

Environmental literacy in higher education: A scopus-based longitudinal bibliometric mapping

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Abstract

Environmental literacy (EL) has become a central concern in Education for Sustainable Development (ESD), yet existing reviews remain conceptually fragmented and rarely integrate longitudinal, structural, and thematic evidence in higher education contexts. This study addresses that gap through an analytical-interpretive Scopus-based longitudinal bibliometric mapping that goes beyond descriptive performance reporting toward field-level diagnosis. A dataset of 229 records (2010–2025) was screened using PRISMA 2020 and finalized to 127 eligible English peer-reviewed journal articles, processed through Bibliometric and Biblioshiny in R after author-name normalization, keyword harmonization, and duplicate removal. Findings revealed an accelerating post-2021 growth pattern ($R^2 = 0.628$), a Lotka-consistent productivity skew indicating a small recurring core within a long tail of one-time contributors, and a national-anchored collaboration profile in which the United States, Spain, and China dominated while cross-regional partnerships remained limited. Thematic mapping showed conceptual convergence around environmental education, ESD, and sustainability-aligned higher education, while classroom pedagogy and instructional implementation persisted as visible but underdeveloped research fronts reframed here as a pedagogical implementation gap rather than a marginal finding. The study contributes (i) theoretically, by linking bibliometric structure to environmental and sustainability literacy theory and ESD frameworks; (ii) methodologically, by integrating productivity, collaboration, and thematic evolution within a single analytical-interpretive design; and (iii) practically, by offering an evidence base for lecturers, curriculum designers, and institutions seeking to translate sustainability discourse into validated classroom practice.

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1. Introduction

Global environmental challenges, including climate change, biodiversity loss, and pollution, intensified scholarly attention toward environmental literacy (EL) development in higher education. EL was increasingly framed as a multidimensional and interdisciplinary university learning construct, extending beyond knowledge transmission toward sustainability reasoning and ethical awareness. Contemporary scholarship increasingly recognizes that addressing complex environmental problems requires citizens who are capable of critical thinking, systems-oriented reasoning, and ethical engagement with socio-environmental issues (Ardoin et al., 2020; Hofreiter et al., 2007; Lezak & Thibodeau, 2016; Mellyzar et al., 2025; Shutaleva, 2023).

Higher education institutions served as central environments for EL knowledge production and sustainability research diffusion. Universities functioned as spaces for conceptual development and interdisciplinary research consolidation, supporting strategic educational transformation rather than acting solely as knowledge transmission sites. Consequently, EL has been progressively integrated into higher education curricula, pedagogical models, and institutional sustainability strategies. Recent studies indicate a growing emphasis on embedding EL within disciplinary learning, sustainability-oriented teaching practices, and

campus-wide initiatives aimed at fostering pro-environmental competencies among students (Mngomezulu & Ramaila, 2025; Santiani et al., 2024; Sohaee & Farsad, 2025).

In the wider educational innovation landscape, prior studies indicated that environmental awareness and sustainability-oriented literacy were strengthened through media-supported learning pathways (Izhar et al., 2022; Widiyatmoko et al., 2022) and were influenced by contextual drivers that shaped learners' perceptions and pro-environmental behavior (Jaya et al., 2024; Sari et al., 2024). Alongside these developments, scholarly research on EL in higher education expanded substantially over the past decade, reflecting increasing interdisciplinary engagement across education, sustainability science, and environmental studies. Empirical investigations examined students' environmental knowledge, attitudes, and behavioral patterns across university contexts (Blanco et al., 2024; Yang et al., 2025). However, the literature remains fragmented and offers limited empirically validated evidence on structured classroom instructional implementation at the level of course delivery. This persistent gap between rapid thematic expansion and classroom-level pedagogical validation is not a peripheral observation; rather, it is symptomatic of a wider asymmetry in which sustainability discourse has moved faster than the design, testing, and reporting of pedagogically grounded EL interventions in university courses.

Although a growing number of bibliometric analyses have explored sustainability education, ESD, and sustainability literacy, the present study differentiates itself in three key respects. First, prior bibliometric work has tended to address either broad sustainability constructs (Dönmez, 2024; Tafese & Kopp, 2025; Veres et al., 2025) or generic sustainability literacy at mixed educational levels (Ariyatun et al., 2024; Saarna & Laius, 2025; Sanchez et al., 2025), without isolating EL as a distinct construct embedded specifically within higher education curricula and pedagogy. Second, earlier mappings have largely emphasized publication performance and descriptive trend reporting, while integrated structural diagnosis linking productivity, geographic collaboration, thematic evolution, and citation-driven knowledge dynamics within a single analytical-interpretive frame remains uncommon. Third, and most consequentially, previous reviews seldom interrogate the relationship between conceptual expansion and classroom-level instructional evidence, leaving the pedagogical translation of EL theory underexamined. The present study is therefore positioned explicitly within the sustainability literacy and ESD research mapping tradition (Kaya & Elster, 2019; Michel et al., 2024; Sanchez et al., 2025) but reorients the analytical lens toward instructional implementation as a structural blind spot in the field.

A central issue has centered on conceptual inconsistency, as EL had been studied through diverse frameworks, disciplinary lenses, and localized institutional contexts. Consequently, cumulative knowledge development became more difficult, limiting analytical clarity on influential contributors and classroom-level instructional evidence. Although localized narrative reviews clarified EL dimensions, these reviews offered limited field-level structural insights into publication growth, collaboration networks, and citation-driven knowledge formation. The scarcity of studies evaluating structured sustainability pedagogy at the course delivery level signals an instructional implementation blind spot rather than a decline in theoretical interest. Read against the wider ESD agenda articulated by UNESCO (2017), this asymmetry suggests that EL is being institutionalized as policy and curricular discourse faster than it is being operationalized as evidence-based classroom practice precisely the kind of gap that integrated bibliometric mapping is well positioned to surface.

Bibliometric mapping provided a quantitative approach to profile influential sources, recurring authors, institutional hubs, and collaboration patterns, supporting strategic sustainability research positioning without relying on narrative speculation (Donthu et al., 2021; Passas, 2024; Surendar et al., 2024). Existing reviews interpreted EL conceptually, while structural, field-level analysis using integrated Scopus bibliometrics remained underutilized. These studies have contributed to clarifying definitions, dimensions, and instructional strategies related to EL development in educational settings (Kaya & Elster, 2019; Saarna & Laius, 2025; Sanchez et al., 2025). Moreover, prior bibliometric studies assessed broad sustainability constructs rather than focusing specifically on EL in higher education, which reduced analytical clarity on instructional research frontiers and cross-regional collaboration patterns. (Ling et al., 2021; Michel et al., 2024).

Building on this positioning, the contribution of the present study is reframed from descriptive mapping to analytical-interpretive synthesis. Rather than reporting publication counts and network statistics in isolation, each indicator is interpreted as a diagnostic of the field's epistemic structure: growth curves are read as signals of disciplinary maturation, productivity skews as indicators of consolidation versus dispersion, collaboration profiles as evidence of global epistemic (in)equity, and thematic structures as proxies for the depth of pedagogical translation. This interpretive layer allows the study to engage directly with sustainability literacy theory and ESD frameworks rather than remaining at the level of metric description.

In light of these limitations, a clear research gap can be identified. To date, there has been no holistic bibliometric study that systematically maps EL research in higher education by integrating longitudinal publication trends, scholarly productivity, geographic distribution and collaboration, thematic and keyword structures, and citation-based influence. Addressing this gap is necessary to consolidate existing knowledge, identify research strengths and blind spots, and support future investigations that align with global

sustainability priorities and higher education policy agendas (Franco et al., 2019; Kessler, 2018; Pompeii et al., 2019; Sule & Greig, 2017).

Accordingly, the present study aims to provide a comprehensive bibliometric analysis of EL research in higher education. Specifically, the study addresses five research questions (RQ). RQ1 examines the annual publication trends of EL research in higher education to identify patterns of growth and development over time. RQ2 analyzes scholarly productivity by identifying the journals, authors, and institutions that have contributed most significantly to the field. RQ3 explores the geographic distribution of research output and examines international collaboration patterns among countries. RQ4 investigates the intellectual and thematic structure of the field by analyzing dominant thematic clusters and keyword co-occurrence patterns. Finally, RQ5 identifies influential publications that constitute the core knowledge base of EL research in higher education based on citation metrics. Through these integrated analyses, this study seeks to offer a structured and evidence-based overview of the field, thereby supporting both theoretical advancement and informed decision-making in sustainability-oriented higher education research.

