curriculum design, and pro-environmental behavior alongside emerging niches like artificial intelligence, citizen science, and health literacy. Collaboration patterns confirm the dominance of the United States, China, and Western Europe, while the Global South, including Pakistan, remains underrepresented. The study contributes a consolidated evidence base that reduces definitional ambiguity, clarifies research trajectories, and highlights opportunities for more inclusive and interdisciplinary work. Future directions call for cross-database analyses, deeper qualitative integration, and stronger South-North partnerships to expand the scope and relevance of environmental literacy research.

INTRODUCTION

Environmental literacy (EL) sits at the heart of education's response to accelerating ecological crises because it links what people know, feel, and can do to protect the systems that sustain life. However, the construct is far from settled: overlapping terms such as ecological literacy and ecoliteracy are used inconsistently across fields, which makes it hard to cumulate knowledge and to design comparable assessments (McBride et al., 2013). Meanwhile, higher education systems, Pakistan included, are increasingly asked to mainstream sustainability and to demonstrate learning outcomes aligned with the SDGs; this policy pressure amplifies demand for clear, evidence-based pictures of how EL scholarship has evolved and where it is heading (Saqib et al., 2020; Habib et al., 2021). A bibliometric study is well suited to this task: beyond counting publications, contemporary science mapping tools can reveal the intellectual, conceptual, and social structures of a domain, trace thematic evolution, and diagnose fragmentation or blind spots (Donthu et al., 2021; Zupic & Čater, 2015). By systematically analyzing EL's publication patterns, co-authorships, co-citations, and keyword networks, we can illuminate how definitions

travel across disciplines, which theories anchor the field, and where Global South contributions (e.g., from Pakistan) are positioned.

Three decades of empirical work has progressively unpacked EL as a multidimensional construct. Early scholarship operationalized EL among teachers and students through knowledge, attitudes/affect, skills, and behavior, and examined how these dimensions predict responsible environmental action (e.g., Hsu & Roth, 1998). Subsequent studies refined the structural relations among components, typically finding that knowledge influences concern and attitudes, which in turn shape responsibility and behavior, using structural equation models and large student samples (Teksoz et al., 2012). Recent instrument development has emphasized short, psychometrically robust tools that practitioners can deploy at scale; for example, the Environmental Literacy Instrument for Adolescents (ELI A) measures ecological knowledge, hope, cognitive skills, and behavior within a 5-15 minute survey and demonstrates good validity and reliability (Szczytko et al., 2018). Collectively, this work provides a foundation of constructs and measures that any review of EL must account for, while also revealing considerable diversity in operationalization and context.

Parallel to advances in measurement, evaluative syntheses have assessed what EL related programs achieve. Stern et al. (2014) reviewed youth environmental education evaluations, cataloging outcome types and methodological patterns. They noted positive effects across knowledge, attitudes, and behavior, while urging greater rigor and clarity in reporting. This evaluative tradition has underlined that how we teach (e.g., outdoor, inquiry rich, culturally responsive learning) often matters as much as what we teach, and it has reinforced the centrality of EL as both an outcome and a pathway to conservation and civic engagement. The thrust of these syntheses, taken together with newer instruments such as ELI A, suggests a maturing but still heterogeneous evidence base that spans education, psychology, conservation, and communication. These features make EL an ideal candidate for a bibliometric mapping that can integrate scattered subfields and identify the intellectual anchors, emergent clusters, and underexplored linkages across disciplines and regions.

Bibliometric Studies and Underrepresentation of the Global South

Although there are bibliometric studies adjacent to EL, most notably in environmental education and education for sustainable development (ESD), they rarely isolate environmental literacy as a precise search and analytical unit (Rafiq et al., 2024). For example, a Scopus based bibliometric analysis of environmental education mapped journals, authors, and collaboration patterns over two decades, but because it targeted the broader EE category, it could not resolve the conceptual structure, definitional drift, or measurement lineages specific to EL (Lopera Perez et al., 2021). More focused attempts that do use EL keywords tend to be brief conference papers with limited windows (e.g., 2010–2020) and methods relying primarily on frequency counts rather than integrated performance and mapping workflows, constraining their ability to capture thematic evolution or intellectual bases (Afandi et al., 2023). In short, the field lacks a comprehensive, cross disciplinary bibliometric synthesis dedicated to EL per se, built on transparent retrieval strategies and contemporary science mapping techniques.

Existing syntheses also underrepresent Global South scholarship and policy-relevant contexts. Pakistan's higher education sector, for instance, has begun to embed sustainability and ESD, yet empirical accounts emphasize institutional initiatives and barriers more than the literacy constructs and learning outcomes that EL research tracks (Saqib et al., 2020; Habib et al., 2021). Across the broader literature, the same pattern appears: EL work is dispersed across education, conservation, and social science journals with varying terminology (environmental literacy, ecological literacy, ecoliteracy), inconsistent measurement, and limited cross talk, conditions that bibliometric mapping is expressly designed to diagnose. The result is that decision makers seeking to strengthen EL (curricula, teacher education, public communication) often confront a fragmented evidence base, especially for contexts outside North America and Europe. A dedicated EL bibliometric analysis can surface where Pakistan authored work sits in global knowledge networks, which journals and

collaborations shape access and influence, and where definitions and instruments converge or diverge across settings.

This study deliver a comprehensive, Web of Science anchored bibliometric analysis of environmental literacy that (a) uses a carefully piloted search strategy combining controlled terms and synonyms (e.g., "environmental literacy," "ecological literacy," "ecoliteracy"), (b) spans multiple disciplines (education, environmental studies, psychology, communication, public health), and (c) includes all document types indexed by web of science that contribute to EL's intellectual base (articles, reviews, and, where relevant, conference papers). Following best practice guidelines, the study conducts a performance analysis (growth, leading journals, authors, institutions, countries) and science mapping (co authorship, co citation, bibliographic coupling, and keyword co occurrence) to reconstruct the field's social, intellectual, and conceptual structures (Donthu et al., 2021; Zupic & Čater, 2015). Special attention be paid to the geographic distribution of contributions and collaborations, highlighting Pakistan's placement and co authorship patterns relative to regional and global networks.

Analytically, the study combine bibliometrix (R) for data handling, performance indicators, and thematic evolution for high resolution network visualization. This toolbox enables rigorous science mapping (e.g., co word thematic maps; strategic diagrams of motor/emerging/declining themes; overlay visualizations of trend topics) and robust clustering of co citation structures (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010; Waltman et al., 2010). Throughout, the study documents parameter choices (similarity measures, counting methods, clustering resolution) to ensure replicability and interpretability, in line with contemporary bibliometric standards. The resulting maps and indicators provide a consolidated evidence base to relate conceptual evolution (e.g., shifts among knowledge, attitudes, and behavior, systems/critical literacies) to outlets, author clusters, and policy salience.

Substantively, the study produces the first cross-disciplinary, methodologically integrated map of EL's intellectual roots (key co-citation clusters), conceptual organization (thematic networks), and social topology (collaboration structures), enabling scholars and practitioners to locate their work within the field and to identify high-leverage bridges across subdomains. Methodologically, it demonstrates a transparent, replicable workflow for EL bibliometrics that other researchers can adapt to subfields (e.g., teacher EL, media, and climate literacy). Practically, it gives curriculum designers, funders, and policymakers, in Pakistan and beyond, an empirical baseline to target gaps (e.g., understudied populations, regions, or competencies) and to align EL assessment and pedagogy with the strongest theoretical and empirical anchors. By juxtaposing Pakistan's contributions with global networks, the study should inform national strategies for research capacity, partnerships, and journal targeting in EL and ESD. Overall, the contribution is a consolidated, navigable knowledge structure that reduces terminological noise and supports evidence-informed EL advancement.