2. Method

2.1. Data Sources and Justification for Database Selection

The decision to rely on Scopus as the primary data source was guided by three interrelated considerations. First, in terms of coverage, Scopus indexes a broader set of peer-reviewed journals in the social sciences, education, and sustainability than Web of Science (WoS), particularly for journals published outside North America and Europe (Mongeon & Paul-Hus, 2016). Given that EL and ESD research has expanded notably in Asia, Latin America, and Africa, Scopus offers greater geographic representativeness than WoS, which historically over-represents Anglophone outlets. Second, in terms of metadata quality, Scopus provides standardized author identifiers, controlled affiliation strings, and structured keyword fields that are essential for reliable productivity, collaboration, and co-occurrence analysis. Google Scholar, although wider in coverage, lacks consistent metadata, includes non-peer-reviewed material, and produces unstable citation counts, making it unsuitable for systematic bibliometric mapping. Third, in terms of analytical interoperability, Scopus exports cleanly into BibTeX and integrates seamlessly with the Bibliometrix package in R, ensuring methodological reproducibility. Although a complementary search in WoS could enrich coverage, prior comparative analyses indicate substantial overlap between Scopus and WoS for sustainability and education topics, and a single high-quality source is preferable to a merged dataset that risks duplication artifacts and inconsistent metadata fields (Donthu et al., 2021; Mongeon & Paul-Hus, 2016).

The search strategy was designed to capture scholarly articles addressing EL within the context of sustainability education in higher education. Accordingly, a structured search query was applied to the TITLE-ABS-KEY fields, combining three core conceptual domains: (1) environmental literacy-related terms, (2) sustainability education-related terms, and (3) higher education-related terms. The final search string was formulated as follows:

(TITLE-ABS-KEY ("Environmental literacy" OR "Environmental education" OR "Environmental awareness") AND ("Sustainability education" OR "Sustainable development education" OR "ESD") AND ("Higher education" OR "University" OR "College" OR "Tertiary education").

This query ensured that only peer-reviewed journal articles written in English and published in final form between 2010 - December 2025 were included. The selected time span was intended to capture both the early development and recent expansion of EL research in higher education, particularly in relation to sustainability and education for sustainable development (ESD). The full BibTeX file used in this study is publicly accessible in the Open Science Framework (OSF) repository (<https://doi.org/10.17605/OSF.IO/HMGTD>).

2.2. Potential Bias and Mitigation Strategies

Bibliometric studies are subject to several recognized sources of bias. To enhance methodological transparency, four potential biases are explicitly acknowledged together with the corresponding mitigation strategies adopted in this study. First, database bias arises because no single database covers the full universe of scholarly outputs; reliance on Scopus may underrepresent regional journals that are not Scopus-indexed. This was mitigated by interpreting findings as a map of the indexed knowledge core rather than the complete global literature, and by triangulating thematic patterns with prior reviews drawing from WoS and Google Scholar. Second, language bias results from restricting the corpus to English-language articles, which may exclude relevant Hispanophone, Lusophone, and Sinophone scholarship; this was mitigated by openly reporting the language filter, retaining English abstracts of multilingual studies where available, and explicitly framing the corpus as the English-medium scientific record. Third, time-span bias may distort growth and citation curves; the 2010–2025 window was selected to align with the post-DESD (UN Decade of Education for Sustainable Development) era, and citation trends from 2023–2025 are interpreted with caution given the time lag in

citation accumulation. Fourth, document-type bias was addressed by restricting the corpus to peer-reviewed journal articles; book chapters, conference papers, and editorials were excluded to ensure quality control, with the trade-off that emerging instructional practice reports in conference proceedings are not represented. These limitations are revisited in the Discussion to ensure that interpretive claims do not exceed what the corpus can support.

2.3. Screening and Selection Procedure

This study followed the PRISMA 2020 guidelines to ensure transparency and methodological rigor in article selection. A structured search was performed in Scopus using the TITLE-ABS-KEY fields, supported by database-embedded automatic filters to restrict document type, publication stage, language, source type, and publication year. The search retrieved 229 records. In the Identification stage, 27 records published outside the target period (2010–2025) were removed, resulting in 202 documents. Language screening then excluded 6 non-English articles, leaving 196 records for further review. In the Screening stage, 64 records were excluded by source and document format, comprising 33 book chapters, 15 conference papers, 14 review articles, and 2 books, which yielded 132 peer-reviewed journal articles. During the Eligibility assessment, 5 in-press articles were removed, producing a final corpus of 127 English peer-reviewed journal articles. The complete selection workflow was presented in Figure 1 using a PRISMA flow diagram.

2.4. Data Extraction and Preparation

All eligible documents were exported from Scopus in BibTeX format, including authorship, affiliations, titles, abstracts, keywords, sources, publication years, and citation data. The exported dataset was imported into the R programming environment for cleaning and analysis. To ensure data quality, three preprocessing steps were performed before analysis. (1) Author name normalization: variant spellings, transliteration differences, and inconsistent middle-initial usage were unified by reconciling Scopus Author IDs with manually inspected name strings, so that contributions by the same author indexed under different formats were merged. (2) Keyword harmonization: author keywords and indexed keywords were lowercased, lemmatized, and merged where they referred to the same concept (for example, "education for sustainable development," "ESD," and "sustainable development education" were consolidated; "pro-environmental behavior" and "pro-environmental behaviour" were unified). Keyword harmonization was performed in R using a manually curated thesaurus to preserve conceptual fidelity rather than relying solely on automated stemming. (3) Duplicate removal: duplicates were screened using DOI as the primary key, with title–author–year matching as a fallback for records with missing DOIs. These steps reduced metadata noise, prevented inflation of productivity counts, and improved the reliability of the co-occurrence and collaboration networks.

2.5. Bibliometric Analysis

The bibliometric analysis was conducted using the Bibliometrix package in R, an open-source tool specifically developed for science mapping and bibliometric research (Aria & Cuccurullo, 2017). Bibliometrix enables the quantitative analysis of large bibliographic datasets and supports a wide range of bibliometric indicators related to publication performance, collaboration patterns, and intellectual structure.

To facilitate interactive exploration and visualization, Biblioshiny, the web-based interface of Bibliometrix, was employed. Biblioshiny supports detailed analyses of annual publication trends, journal and author productivity, institutional and country-level contributions, collaboration networks, keyword co-occurrence patterns, thematic evolution, and citation structures.

The analyses conducted in this study included annual scientific production, most relevant sources and authors, institutional and country productivity, international collaboration networks, keyword co-occurrence analysis, thematic mapping, and citation analysis. All analyses were performed directly within the Bibliometrix/Biblioshiny environment without the use of external visualization software.

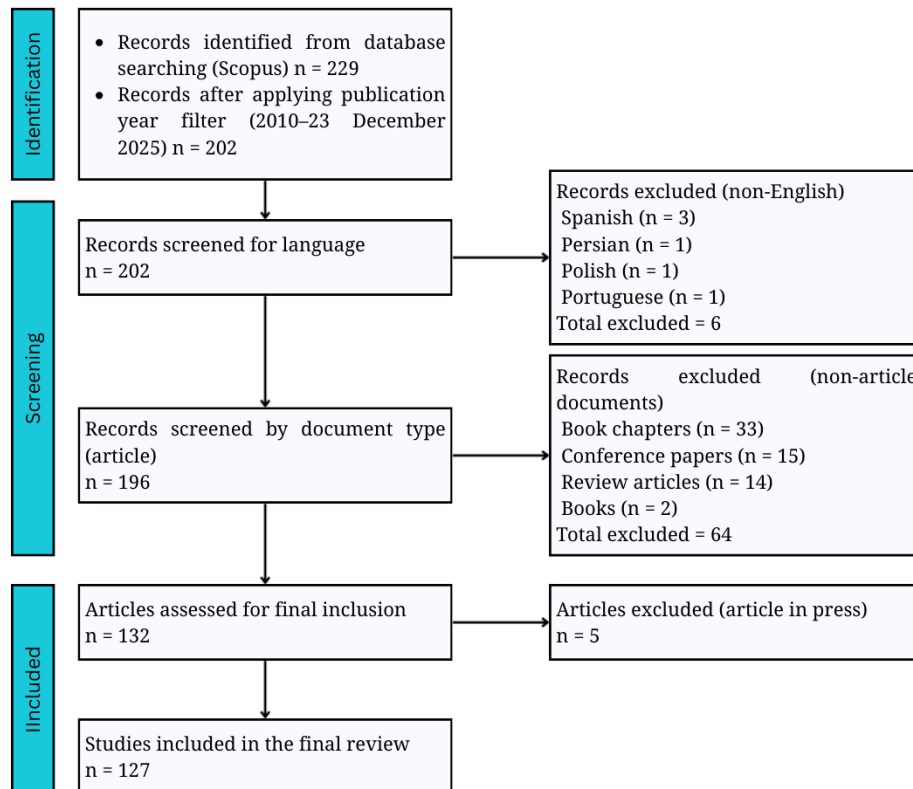


Figure 1. PRISMA Flow Diagram for The Selection of Studies on EL in Higher Education

2.6. Analytical Alignment with Research Questions

Annual publication trajectories informed RQ1. Journal, author, and institutional productivity analyses addressed RQ2. Country productivity and collaboration structures informed RQ3. Keyword co-occurrence networks and thematic mapping answered RQ4. Citation influence metrics consolidated the core knowledge base to answer RQ5. Figure 2 shown a workflow to clarify the research process.