Given the definitional ambiguity around EL, its sprawling multidisciplinary footprint, and the policy urgency to document learning outcomes linked to sustainability, a targeted bibliometric synthesis offers both scholarly and societal value. It advances theory by clarifying EL's intellectual architecture; it advances method by standardizing search, modeling, and visualization practices; and it advances practice by highlighting where, how, and with whom evidence is being generated. Accordingly, this study poses the following research question: RQ1. How has EL scholarship evolved over time (volume, growth rates, and disciplinary diffusion)? RQ2. Which journals, authors, institutions, and countries structure EL's scientific output and influence, and where does Pakistan sit in these networks? RQ3. What is EL's intellectual base (co-citation clusters) and how have its conceptual themes evolved (co-word/thematic evolution) across time? RQ4. What collaboration patterns (co-authorship networks) and knowledge flows (bibliographic coupling) characterize the field, and what do they imply for capacity building in the Global South? RQ5. Which emerging topics and citation bursts suggest future EL frontiers?

Method

Study design and overview

This study adopts a performance-and-science-mapping bibliometric design to (a) quantify the growth, dispersion, and influence structure of *environmental*

literacy (EL) research and (b) reconstruct its social (collaboration), intellectual (co-citation), and conceptual (co-word) architectures. We follow established guidance for transparent bibliometric workflows, clearly specifying data sources, search strings, cleaning rules, counting choices, thresholds, and clustering settings, so that results are auditable and replicable by other scholars (Aria & Cuccurullo, 2017; Donthu et al., 2021; Zupic & Čater, 2015). All analyses were executed on a frozen snapshot of records retrieved as of 2025 and the complete search strategy, cleaning dictionary, and scripts are documented.

Data source, retrieval window, and export fields

Web of Science and Scopus served as the primary bibliographic source because of their broad coverage across education, environmental studies, psychology, and allied domains, as well as their structured export of author affiliations and reference lists required for co-authorship, co-citation, and bibliographic-coupling analyses (Donthu et al., 2021). This study targeted the entire period from 1970 to 2025 in the Web of Science, allowing the analysis to capture the earliest usage of EL terminology through contemporary developments. This study exported the following metadata for each record: authors, title, abstract, author keywords, index keywords, year, source title and type, volume/issue/pages, DOI, publisher, author affiliations (institution, country), funding text (if available), and complete cited reference lists. Exports were saved in CSV and BibTeX formats to support cross-tool processing in Bibliometrix (R) (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010).

Search strategy and query syntax

To maximize recall while maintaining conceptual precision on EL (and cognate terms used interchangeably in the literature), this study operationalized the topic using exact phrases and documented variants. The WoS search was run in the TITLE-ABS-KEY fields with no subject-area restrictions and limited to articles, reviews, conference papers, and book chapters. The core query was: TITLE-ABS-KEY("environmental literac*" OR "ecological literac*" OR ecoliterac* OR "eco-literacy" OR "eco literacy" OR "eco-literate" OR "eco literate" OR ("environment*" W/1 literate*)) AND NOT TITLE-ABS-KEY("information literacy" OR "financial literacy" OR "digital literacy" OR "media literacy" OR "statistical literacy"). The proximity term captures "environmentally literate," while the negative filter excludes near-homonyms unrelated to EL. This study piloted the string against a seed set of canonical EL papers to test precision/recall and refined it iteratively (Aria & Cuccurullo, 2017; Zupic & Čater, 2015). This study was restricted by language at retrieval, and for co-word analyses, we used English-language keywords (author and index) to ensure semantic comparability across documents.

Screening, eligibility, and deduplication

Records were screened in two passes. Pass one programmatically filtered out document types unsuited to citation/network analysis (editorials, notes, errata) and removed exact duplicates (same DOI) and near-duplicates (identical title/first author/year). Pass two entailed manual title-and-abstract screening to eliminate false positives where EL phrasing appeared only tangentially (e.g., a passing mention in a literature review unrelated to EL conceptualization or assessment). Two reviewers independently screened a 20% random subset to calibrate inclusion rules ($\kappa \geq .80$), then one reviewer completed the remaining set with periodic spot checks. Inclusion criteria required that the article's explicit focus involved defining, measuring, developing, or applying *environmental literacy*, *ecological literacy*, or *ecoliteracy* as a construct or outcome (Hsu & Roth, 1998; McBride et al., 2013).

Data cleaning and normalization

Metadata were harmonized prior to analysis. Author names were standardized (surname-initials) with additional rules for common variants (e.g., "Waltman L." vs "Waltman, Ludo"), and institutions were unified using string-distance matching plus manual verification for high-frequency entities. Countries were normalized to ISO-3166 names. Keyword dictionaries collapsed orthographic variants and near-synonyms (e.g., *eco-literacy* ↔ *ecoliteracy*; *knowledge-attitudes-behavior* ↔ *KAB*), removed stop words, and stemmed to unigrams and selected bigrams. For collaboration networks, we used fractional counting to mitigate inflation from multi-authored, multi-country papers; for co-citation, bibliographic coupling, and co-word networks, we

used full counting (Perianes-Rodríguez et al., 2016; Waltman et al., 2010). All preprocessing steps and dictionaries are archived to enable exact reproduction.

Ethics, reproducibility, and software

This study analyzes public bibliographic metadata and does not involve human subjects; ethics approval was therefore not required. We report the exact search date, query string, inclusion/exclusion rules, and all parameter settings. Analyses were performed in R (bibliometrix/biblioshiny) and VOSviewer; project files (cleaning dictionary, R scripts, VOSviewer map/cluster files) and the de-identified metadata be deposited in an open repository upon publication to support reuse and extension (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010; Cobo et al., 2011).

Results

The Web of Science collection spans 1971–2026, covering over five decades of research and reflecting a comprehensive view of the field's development, with the 2026 entries likely representing early access publications. The dataset comprises 660 documents published across 386 diverse sources, indicating a multidisciplinary and vibrant research landscape. While the reported annual growth rate of 0% appears anomalous and requires clarification, the average document age of 6.85 years shows that the collection is relatively young and representative of current trends. A total of 1,844 authors have contributed, averaging 3.22 co-authors per paper, highlighting strong collaboration, although 118 single-authored works (by 109 individuals) remain part of the record. International collaboration accounts for 14.09% of the works, showing moderate cross-border engagement but with most research produced nationally. The impact of this body of literature is evident in its average of 12.51 citations per document and 24,465 references overall, demonstrating both scholarly recognition and reliance on a solid knowledge base. Thematic richness is illustrated by 1,759 author keywords compared to 770 Keywords Plus, pointing to diverse and evolving sub-themes. In terms of document types, journal articles dominate (486), followed by proceedings papers (109), while reviews (17) and early access items (19) confirm both consolidation and contemporaneity.

Annual scientific production of documents in the field (Figure 1) reveals a long period of relatively low and steady output between 1971 and the early 2000s, during which annual publications rarely exceeded ten articles. From 2005 onward, however, a gradual upward trajectory becomes apparent, culminating in a sharp increase after 2015. The peak was observed in 2024 with close to 80 publications, marking the highest output in the dataset. The apparent drop in 2025 should be interpreted with caution, as it most likely reflects incomplete data indexing for that year rather than an actual decline in productivity. This temporal trend underscores the growing relevance of the field, especially in the last decade.