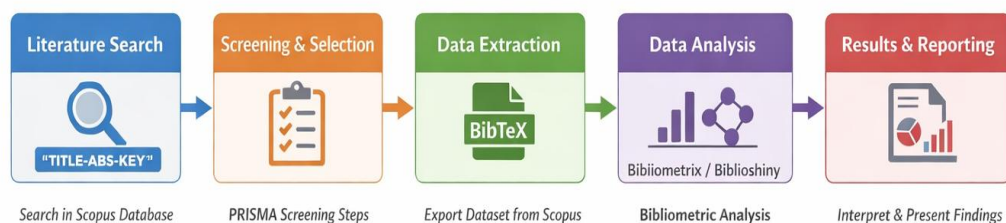


Figure 2. Workflow to Clarify the Research Process

3. Results and Discussion

This section reports the findings of the Scopus-based longitudinal bibliometric analysis of EL research in higher education. The results are organized according to the five research questions and cover annual publication trajectories, productivity of core sources, country-level collaboration patterns, citation influence, and thematic knowledge structures. Each finding is presented in a three-layer analytical structure interpretation (what the pattern means), explanation (why the pattern emerged), and implication (what it means for theory, policy, and practice) so that the discussion moves consistently beyond descriptive reporting toward field-level diagnosis.

3.1. RQ1: What are the annual publication trends and growth patterns of EL research in higher education?

Publications were low between 2010 and 2013, fluctuating from 2 to 6 articles per year, indicating an early exploratory phase. From 2014 to 2019, publication output increased gradually and reached a local peak of 10 articles in 2019. A temporary decline occurred in 2020 (7 articles) before output accelerated markedly after

2021, reaching 19 articles in 2022 and 20 articles in 2025 (Figure 3). The life-cycle model in Figure 4 returned $R^2 = 0.628$, with a projected maximum of 46 publications around 2039. The cumulative curve in Figure 5 followed a sigmoidal trajectory with clear acceleration after 2020 but had not reached the 90% threshold, indicating that the field has not yet entered saturation.

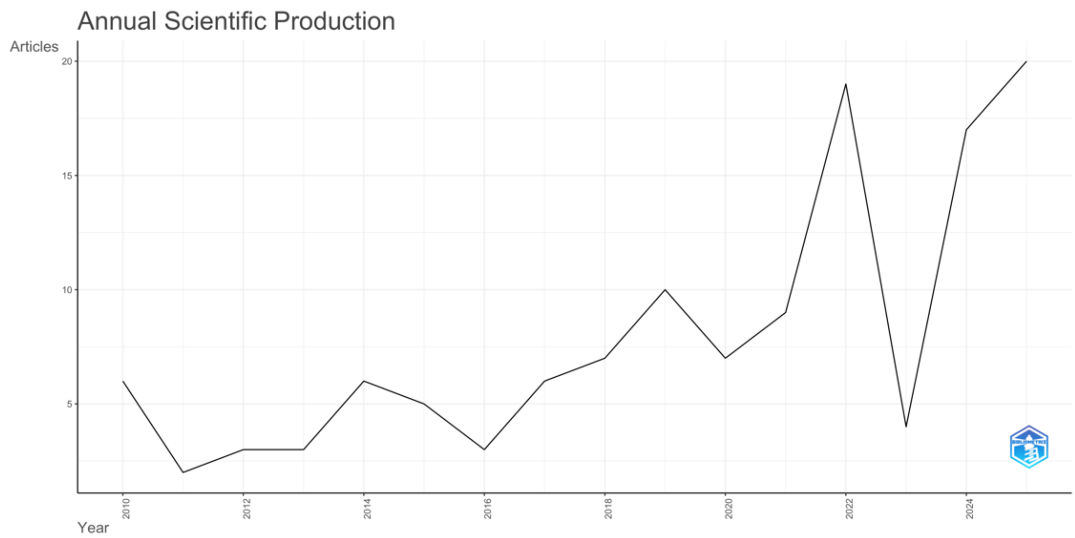


Figure 3. Annual Scientific Production on EL in Higher Education (2010-2025)

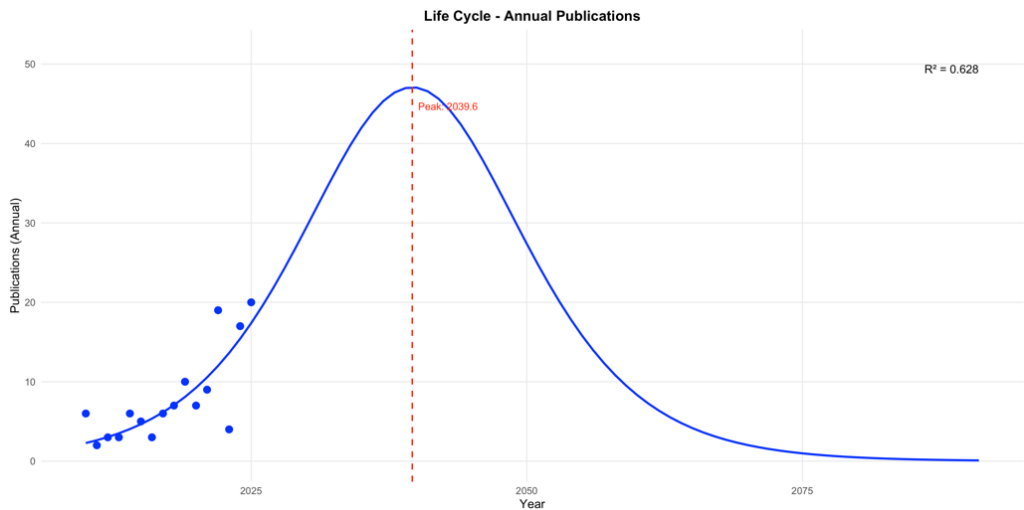


Figure 4. Life Cycle of EL Research in Higher Education

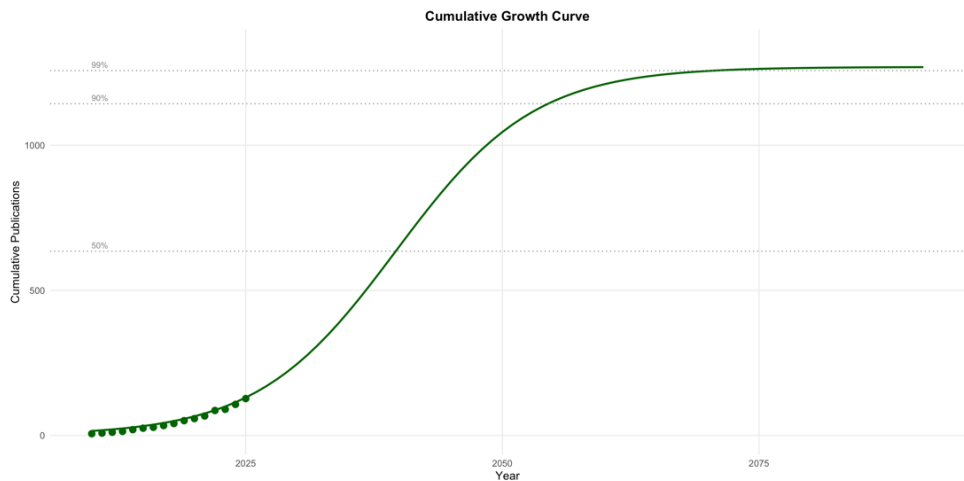


Figure 5. Cumulative Growth of EL Publications in Higher Education

The post-2021 acceleration is not a random uptick but a structural transition from an exploratory phase to an active expansion phase. The R^2 of 0.628 indicates a moderately strong systematic growth signalsufficient to reject random fluctuation as the dominant explanation, while leaving room for context-specific drivers behind year-to-year variation.

Three plausible drivers converge to explain the inflection. First, the post-2020 acceleration coincides with the consolidation of the UN 2030 Agenda and the widespread integration of SDG 4 (quality education) and SDG 13 (climate action) into university strategic plans, which catalyzed funded EL research. Second, the COVID-19 pandemic reframed environmental and health risks as interconnected, encouraging higher education researchers to examine sustainability literacy as part of post-pandemic curricular reform (Franco et al., 2019; UNESCO, 2017). Third, the diffusion of the ESD-for-2030 framework normalized sustainability competencies as legitimate higher education learning outcomes, expanding the set of journals willing to publish EL research.

Because the field has not yet entered saturation, current contributions are positioned to shape its long-term intellectual identity. This is the moment in which methodological standards, instructional design conventions, and assessment instruments are still negotiable. For the journal community, this implies that editorial priorities set now will disproportionately influence which research streams conceptual, policy-focused, or classroom-based come to define EL scholarship over the next decade.