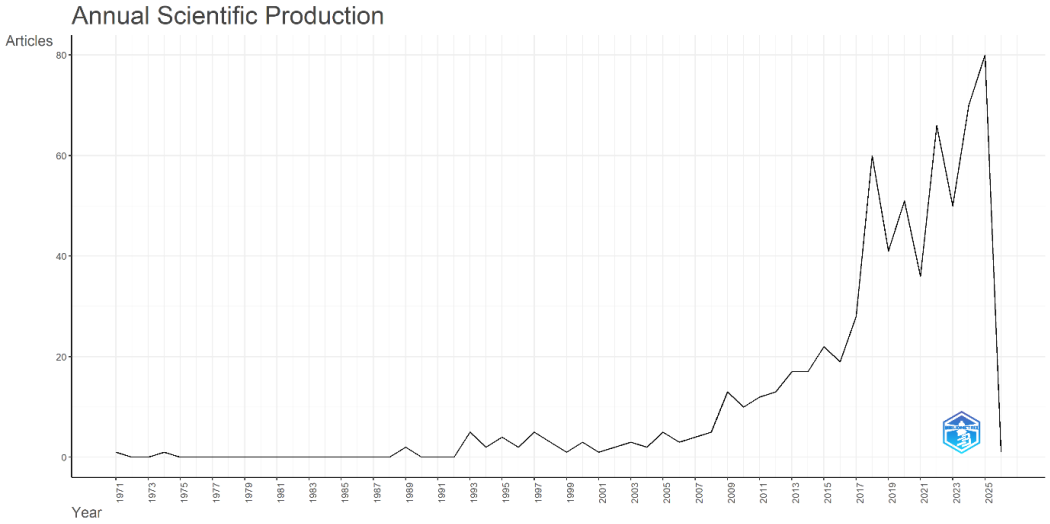


Figure 1. Annual Scientific Production

The three-field plot linking cited references, authors, and merged keywords (Figure 2) demonstrates the intellectual structure of the research domain. Foundational works such as Roth (1992) on environmental literacy, Hines (1987) and Hungerford (1990) on environmental education, and Ajzen (1991) on behavioral theory are highly cited and provide the conceptual backbone of the field. These works arefrequently cited by central authors such as Goldman, Pe'er, Kroufek, Erdoğan, and Stevenson, who act as key knowledge brokers. The dominant themes associated with these authors include *environmental literacy*, *environmental education*, *knowledge*, *attitudes*, *behavior*, and *climate change*. The presence of terms such as *curriculum*, *impact*, and *awareness* further highlights the educational and evaluative dimension of this body of literature.

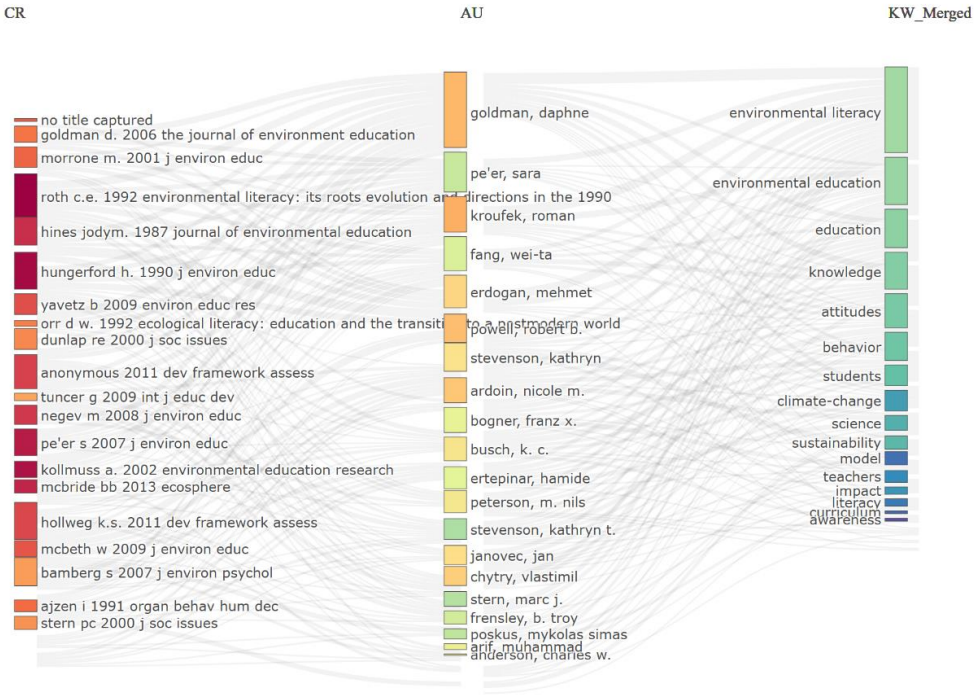


Figure 2. Intellectual Structure: References, Authors, and Keywords

The distribution of publications across journals (Figure 3) indicates that research is concentrated in a small number of highly relevant outlets. *Environmental Education Research* is the most prolific source, with 53 documents, followed closely by *Sustainability* (48 documents) and the *Journal of Environmental Education* (24 documents). Several interdisciplinary journals, such as *Journal of Cleaner Production* and *Environment, Development and Sustainability*, also appear among the top outlets, indicating the cross-cutting nature of the field.

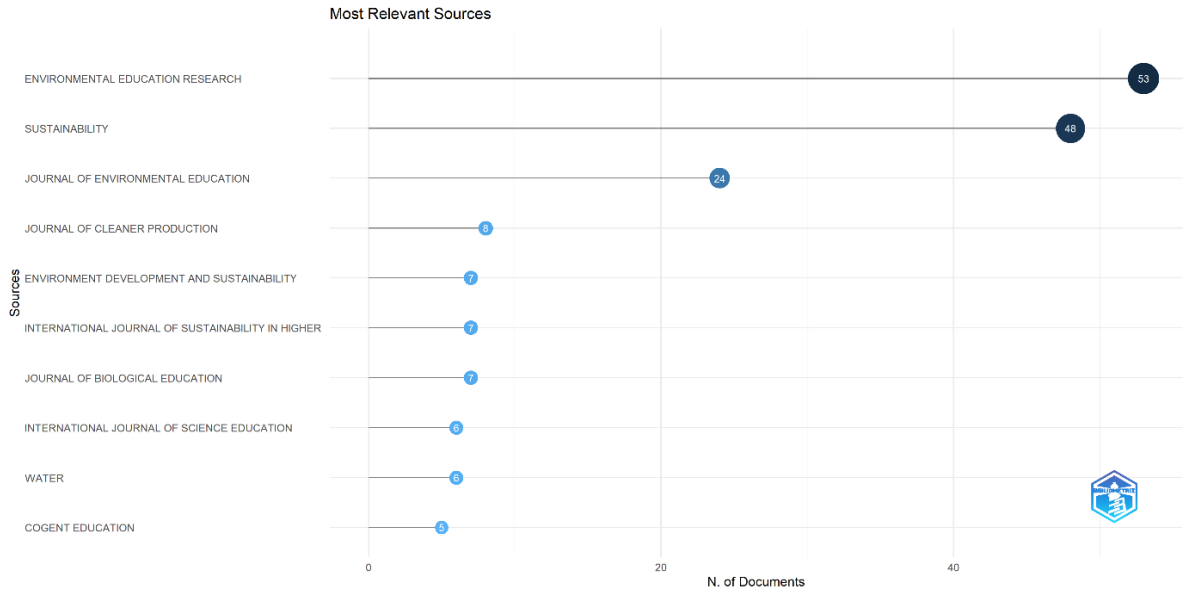


Figure 3. Sources and Publication Outlets

When examined longitudinally (Figure 4), it is evident that *Sustainability* and *Environmental Education Research* have emerged as the dominant outlets particularly after 2015, with cumulative publication counts far surpassing those of other journals. This trend suggests that both specialized and interdisciplinary venues have increasingly served as the main platforms for disseminating research on environmental education and literacy.