3.2. RQ2. Which publication sources, authors, and institutions formed the core productivity structure of Scopus-indexed EL research in higher education?

The analysis of scholarly productivity reveals a clear concentration of publications within a limited number of core journals. As illustrated in Figure 6, Sustainability (Switzerland) emerged as the most prolific source, contributing a substantially higher number of documents, with a total of 36 publications. This journal was followed by the International Journal of Sustainability in Higher Education with 14 documents, while Environmental Education Research and the Journal of Environmental Studies and Sciences each contributed 7 publications. Other journals, such as Discover Sustainability and the Australian Journal of Environmental Education, showed more modest outputs. This distribution indicates that EL research in higher education is strongly anchored in sustainability and education-focused journals, reflecting the interdisciplinary nature of the field and aligning with previous bibliometric findings that highlight the dominance of sustainability journals in higher education research (Aikowe & Mazancova, 2023; Ariyatun et al., 2024).

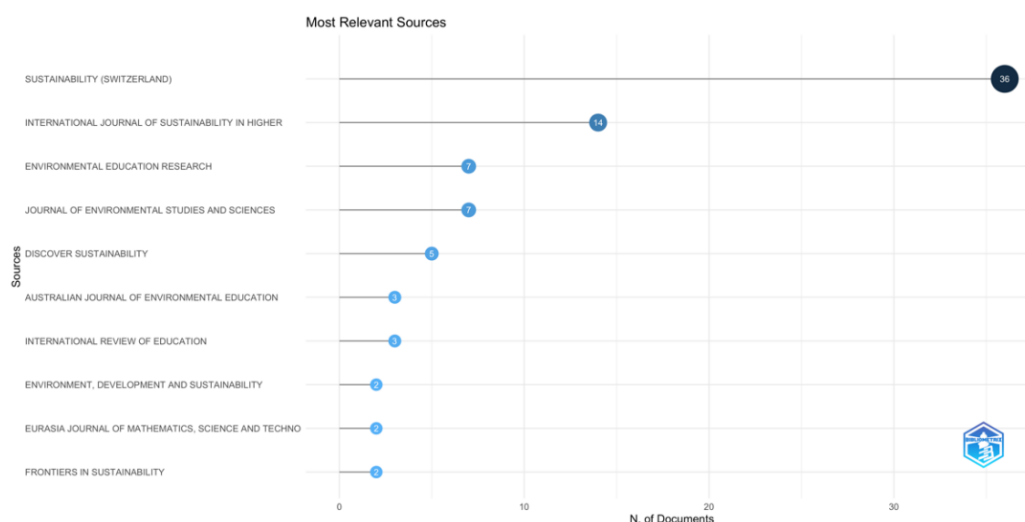


Figure 6. Most Relevant Journals Publishing on EL Research in Higher Education

At the author level, a clear intensification of output was observed at the author level after 2019, supported by recurring contributors such as Acosta Castellanos, P. M. and Queiruga-Dios, A. (Figure 7). The empirical Lotka curve in Figure 8 showed a steep decline at one published document, where 80–90% of authors contributed only a single publication, followed by a long flattened tail for authors producing two or more documents. The institutional dimension was clarified through a three-field plot linking sources, authors, and affiliations (Figure 9), in which Universidad de Salamanca, the National Council for Science and the Environment, and Universidad Santo Tomás appeared as major organizational nodes.

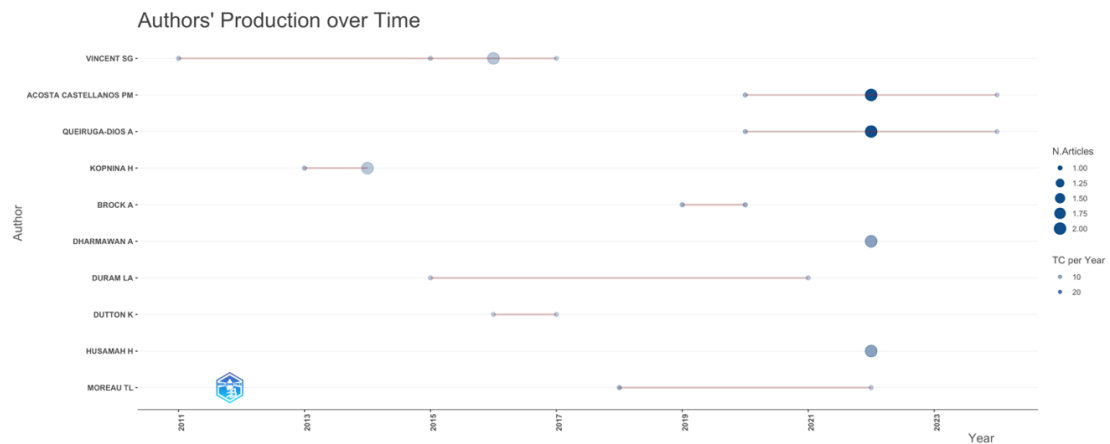


Figure 7. Authors' Publication Productivity on EL Research in Higher Education Over Time

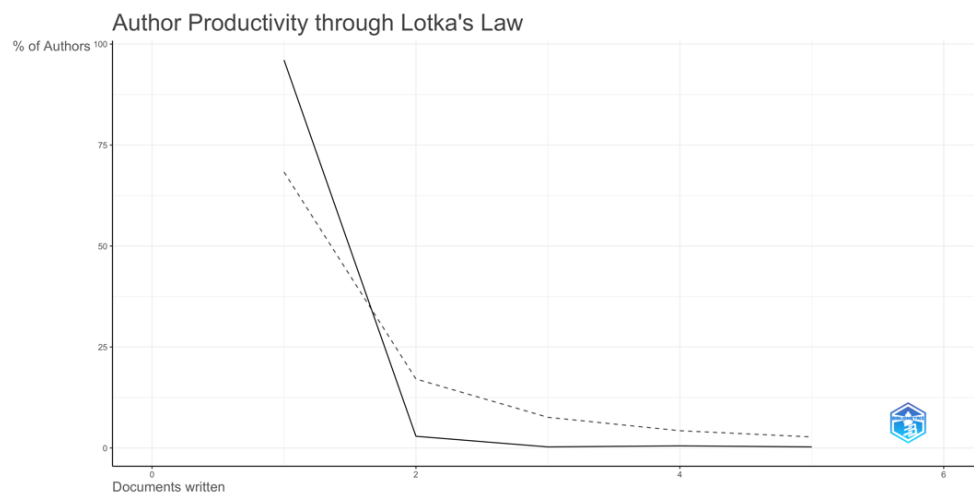


Figure 8. Author Productivity Distribution of EL Research in HE Based on Lotka's Law

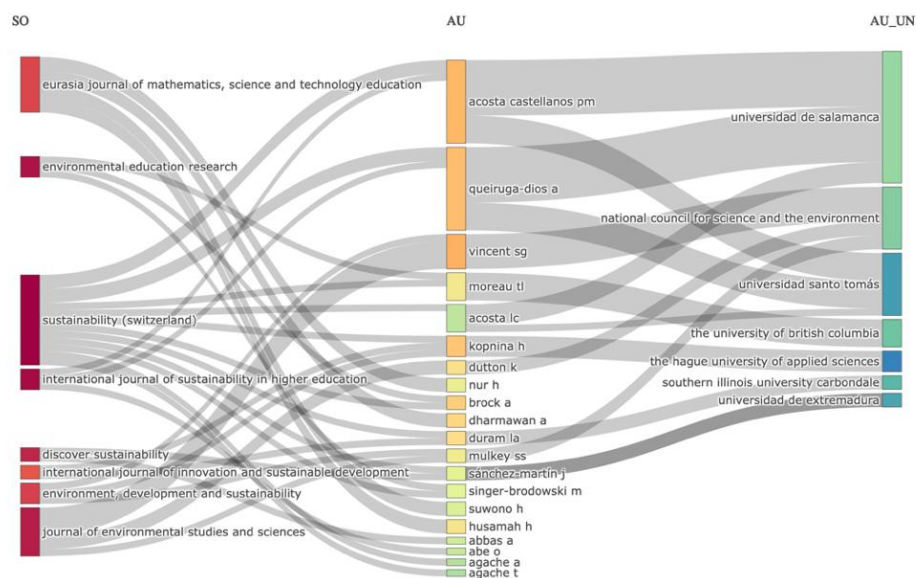


Figure 9. Three-Field Plot of Sources, Authors, and Institutions in EL Research in Higher Education

The Lotka-consistent skew is more than a statistical regularity; it is a signature of a field in early-to-middle consolidation. A small recurring core supplies the conceptual backbone, while a long tail of one-time contributors signals broad but shallow disciplinary engagement. Source concentration in Sustainability and the International Journal of Sustainability in Higher Education indicates that sustainability-oriented outlets, rather than dedicated environmental education journals, currently frame EL discourse in higher education.