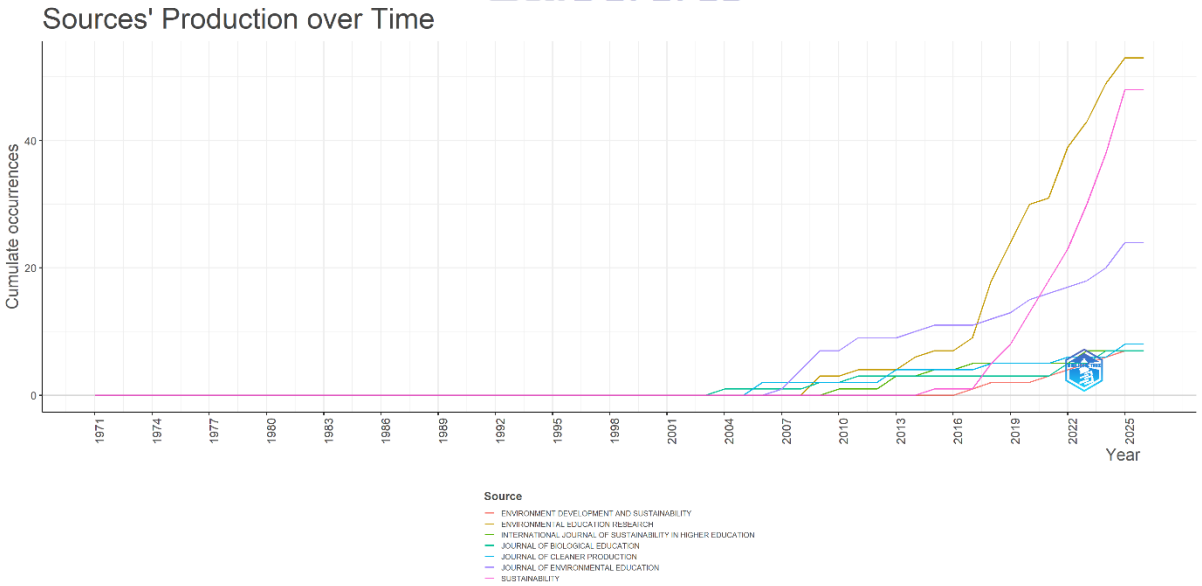


Figure 4. Production of Sources

The temporal distribution of author contributions (Figure 5) provides further insights into productivity patterns. Authors such as Goldman, Powell, and Ardoin have demonstrated sustained contributions across multiple years, indicating their long-term

involvement in the field. In contrast, others like Kroufek and Erdoğan show more recent bursts of activity, particularly in the last decade. The balance between established contributors and newer voices suggests both stability and renewal in the field's research community.

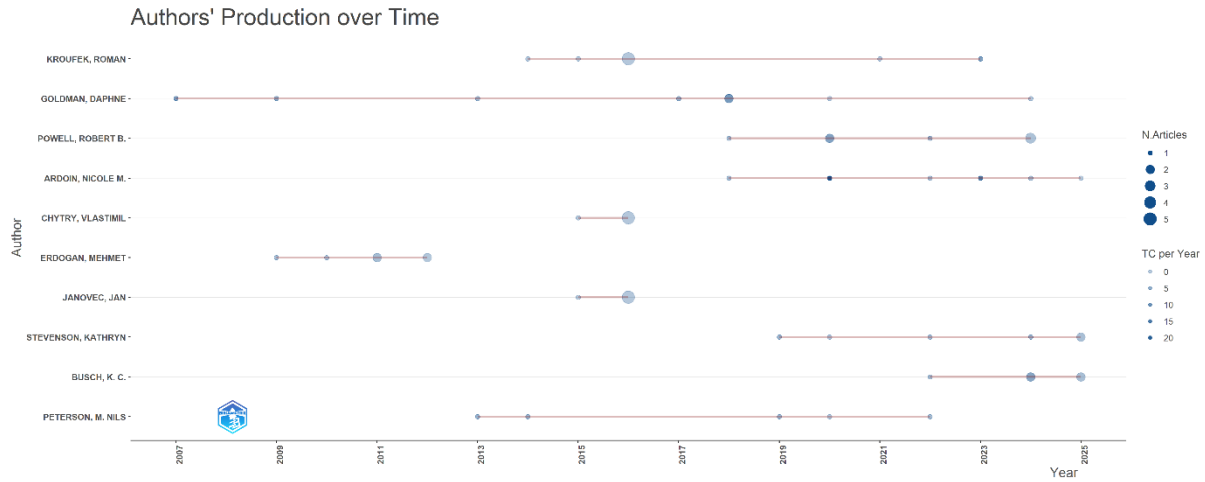


Figure 5. Temporal distribution of authors

Analysis of authorship patterns shows that *Kroufek, Roman* is the most productive author with nine publications, followed by *Goldman, Daphne* with eight, and *Powell, Robert B.* with seven (Figure 6). Several other authors, including Ardoin, Chytry, Erdoğan, and Janovec, have contributed six publications each, reflecting a moderately concentrated authorship structure.

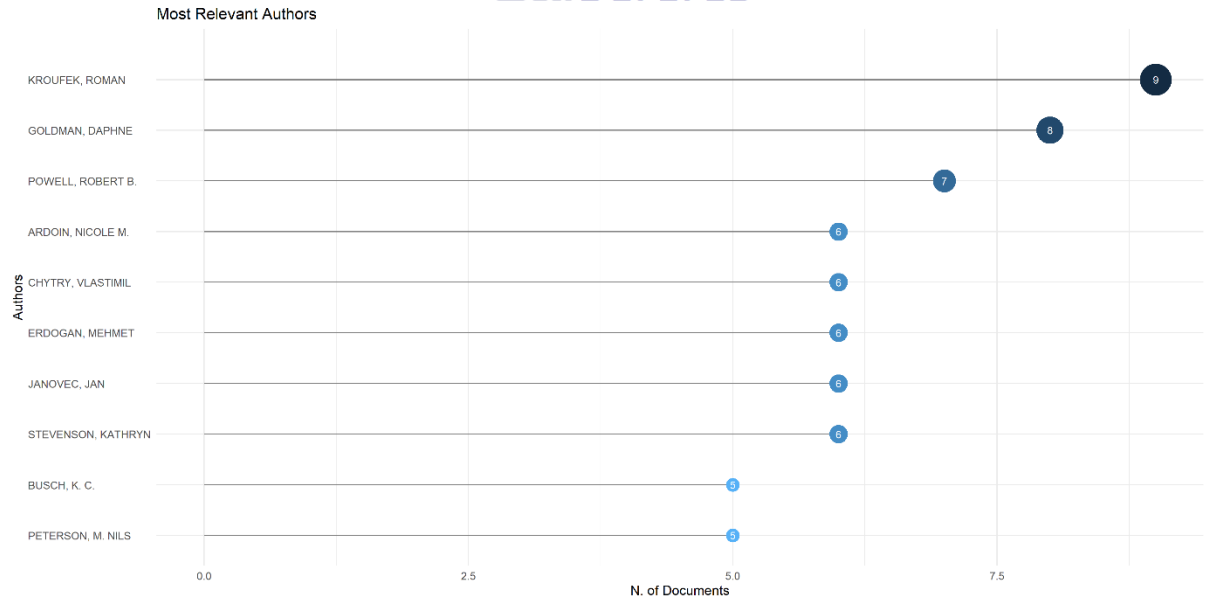


Figure 6. Authorship Patterns

The citation analysis (Figure 7) highlights a small number of highly influential publications. *Hoffman (2020, Climate)* stands out with 502 global citations, making it the single most impactful article in the collection. Other highly cited works include

McBride (2013, Ecosphere) with 186 citations and *Pe'er (2007, Journal of Environmental Education)* with 165 citations. Additional notable contributions include Ardoin (2020), Chen (2018), and Negev (2008), each surpassing 100 citations. The diversity of journals represented among these highly cited works reflects both the interdisciplinary nature of the field and the wide scholarly attention it has attracted.

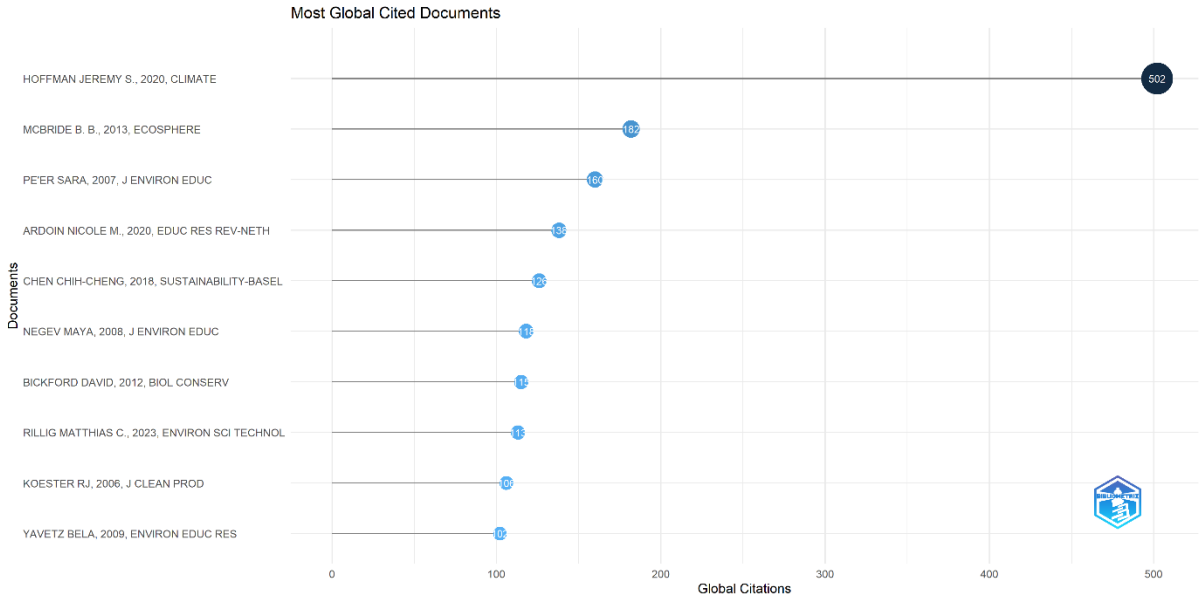


Figure 7. Most Globally Cited Documents

The analysis of trend topics from 2009 to 2025 (Figure 8) demonstrates the dynamic evolution of the field, beginning with early regionally focused and methodological terms such as *Turkey*, *ecology*, and *qualitative research* (2010–2015), progressing toward pedagogical foundations like *pre-service teachers*, *models*, and *higher education* (2014–2016), and later expanding to direct learner-centered themes including *curriculum*, *students*, *attitudes*, *knowledge*, and *environmental literacy* (2017–2020). From 2020 onwards, the focus shifts sharply to global and interdisciplinary challenges, with terms such as *climate change*, *sustainability*, *behavior*, *health*, and *risk* emerging as dominant, reflecting alignment with international environmental agendas and policy discourses. The bubble sizes and ranges highlight particularly "hot" topics in specific years, such as *climate change* (2021) and *sustainability* (2021–2022), which achieved exceptional prominence.

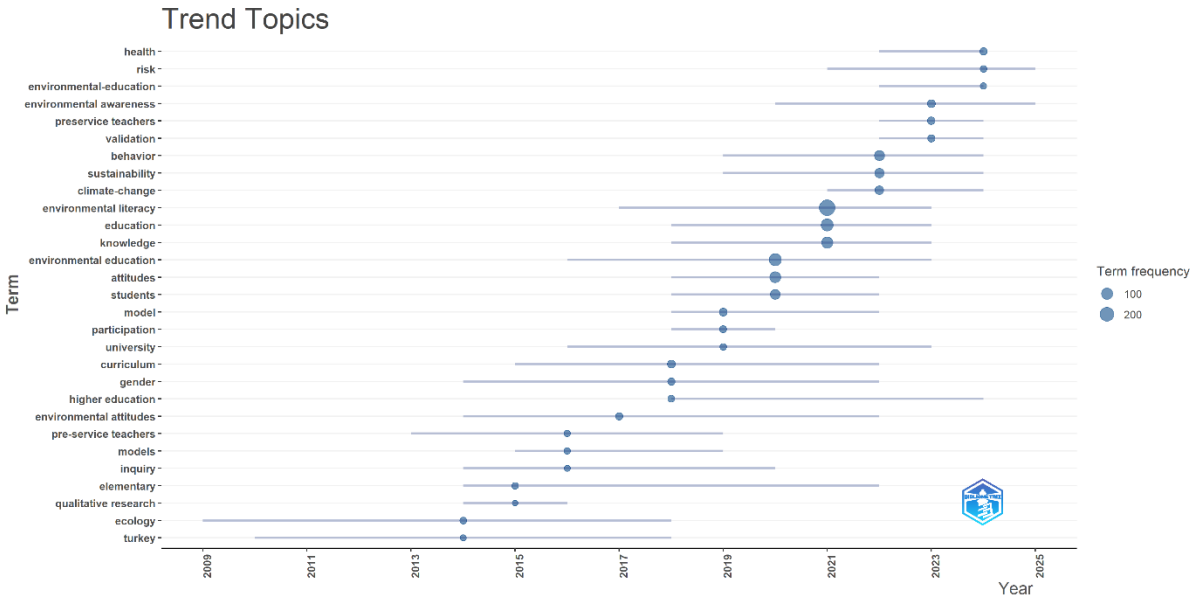


Figure 8. Trend Topics

Complementing this, the word cloud visualization (Figure 9) underscores the persistent dominance of core concepts like *environmental literacy*, *environmental education*, *knowledge*, *education*, *attitudes*, and *behavior*, while also highlighting the recurrent roles of *students*, *teachers*, and *sustainability*. Together, these results indicate that the field has evolved from localized and pedagogical beginnings to a more diverse, interdisciplinary, and globally engaged research domain, with education and literacy consistently serving as the intellectual anchor points around which emerging challenges and methodologies are organized.

IEER
Institute for Excellence in Education & Research



Figure 9. Word cloud visualization

The document coupling analysis (Figure 10) reveals two main clusters that map the intellectual organization of the field. On the left side of the plot, themes such as environmental literacy, environmental education, and ecological literacy appear with moderate to high impact but relatively lower centrality, suggesting that while they are influential in terms of citations and scholarly recognition, they are less integrated into the overall network structure. By

contrast, the cluster on the right, which includes environmental literacy, environmental education, and environmental behavior, demonstrates both higher centrality and strong impact, indicating that these topics function as the intellectual core of the field, connecting diverse strands of research while also driving influence. The positioning of environmental behavior with the highest centrality score (100%) underscores its bridging role, linking educational concepts with applied behavioral outcomes. Collectively, this visualization suggests that the field is anchored by a central cluster emphasizing education, literacy, and behavior, while adjacent clusters like ecological literacy remain impactful but more specialized.