The skew is consistent with classic Lotka dynamics in emerging interdisciplinary fields, where entry costs are low (any educator can contribute one EL study from their context) but sustained productivity requires institutional infrastructure doctoral pipelines, funded research groups, and recurring co-author networks. The dominance of Spanish institutions in the recurring author core suggests that targeted national sustainability research investment, particularly in Spain's higher education system, has translated into bibliometric visibility.

For early-career researchers, the Lotka pattern means that joining or building a recurring author network is more strategic than producing isolated contributions. For journal editors, the source concentration suggests an opportunity to broaden the publication ecology particularly toward journals specializing in higher education pedagogy and discipline-specific science education so that EL scholarship is not over-determined by sustainability-policy framing. For institutions, the visibility of a small set of universities indicates that consistent, programmatic support, rather than ad hoc projects, is the strongest predictor of sustained scholarly contribution.

3.3. RQ3. Which countries formed the highest productivity nodes in Scopus-indexed EL research in higher education, and how were international collaboration patterns structured across regions?

Figure 10 shows that EL research in higher education is geographically concentrated. The United States led the corpus with 38 publications, followed by Spain (31) and China (26). Malaysia (16), Australia (15), Indonesia (13), Portugal (12), the United Kingdom (12), and Germany (9) contributed at moderate levels. A cross-national co-authorship link between Colombia and Spain produced four jointly authored publications. Figure 11 distinguishes single-country publications (SCP) and multiple-country publications (MCP). Output for the United States and Spain was dominated by SCP, whereas China, Indonesia, Canada, and Colombia exhibited higher proportions of MCP.

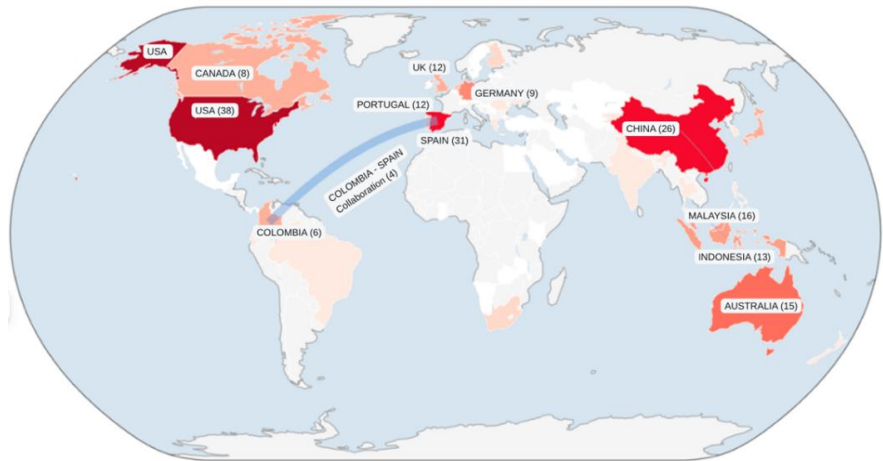


Figure 10. Geographic Distribution of EL Research in Higher Education by Country Productivity

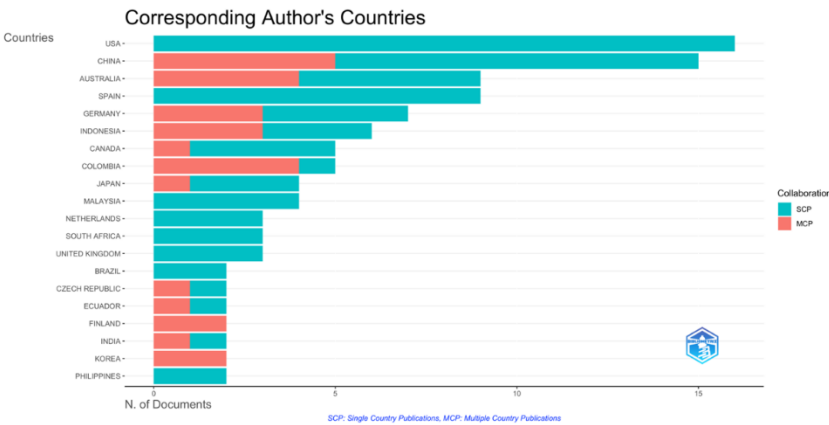


Figure 11. Collaboration Profile of Corresponding Authors by Country in EL Research in Higher Education

The collaboration profile reveals a paradox: the most productive countries (United States, Spain) are not the most internationally collaborative, while several mid-tier producers (China, Indonesia, Colombia, Canada) display proportionally higher international engagement. International collaboration in EL research is therefore concentrated in countries that strategically use co-authorship as a route to global scholarly visibility, rather than in countries with established domestic research bases.

This pattern reflects two underlying dynamics. First, large domestic higher education systems (United States, Spain) sustain strong national research networks, reducing the structural pressure to collaborate internationally. Second, mid-tier producers in the Global South and Global East often rely on international co-authorship particularly with European partners to access methodological resources, publication outlets, and citation networks. The Colombia–Spain link exemplifies this dynamic, in which Hispanophone scholarly networks function as collaboration corridors that bridge regional and global circuits.

The relatively low overall level of international collaboration is not unique to EL research. Similar patterns have been documented in sustainability literacy mapping (Sanchez et al., 2025), ESD bibliometric studies (Tafese & Kopp, 2025; Veres et al., 2025), and broader sustainability science (Yarime et al., 2010). Across these adjacent fields, leading producers consistently rely on national networks, while emerging producers expand through international links. This suggests that limited global collaboration is a structural feature of sustainability-oriented education research rather than a peculiarity of EL alone. For policy actors, the implication is that international funding mechanisms (Erasmus+, Horizon Europe, ASEAN–EU partnerships) are the most plausible levers for narrowing this collaboration asymmetry, particularly through funded co-supervised doctoral programs and joint EL curriculum development consortia.

3.4. RQ4. How was the intellectual and thematic structure of Scopus-indexed EL research in higher education shaped based on dominant thematic clusters and keyword co-occurrence networks?

Keyword co-occurrence analysis (Figure 12) showed that environmental education, higher education, and sustainable development served as the most connected nodes. Less-frequent but connected terms including environmental awareness, curriculum, critical thinking, and pro-environmental behavior appeared as secondary thematic fronts. The thematic evolution map (Figure 13) traced four sequential periods (2010–2017, 2018–2021, 2022–2024, 2025), revealing thematic merging between 2018 and 2021, splitting in 2022–2024, and emerging stabilization in 2025. The strategic thematic map (Figure 14) located core sustainability constructs in the basic-themes quadrant, teaching, critical thinking, and learning experience as motor themes, and institutional support, assessment, and knowledge goal as niche themes. The word cloud (Figure 15) confirmed the bibliometric centrality of environmental education, higher education, sustainability education, and ESD.