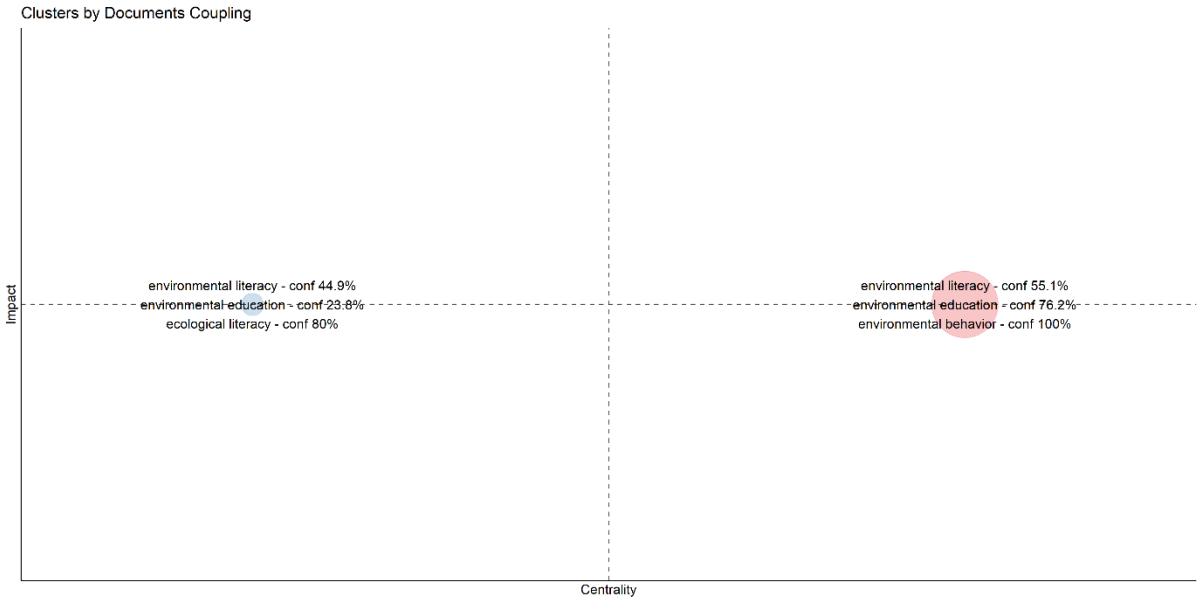


Figure 10. Document coupling analysis

The keyword co-occurrence network (Figure 11) highlights *environmental literacy* as the most central and influential theme, strongly connected to *student attitudes*, which together form the intellectual core of the field. Surrounding this hub, several thematic communities emerge. The largest (red) cluster revolves around environmental education and pedagogy, incorporating terms such as *school*, *higher education*, *teachers*, *curriculum*, *science education*, *sustainability*, and *conservation*, reflecting the centrality of teaching and learning processes in fostering literacy. The green cluster emphasizes psychological and behavioral drivers, with keywords such as *environmental knowledge*, *awareness*, *attitudes*, and *pro-environmental behavior*, showing the link between cognitive and affective dimensions and actual behaviors. The light-blue cluster situates environmental literacy in broader socio-cultural contexts, connecting terms like *climate change*, *perceptions*, *values*, *gender*, and *determinants*, which highlight the influence of social norms and demographic factors. A smaller orange cluster points toward citizen engagement and interdisciplinary overlaps, featuring terms like *citizen science*, *participation*, *framework*, and *health literacy*, suggesting a growing interest in public involvement and cross-domain integration. Peripheral nodes such as *biodiversity*, *ecological literacy*, and *health* show emerging or less integrated but significant directions. Overall, this network underscores that environmental literacy is the central anchor of the field, linking educational practices, psychological constructs, societal influences, and participatory approaches, thereby reflecting the interdisciplinary and evolving nature of the research landscape.

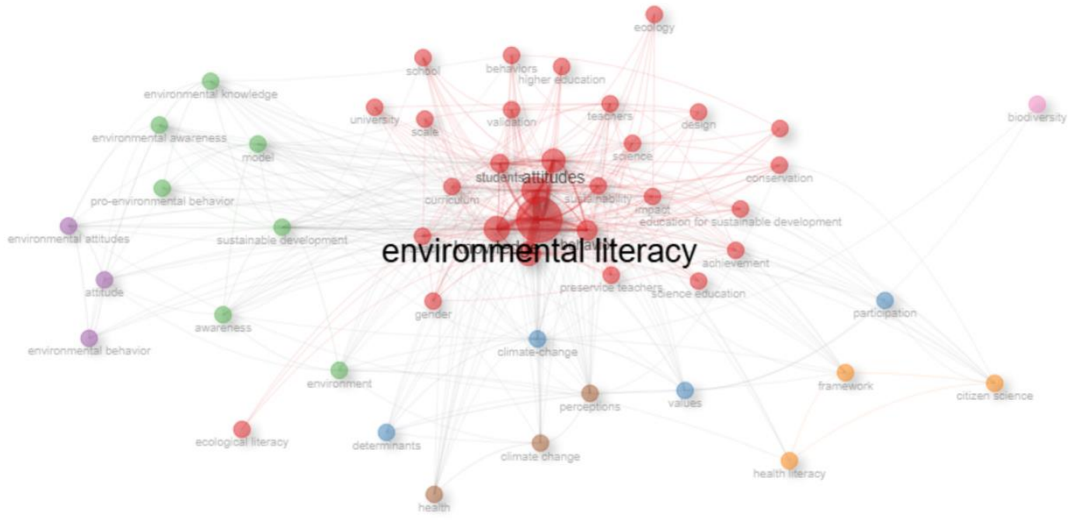


Figure 11. Keyword Co-occurrence Network

The strategic thematic map (Figure 12) provides an overarching view of the intellectual and conceptual structure of environmental and sustainability education research by classifying themes into four quadrants based on their centrality (relevance) and density (development). The Basic Themes quadrant (bottom-right) dominates, with clusters such as *environmental literacy*, *environmental education*, *science*, *climate change*, *teachers*, *models*, *awareness*, and *environmental knowledge* serving as the intellectual backbone of the field. These highly central but less internally cohesive themes represent broad, foundational areas that connect diverse research strands. The Niche Themes quadrant (top-left) contains clusters like *environmental impact*, *climate*, *artificial intelligence*, and *biodiversity/ecosystem services*, which are internally well-developed but less connected to the broader field, indicating specialized yet somewhat isolated areas of inquiry. The Motor Themes quadrant (top-right) is less populated, though themes like *risk*, *public health*, *environmental health literacy*, *energy*, and *education for sustainability* show high density and moderate-to-high centrality, marking them as emerging drivers that integrate environmental education with public health and applied sustainability practices. The Emerging or Declining Themes quadrant (bottom-left) features clusters such as *ecological literacy* and *ecological knowledge*, which currently have low density and centrality, suggesting they are either developing into more prominent areas or declining in broader relevance. Overall, this map highlights that the field is strongly anchored in educational foundations, increasingly diversifying into health, risk, and sustainability concerns, while simultaneously exploring cutting-edge approaches like artificial intelligence and citizen science that may grow into future motor themes.