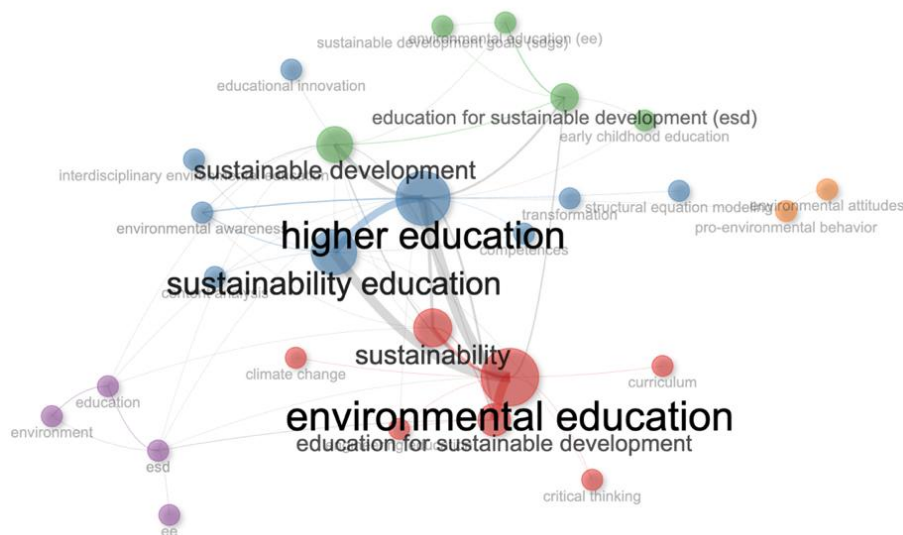


Figure 12. Keyword Co-Occurrence Network of EL Research in Higher Education

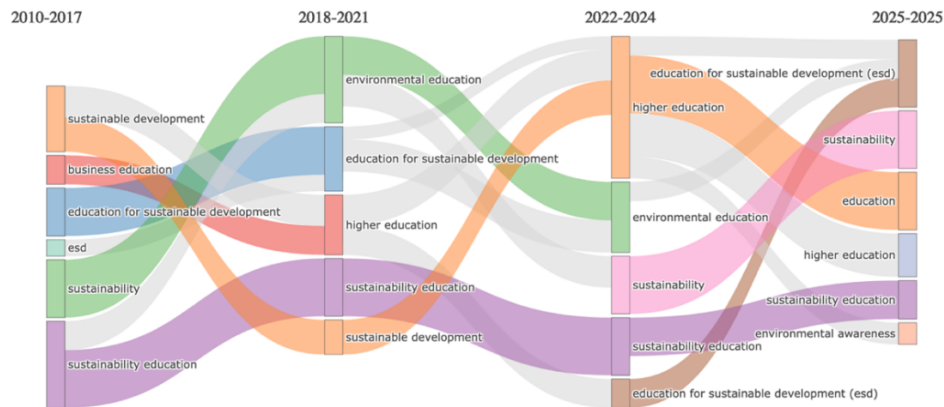


Figure 13. Evolution of Core Themes in EL Research in Higher Education Over Time

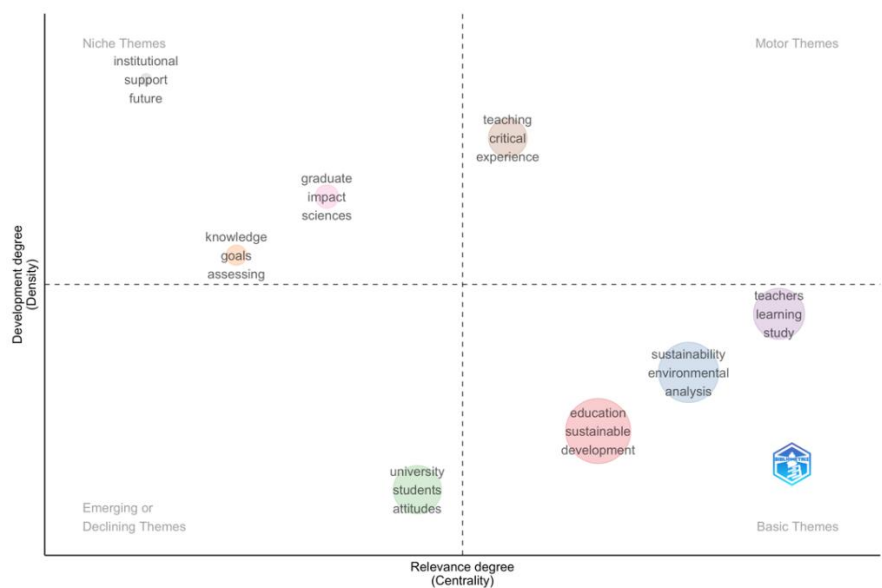


Figure 14. Thematic Strategic Mapping of EL Research in Higher Education



Figure 15. Dominant Keywords in EL Research within Higher Education

The thematic structure reveals a field that is conceptually consolidated at its core but pedagogically thin at its periphery. Core sustainability constructs occupy the basic-themes quadrant, indicating high centrality but moderate density well-established but still expanding. The presence of teaching, critical thinking, and learning experience as motor themes signals that pedagogy is rhetorically central, yet their location in the motor-theme

quadrant reflects discursive prominence rather than empirical depth: they are frequently invoked but not always operationalized through validated classroom interventions.

The thematic merging observed in 2018–2021 reflects the post-DESD reorientation, in which previously distinct strands (environmental education, sustainability education, ESD) were absorbed into a more integrated sustainability-education discourse. The subsequent splitting in 2022–2024 is consistent with a maturing field that diversifies into applied sub-streams (environmental awareness, competency-aligned education) once the conceptual core is stable. The persistence of institutional support, assessment, and knowledge goal as niche themes rather than as motor themes indicates that the operational machinery required to enact EL in courses (assessment instruments, learning-design protocols, lecturer support structures) remains structurally underdeveloped relative to conceptual discourse.

3.5. The Pedagogical Implementation Gap as a Core Analytical Finding

Across RQ1–RQ4, a recurring structural signature emerges: the pedagogical implementation gap. This gap is not a marginal observation but a central, cross-cutting finding of the present mapping, and it is here developed in greater depth as required for analytical–interpretive contribution.

Three converging lines of evidence support this conclusion. First, the thematic map (Figure 14) places teaching and learning experience in the motor-theme quadrant, but assessment and institutional support remain in the niche quadrant, where empirical validation is typically operationalized. This asymmetry indicates that EL pedagogy is discussed more frequently than it is empirically tested. Second, the corpus-wide review of the most-cited works (see Table 1 below) shows that the dominant studies are systematic reviews, frameworks, and conceptual–ideological reformulations rather than randomized, quasi-experimental, or design-based classroom investigations. Third, the productivity skew (RQ2) suggests that classroom-level studies often single-context, time-bounded efforts are concentrated in the long tail of one-time contributors, where they receive limited citation traction and therefore do not consolidate into a recognizable instructional research stream.

From the perspective of higher education pedagogy and sustainability learning theory, this gap matters for substantive reasons. EL is theorized as a multidimensional construct that integrates cognitive, affective, behavioral, and competence dimensions (Kaya & Elster, 2019; Sanchez et al., 2025). Such a construct can only be fully developed through pedagogically structured experiences problem-based learning, place-based pedagogy, transformative learning, and ecopedagogy whose efficacy depends on careful instructional design and longitudinal assessment. The bibliometric evidence indicates that this empirical layer is precisely where EL scholarship is thinnest. The field has constructed a sophisticated conceptual architecture but has not, to a comparable degree, generated the classroom-level evidence base required to translate that architecture into validated pedagogical practice.

Read in the context of ESD frameworks (UNESCO, 2017), the pedagogical implementation gap also signals an alignment problem. ESD frameworks emphasize key sustainability competencies systems thinking, anticipatory thinking, normative reasoning, strategic action, and collaboration which require active, transformative pedagogies. Yet bibliometric evidence shows that the operational vocabulary of these competencies (e.g., assessment, instructional design, course-level intervention) sits at the periphery of the corpus rather than at its core. This is the structural blind spot that distinguishes the present analytical contribution from prior descriptive bibliometric studies of EL.

3.6. RQ5. Influential Publications: Which publications constitute the core knowledge base of EL research in higher education based on citation metrics?

Figure 16 shows that average annual citations increased steadily after 2015 and peaked in 2020, indicating that the strongest citation uptake is associated with foundational publications. The decline in citation averages after 2021 reflects the natural time lag in citation diffusion for newer publications rather than reduced scholarly relevance. Figure 17 shows that a small number of publications account for a disproportionately large share of total citations a classic cumulative-advantage effect. These highly cited works are predominantly published in *Sustainability*, the *International Journal of Sustainability in Higher Education*, and *Environmental Education Research*. Local citation analysis (Figure 18) shows that several recent publications have not yet accumulated significant local citations, reflecting temporal dynamics rather than limited scholarly value (Small, 2004; Tahamtan & Bornmann, 2022).