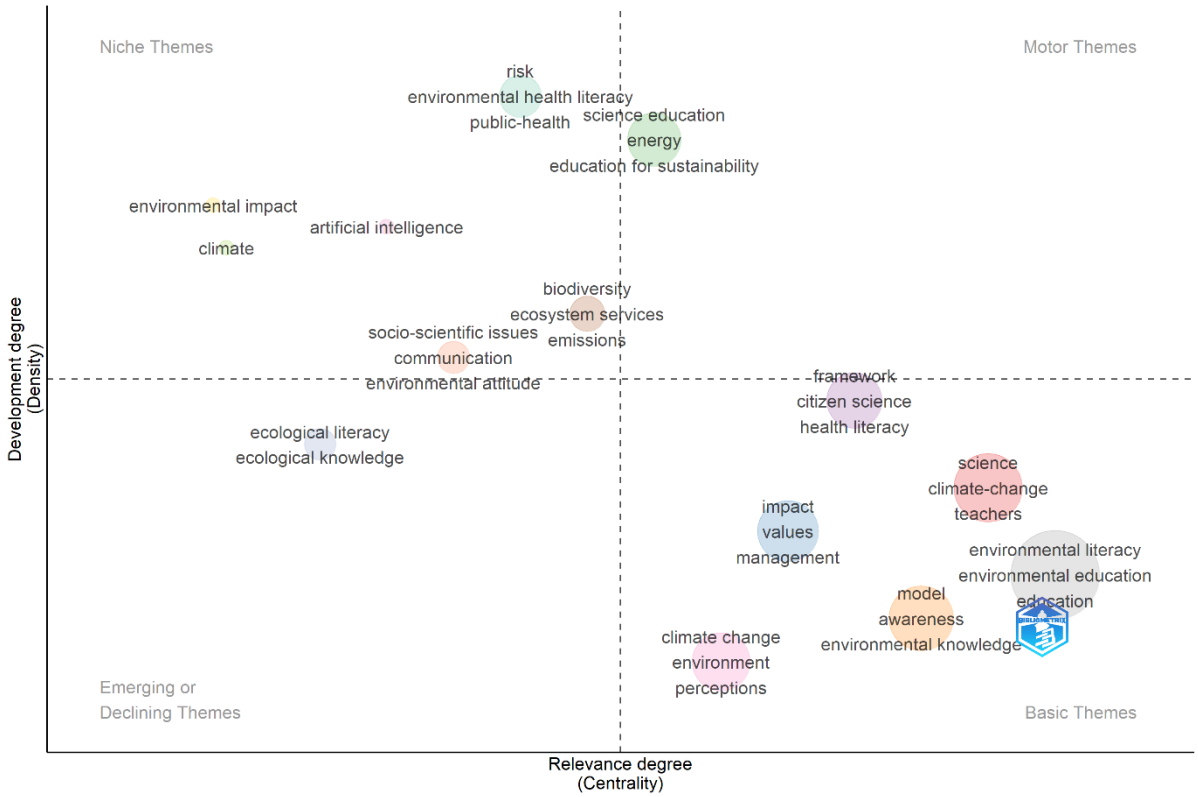


Figure 12. Thematic Map

The country collaboration map (Figure 13) highlights the global distribution and intensity of research partnerships in environmental and sustainability education. The United States emerges as the central hub, producing the highest volume of publications and maintaining the strongest international ties, particularly with Western Europe (UK, Germany, France), China, Canada, and Australia. China stands out as the second most influential hub, not only with a strong bilateral link to the USA but also with expanding collaborations across Europe and Oceania, reflecting its rapid integration into the global research network. Western Europe demonstrates both dense internal collaboration and robust external connections with North America and Asia, reinforcing its position as a critical bridge in global knowledge production. Australia also shows a globally oriented strategy, linking strongly with the USA, China, and European countries, while Canada mirrors this pattern within North America and the Commonwealth. Beyond these hubs, countries like Japan, India, and Brazil show notable participation, though their collaborative intensity is less pronounced. Overall, the map illustrates that research production and collaboration are dominated by the "Global North," structured along two primary axes: a Transatlantic axis (USA–Europe) and a Trans-Pacific axis (USA–China–Australia). This reflects a multipolar system where the USA remains central but is complemented by China's rise and Europe's collective strength, while large parts of Africa, the Middle East, and Southeast Asia remain underrepresented, highlighting an ongoing imbalance in global scientific participation.

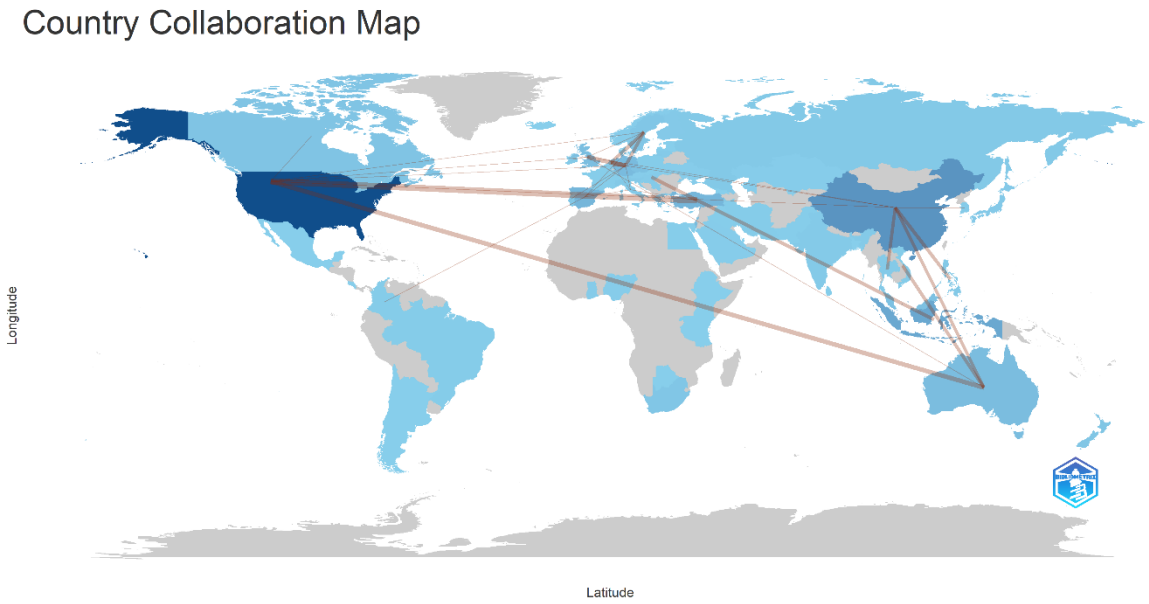


Figure 13. Collaboration Map

Discussion

The bibliometric analysis of environmental literacy scholarship reveals a field that has transitioned from a nascent, sporadic exploration of foundational concepts in environmental education and behavioral influences to a robust, interdisciplinary endeavor increasingly attuned to global sustainability imperatives and pedagogical innovations (Rafiq et al., 2022). Core intellectual anchors, drawn from early works on literacy constructs and attitude-behavior linkages, continue to underpin the domain, bridging foundational theories with practical applications in teaching and learning environments. Dominant publication outlets reflect this maturation, with specialized environmental education journals alongside broader sustainability-focused venues serving as key dissemination channels, while authorship patterns showcase a blend of enduring contributors and emerging voices fostering renewal. Citation landscapes highlight influential syntheses and empirical advancements that have shaped the field's trajectory, emphasizing measurement tools and evaluative frameworks.

Thematic evolution traces a progression from localized methodological inquiries and teacher-focused pedagogies to expansive concerns encompassing climate action, health risks, and citizen engagement, with persistent motifs of knowledge, attitudes, and behaviors forming the connective tissue across clusters. Network visualizations of keywords and documents illustrate a centralized hub around literacy and education, radiating into psychological, sociocultural, and participatory peripheries, while strategic maps position foundational educational themes as the bedrock, with motor themes in health and sustainability signaling dynamic growth. Collaboration geographies underscore a multipolar global structure dominated by transatlantic and trans-Pacific alliances, revealing persistent peripheries in the Global South that limit equitable knowledge flows. Overall, these structures portray environmental literacy not as a static construct but as a vital, evolving nexus for addressing ecological challenges through education, with untapped potential for broader inclusivity and integration.

The temporal unfolding of EL scholarship traces a trajectory of exponential maturation, commencing with sparse, foundational inquiries into conceptual delineation and affective predictors in the late 20th century, and accelerating into a prolific surge aligned with the proliferation of sustainability mandates post-millennium, which has diffused the construct across educational praxis into allied realms like public health and policy advocacy (Callon et al., 1991). This diffusion manifests not merely as volumetric expansion but as a conceptual osmosis, wherein early silos of teacher training and attitudinal surveys have

permeated interdisciplinary boundaries, engendering hybrid discourses on ecoliteracy's role in civic mobilization and systems thinking, as evidenced by the ingress of sustainability and climate motifs into core thematic repertoires (Rafols & Leydesdorff, 2009). Critically, this evolution underscores a tension between proliferation and coherence: while growth rates attest to EL's policy salience amid ecological urgencies, the attendant terminological sprawl, encompassing ecological literacy variants, risks diluting cumulative knowledge, necessitating meta-analytic safeguards to harmonize divergent operationalizations (McBride et al., 2013). In Pakistan's context, this diffusion highlights a lag in local assimilation, where nascent ESD integrations lag global paces, yet portend fertile ground for culturally attuned adaptations that could accelerate regional uptake and counter imported Eurocentric biases (Habib et al., 2021). Ultimately, the field's arc affirms bibliometric utility in prognosticating disciplinary vitality, revealing EL as a resilient nexus poised for further hybridization with emerging paradigms like digital literacies.

The analysis identifies a concentration of publications in journals like *Environmental Education Research*, *Sustainability*, and the *Journal of Environmental Education*, which serve as the main platforms for scholarly debate. Leading authors such as Goldman, Kroufek, and Powell illustrate a moderately concentrated authorship structure with knowledge brokers shaping discourse across subfields. These findings are consistent with prior bibliometric analyses that emphasize the role of specialized journals and central authors in structuring environmental education and literacy fields (Afandi etb al., 2023). The country analysis shows dominance of the United States, China, and Western Europe, while Global South countries, including Pakistan, remain underrepresented. This imbalance reflects broader structural inequalities in research production and visibility.