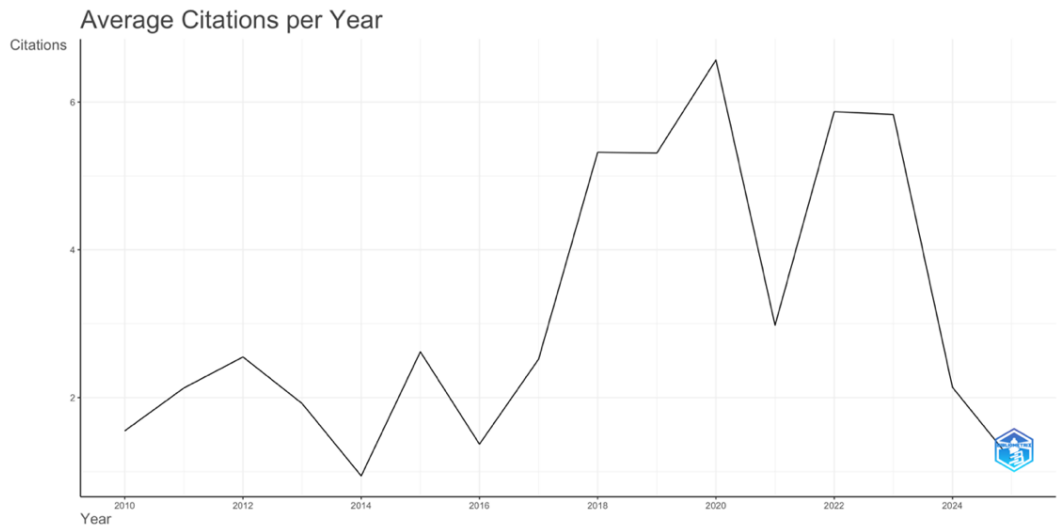


Figure 16. Average Citations per Year of EL Research in Higher Education

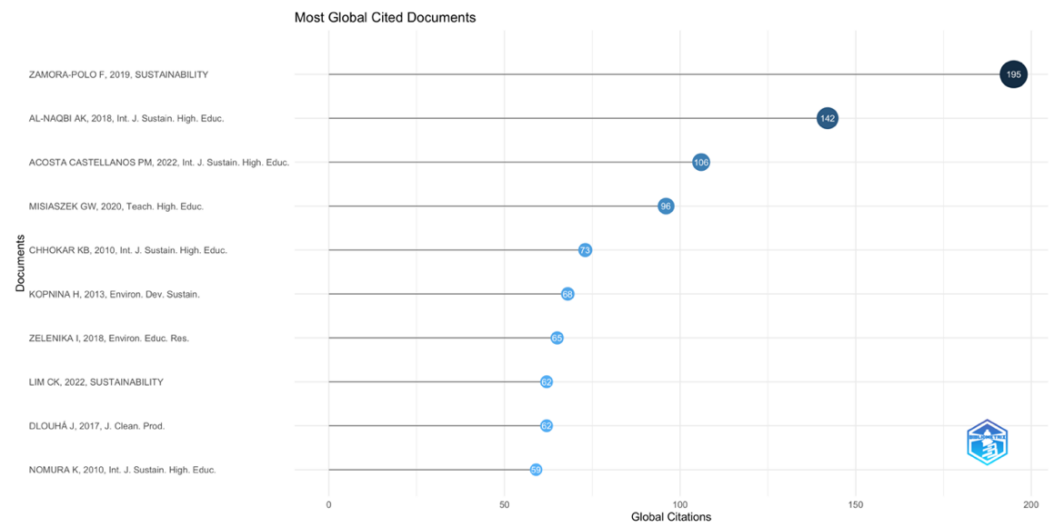


Figure 17. Most Globally Cited Documents in EL Research in Higher Education

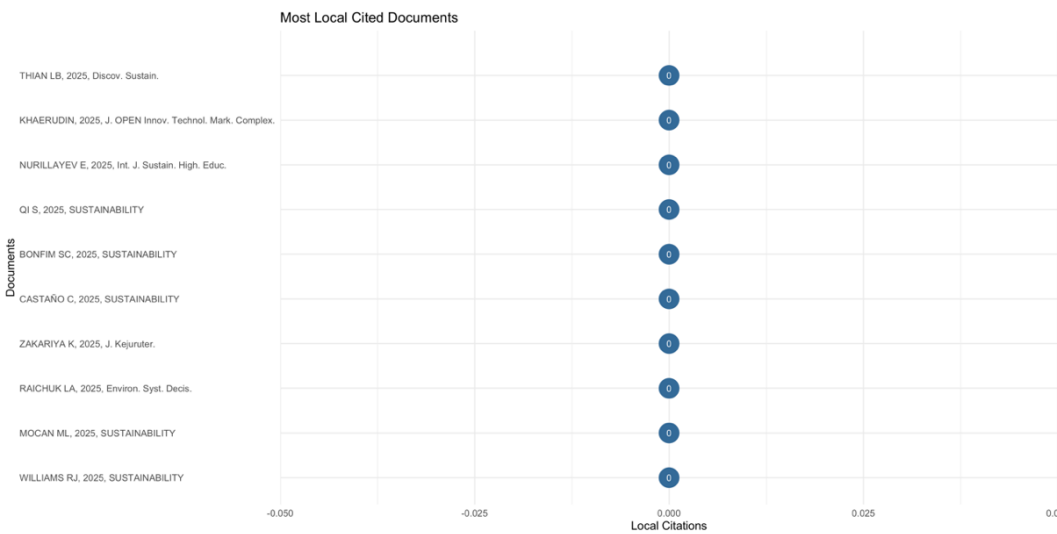


Figure 18. Most Locally Cited Documents in EL Research in Higher Education

Table 1 summarizes the bibliometric profile of the five most-cited publications, while the extended version of the table is available in the Appendix.

Table 1. Top 5 Highest-Cited Publications in EL Research in Higher Education

Author (Year)	Journal & Quartile	Citations	Country	Discipline Focus	Key Outcomes
Zamora-Polo & Sánchez-Martín (2019)	Sustainability (Q1)	195	Spain	Teacher education science pedagogy	SDG knowledge, 4C, ethics
Al-Naqbi & Alshannag (2018)	International Journal of Sustainability in Higher Education (Q1)	142	UAE	Campus sustainability learning	Knowledge-behavior gap
Acosta Castellanos & Queiruga-Dios (2022)	Sustainability (Q1)	106	Colombia & Spain	Engineering sustainability currents	EE→ESD traction
Misiaszek (2020)	Teaching and Higher Education (Q1)	96	USA	Ecopedagogy ideological framing	Critical literacy
Banga Chhokar (2010)	International Journal of Sustainability in Higher Education (Q1)	73	India	Policy & institutional practices	Mandated EL course

The synthesis indicates that EL research in higher education has been shaped primarily by framework development and curriculum profiling, reflecting strong intellectual concentration but limited empirical testing at the instructional implementation level. Influential studies have positioned sustainability particularly SDG and ESD-aligned approaches as the dominant curricular current across teacher education, engineering programs, and disciplinary coursework. Although curricular exposure has enabled students to demonstrate high sustainability knowledge and positive attitudes, pro-environmental behaviors have remained moderate, confirming a persistent knowledge behavior gap.

The cumulative advantage observed in citation distribution is not neutral; it shapes whose theoretical voices define the field. The dominance of conceptual and review-oriented works among the most-cited publications means that classroom-level studies, even if methodologically rigorous, struggle to enter the canonical knowledge core. This citation structure reinforces the pedagogical implementation gap by privileging discourse over evidence.

Conceptual works tend to be cited across multiple sub-fields (curriculum studies, policy analysis, environmental education, teacher education), accumulating citation advantage faster than empirical classroom studies that are typically cited within narrower disciplinary corridors. In addition, journals dominating the corpus prioritize broad sustainability framing, which further amplifies framework-oriented works. To rebalance the knowledge core, the community needs deliberate strategies: special issues dedicated to empirical classroom EL research, citation-aware reviewing practices that recognize design-based and longitudinal studies, and methodological standards that make instructional studies more comparable and therefore more citable

3.7. Comparative Analysis with Adjacent Bibliometric Studies

To address whether the patterns observed here are field-specific or representative of broader research trends, the findings are explicitly compared with prior bibliometric studies of sustainability literacy, ESD, and sustainable higher education. Trend trajectory. The post-2020 acceleration observed in this study is consistent with sustainability literacy bibliometric reviews (Saarna & Laius, 2025; Sanchez et al., 2025) and ESD mapping studies (Tafese & Kopp, 2025; Veres et al., 2025), which similarly report rapid expansion after 2018–2020. EL is therefore not anomalous but moves in step with the broader sustainability-education research wave. Productivity concentration. The Lotka-consistent skew documented here mirrors that reported by Ariyatun et al (2024) for sustainable-development EL and by Michel et al (2024) for higher education sustainability competencies, indicating that author concentration is a generic property of emerging interdisciplinary fields rather than a peculiarity of EL. Collaboration profile. The limited international collaboration found in EL research closely parallels patterns reported in sustainability science (Yarime et al., 2010), ESD bibliometrics (Tafese & Kopp, 2025), and sustainable universities mapping (Veres et al., 2025), in which leading countries rely on national networks while mid-tier producers expand through international linkages. Low global collaboration is therefore a structural feature of sustainability-oriented education research rather than a sign of EL’s isolation. Thematic concentration. The convergence around environmental education, ESD, and sustainability education observed here aligns with Dönmez (2024) and Veres et al (2025), but the present study departs from those analyses by foregrounding the pedagogical implementation gap as a structural finding rather than as a residual observation. This is the principal point of analytical differentiation between the present mapping and previously published bibliometric reviews.

3.8. Theoretical Implications

The findings extend three interrelated theoretical conversations. First, environmental literacy theory. By demonstrating that the field's thematic core is conceptually rich but empirically thin at the instructional layer, the study refines the operational definition of EL: the construct cannot be considered fully theorized until cognitive, affective, behavioral, and competence dimensions are matched by validated pedagogical mechanisms (Kaya & Elster, 2019). This implies that EL theory must be developed not only at the level of constructs and dimensions but also at the level of pedagogical instantiation. Second, sustainability literacy. The bibliometric evidence supports the typological argument advanced by Sanchez et al. (2025) that sustainability literacy and EL are overlapping but distinct constructs, while adding a structural dimension: EL is institutionalized within higher education through different journal and author networks than generic sustainability literacy, indicating that the two constructs occupy different epistemic infrastructures and should not be conflated. Third, ESD frameworks. The findings show that ESD has functioned as an organizing meta-discourse for EL in higher education but has not yet penetrated the instructional research layer with the same intensity. This refines the ESD framework by clarifying that its competence-based ambitions remain largely aspirational at the level of bibliometrically visible classroom evidence, providing a diagnostic baseline against which future ESD-aligned EL interventions can be evaluated.