Foundational works such as Roth (1992), Hines (1987), and Ajzen (1991) remain central, anchoring the intellectual base in behavioral and educational theories. Subsequent research has operationalized environmental literacy as a multidimensional construct linking knowledge, attitudes, and behavior, with instruments like the Environmental Literacy Instrument for Adolescents (Szczytko et al., 2019) representing recent advances. The thematic evolution demonstrates a shift from localized, pedagogy-driven studies to more global, interdisciplinary concerns. This trajectory mirrors McBride et al.'s (2013) observation that definitions of environmental literacy remain fluid but increasingly encompass cross-disciplinary linkages.

Authorship and collaboration analyses show moderate co-authorship rates and relatively low international collaboration, with only around 14% of works being cross-border. The USA-Europe and USA-China axes dominate, while underrepresentation of regions such as Africa and South Asia indicates limited global inclusivity. These findings echo Donthu et al. (2021), who note that bibliometric patterns often reproduce existing inequalities in global science. For Pakistan, while sustainability and environmental education are gaining policy traction, limited collaboration networks constrain visibility and integration into global debates (Habib et al., 2021). Building stronger co-authorship ties could help bridge these gaps and situate Pakistan more centrally in the field.

Trend analyses highlight the rise of themes such as climate change, sustainability, health, and risk after 2020, alongside emerging intersections with artificial intelligence and citizen science. This aligns with Zupic and Čater's (2015) argument that bibliometrics can identify emerging research fronts and thematic shifts. The strong prominence of sustainability-related keywords underscores the growing convergence between environmental literacy and broader sustainability education discourses. At the same time, ecological literacy and biodiversity remain underdeveloped themes, suggesting potential for future growth.

This study relies on Web of Science as the sole bibliographic database, which, while authoritative, does not index all journals, particularly those from the Global South. As a result, regional contributions may be underrepresented, and thematic diversity may not be fully captured. The exclusive reliance on one database also limits cross-validation against alternative sources such as Scopus or Google Scholar. Future research should expand to include multiple bibliographic databases to ensure greater inclusivity and capture of regional voices. Cross-comparison of

Web of Science and Scopus would strengthen reliability and reveal discrepancies in coverage. Deeper qualitative analysis could complement bibliometrics by examining how environmental literacy is contextualized in diverse educational and cultural settings. Greater attention should be directed toward Global South contributions, not only to correct geographic imbalances but also to diversify theoretical and methodological perspectives. Finally, future studies should integrate emerging intersections such as digital literacy, climate justice, and citizen engagement to capture the expanding scope of environmental literacy.

Conclusion

This study provides the first comprehensive bibliometric synthesis of environmental literacy, tracing its conceptual, intellectual, and social development over five decades. The analysis shows that environmental literacy has matured into an interdisciplinary domain anchored in education and behavior, while increasingly intersecting with sustainability, climate change, and public health concerns. Influential journals and authors consolidate the field, but global participation remains uneven, with strong dominance of the Global North and underrepresentation of the Global South. Pakistan and similar contexts are emerging but remain peripheral in global research flows. The findings emphasize the dual character of the field: it has developed a clear intellectual foundation through theories of behavior and education, yet continues to diversify with new approaches, instruments, and themes. By mapping publication patterns, knowledge structures, and collaboration networks, this study offers scholars and policymakers an evidence base to situate their work, identify gaps, and design future agendas that prioritize inclusivity, interdisciplinary integration, and stronger South–North partnerships.

REFERENCES

Afandi, A., Ningsih, K., Sari, M., Indriyani, S., & Djaroneh, E. (2023). Bibliometric analysis of environmental literacy: A systematic literature review using VOSviewer. *AIP Conference Proceedings, 2751*(1), 020001. https://doi.org/10.1063/5.0143401

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Boyack, K. W., & Klavans, R. (2010). Co-citation analysis, bibliographic coupling, and direct citation: Which citation approach represents the research front most accurately? *Journal of the American Society for Information Science and Technology, 61*(12), 2389-2404. https://doi.org/10.1002/asi.21419

Callon, M., Courtial, J. P., & Laville, F. (1991). Co-word analysis as a tool for describing the network of interactions between basic and technological research: The case of polymer chemsitry. *Scientometrics, 22*(1), 155–205. https://doi.org/10.1007/bf02019280

Chen, C. (2006). CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology, 57*(3), 359–377. https://doi.org/10.1002/asi.20317

Cobo, M., López-Herrera, A., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology, 62*(7), 1382–1402. https://doi.org/10.1002/asi.21525

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Habib, M. N., Khalil, U., Khan, Z., & Zahid, M. (2021). Sustainability in higher education: What is happening in Pakistan? *International Journal of Sustainability in Higher Education, 22*(3), 681–706. https://doi.org/10.1108/IJSHE-06-2020-0207

Hsu, S.-J., & Roth, R. E. (1998). An Assessment of Environmental Literacy and Analysis of Predictors of Responsible Environmental Behaviour Held by Secondary Teachers in the Hualien Area of Taiwan. *Environmental Education Research*, *4*(3), 229–249. https://doi.org/10.1080/1350462980040301

Lopera-Perez, M., Maz-Machado, A., Madrid, M. J., & Cuida, A. (2021). Bibliometric analysis of the international scientific production on environmental education. *Journal of Baltic Science Education*, *20*(3), 428–442. https://doi.org/10.33225/jbse/21.20.428

McBride, B. B., Brewer, C. A., Berkowitz, A. R., & Borrie, W. T. (2013). Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere (Washington, D.C)*, *4*(5), art67-20. https://doi.org/10.1890/ES13-00075.1

Perianes-Rodriguez, A., Waltman, L., & Van Eck, N. J. (2016). Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of Informetrics*, *10*(4), 1178–1195. https://doi.org/10.1016/j.joi.2016.10.006

Rafiq, S., Afzal, A., & Kamran, F. (2022). Impact of School Environment on Students' Academic Achievements at the University Level. *VFAST Transactions on Education and Social Sciences* *10*(4), 19-30. https://doi.org/10.21015/vtess.v10i4.1216

Rafiq, S., Kamran, F., & Afzal, A. (2024). Assessing Environmental Awareness Integration in the Curriculum: A Case Study of Lahore's Private Schools. *Al-Qudwah*, *02*(04), 86-100. https://al-qudwah.com/index.php/aqrj/article/view/36

Rafols, I., & Leydesdorff, L. (2009). Content-based and algorithmic classifications of journals: Perspectives on the dynamics of scientific communication and indexer effects. *Journal of the American Society for Information Science and Technology*, *60*(9), 1823-1835. https://doi.org/10.1002/asi.21086

Saqib, Z. A., Zhang, Q., Ou, J., Saqib, K. A., Majeed, S., & Razzaq, A. (2020). Education for sustainable development in Pakistani higher education institutions: an exploratory study of students' and teachers' perceptions. *International Journal of Sustainability in Higher Education*, *21*(6), 1249–1267. https://doi.org/10.1108/IJSHE-01-2020-0036

Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science*, *24*(4), 265-269. https://doi.org/10.1002/asi.4630240406

Stern, M. J., Powell, R. B., & Hill, D. (2014). Environmental education program evaluation in the new millennium: what do we measure and what have we learned? *Environmental Education Research*, *20*(5), 581–611. https://doi.org/10.1080/13504622.2013.838749

Szczytko, R., Stevenson, K., Peterson, M. N., Nietfeld, J., & Strnad, R. L. (2019). Development and validation of the environmental literacy instrument for adolescents. *Environmental Education Research*, *25*(2), 193–210. https://doi.org/10.1080/13504622.2018.1487035

Teksoz, G., Sahin, E., & Tekkaya-Oztekin, C. (2012). Modeling Environmental Literacy of University Students. Journal of Science Education and Technology, 21(1), 157–166. https://doi.org/10.1007/s10956-011-9294-3

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Waltman, L., van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics*, *4*(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods*, *18*(3), 429–472. https://doi.org/10.1177/1094428114562629.

IEER
Institute for Excellence in Education & Research