3.9. Practical and Pedagogical Implications

For lecturers, the pedagogical implementation gap suggests that designing, documenting, and publishing structured classroom EL interventions however small in scale is currently a high-leverage research activity, both because the empirical base is thin and because such studies can shape the next phase of the field. Lecturers are encouraged to adopt design-based or quasi-experimental approaches, integrate validated EL assessment instruments, and report instructional design at a level of detail that allows replication.

For curriculum designers, the thematic structure indicates that sustainability concepts are well represented at the level of program description but underrepresented at the level of course-by-course instructional architecture. Curriculum designers should articulate explicit alignment between EL learning outcomes, pedagogical strategies (problem-based, place-based, transformative), and assessment instruments. The findings also suggest that interdisciplinary course modules linking science, engineering, social sciences, and education are more likely to develop the systems-thinking dimension of EL than discipline-locked offerings.

For institutions, the visibility of a small set of universities in the recurring author core suggests that programmatic, sustained institutional commitment, rather than episodic projects, drives bibliometric presence. Institutions seeking to strengthen sustainability profiles should invest in (i) dedicated EL/ESD research clusters, (ii) doctoral training pipelines, (iii) cross-faculty teaching collaborations, and (iv) participation in international ESD networks to expand co-authorship beyond domestic circuits. For policy actors, the asymmetry between policy-level discourse and classroom evidence implies that funding mechanisms should explicitly target instructional research, not only curricular review or strategic planning.

Synthesis, taken together, the analytical results show that EL research in higher education has reached a stage where its conceptual scaffolding is broadly stable, while its pedagogical and empirical scaffolding remain underbuilt. The strategic priority for the next phase of the field is to translate the consolidated discourse into validated, replicable, and contextually responsive classroom practice.

4. Conclusion

This study set out to provide an analytical–interpretive bibliometric mapping of EL research in higher education between 2010 and 2025. Rather than recapitulating the descriptive findings, the conclusion foregrounds the contributions, implications, and forward-looking directions that follow from the analysis. Theoretical contributions: the study refines environmental literacy theory by showing that its conceptual core is rich but its pedagogical layer is structurally thin, and it sharpens the distinction between EL and broader sustainability literacy by mapping their differing epistemic infrastructures. It also offers a diagnostic reading of ESD frameworks, demonstrating that competence-based ambitions are unevenly translated into classroom-level research. Methodologically, the study contributes an integrated analytical–interpretive design that links productivity, collaboration, thematic evolution, and citation dynamics to field-level diagnosis, moving bibliometric analysis beyond performance reporting toward epistemic interpretation. Policy implications for higher education and research funding policy, the findings imply that sustainability strategies should be matched by explicit investment in instructional research on EL, including funded design-based studies, longitudinal assessment instruments, and international consortia for joint EL curriculum development. National research councils and ministries of higher education in regions currently underrepresented in the corpus particularly Africa, parts of Southeast Asia, and Latin America beyond Colombia are positioned to make distinctive contributions if targeted funding instruments and Open Science incentives are introduced. Pedagogical implications: the pedagogical implementation gap identified here translates directly into actionable guidance: instructors should design, evaluate, and report EL interventions at the course level using validated

instruments; programs should align EL learning outcomes with active, transformative pedagogies; and institutions should treat EL not as a generic graduate attribute but as a curriculum-embedded competence supported by assessment and lecturer development.

Specific future research directions. Five priorities emerge. (1) Design-based and quasi-experimental classroom studies that test sustainability pedagogies (problem-based learning, place-based learning, ecopedagogy) on EL outcomes across disciplines. (2) Validation and cross-cultural calibration of EL assessment instruments to enable comparable measurement across institutional and national contexts. (3) Comparative cross-regional studies, particularly bridging Global South and Global North higher education systems, to address the collaboration asymmetry documented here. (4) Longitudinal investigations of the knowledge-behavior gap to identify pedagogical mechanisms that move students from sustainability knowledge to pro-environmental action. (5) Integrative reviews that explicitly distinguish EL from sustainability literacy and trace how each construct is enacted differently across disciplinary curricula. Pursuing these directions will allow EL scholarship to convert its current conceptual momentum into the empirical and pedagogical depth required to support sustainability-oriented transformation in higher education.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

References

- Acosta Castellanos, P. M., & Queiruga-Dios, A. (2022). From environmental education to education for sustainable development in higher education: a systematic review. *International Journal of Sustainability in Higher Education*, 23(3), 622–644. <https://doi.org/10.1108/IJSHE-04-2021-0167>
- Aikowe, L. D., & Mazancova, J. (2023). Pro-environmental awareness of university students – assessment through sustainability literacy test. *International Journal of Sustainability in Higher Education*, 24(3), 719 – 741. <https://doi.org/10.1108/IJSHE-06-2021-0219>
- Al-Naqbi, A. K., & Alshannag, Q. (2018). The status of education for sustainable development and sustainability knowledge, attitudes, and behaviors of UAE University students. *International Journal of Sustainability in Higher Education*, 19(3), 566–588. <https://doi.org/10.1108/IJSHE-06-2017-0091>
- Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, 241, 108224. <https://doi.org/10.1016/j.biocon.2019.108224>
- 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>
- Ariyatun, A., Sudarmin, S., Wardani, S., Saptono, S., & Winarto, W. (2024). Bibliometric Analysis of Environmental Literacy in Sustainable Development: A Comprehensive Review Based on Scopus Data From 2013 to 2023. *International Journal of Educational Methodology*, 10(1), 179–195. <https://doi.org/10.12973/ijem.10.1.979>
- Banga Chhokar, K. (2010). Higher education and curriculum innovation for sustainable development in India. *International Journal of Sustainability in Higher Education*, 11(2), 141–152. <https://doi.org/10.1108/14676371011031865>
- Blanco, M. A., Blanco, M. E., Vila Hinojo, B. T., Guzmán Rodríguez, R. L. de J., & Vilchez Casas, L. (2024). Competencias ambientales de los estudiantes universitarios frente al cambio climático: hacia una nueva cultura ambiental. *AiBi Revista de Investigación, Administración e Ingeniería*, 12(2). <https://doi.org/10.15649/2346030X.3162>
- Dönmez, İ. (2024). Sustainability in Educational Research: Mapping the Field with a Bibliometric Analysis. *Sustainability*, 16(13), 5541. <https://doi.org/10.3390/su16135541>

- 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>
- Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., & Takemoto, K. (2019). Higher education for sustainable development: actioning the global goals in policy, curriculum and practice. *Sustainability Science*, 14(6), 1621–1642. <https://doi.org/10.1007/s11625-018-0628-4>
- Hofreiter, T. D., Monroe, M. C., & Stein, T. V. (2007). Teaching and Evaluating Critical Thinking in an Environmental Context. *Applied Environmental Education & Communication*, 6(2), 149–157. <https://doi.org/10.1080/15330150701598197>
- Izhar, G., Wardani, K., & Nugraha, N. K. (2022). The Development Enviromental Literacy Media Learning for Elementary School Student. *Journal of Innovation in Educational and Cultural Research*, 3(3), 397–404. <https://doi.org/10.46843/jiecr.v3i3.116>
- Jaya, A. C., Azizah, N., & Aulia, M. F. (2024). The Relationship Between School Culture And Pro Environmental Behavior Among Senior High School Students In Yogyakarta. *Journal of Innovation in Educational and Cultural Research*, 5(1), 1–7. <https://doi.org/10.46843/jiecr.v5i1.1064>
- Kaya, V. H., & Elster, D. (2019). A Critical Consideration of Environmental Literacy: Concepts, Contexts, and Competencies. *Sustainability*, 11(6), 1581. <https://doi.org/10.3390/su11061581>
- Kessler, C. (2018). Re-connecting Design, Education, and Sustainability: The Essential Role of Research in Higher Education Curriculum Development. *The International Journal of Sustainability in Economic, Social, and Cultural Context*, 14(1), 15–24. <https://doi.org/10.18848/2325-1115/CGP/v14i01/15-24>
- Lezak, S. B., & Thibodeau, P. H. (2016). Systems thinking and environmental concern. *Journal of Environmental Psychology*, 46, 143–153. <https://doi.org/10.1016/j.jenvp.2016.04.005>
- Ling, S., Landon, A., Tarrant, M., & Rubin, D. (2021). The Influence of Instructional Delivery Modality on Sustainability Literacy. *Sustainability*, 13(18), 10274. <https://doi.org/10.3390/su131810274>
- Mellyzar, M., Nahadi, N., Rochintaniawati, D., Riandi, R., Hernani, H., Supriatna, A., & Lee, T. T. (2025). Is higher education curriculum prepare to support sustainable environmental chemistry learning? *Journal of Environment and Sustainability Education*, 3(3), 414–434. <https://doi.org/10.62672/joease.v3i3.100>
- Michel, J. O., Siciliano, P., Zint, M., & Collins, S. (2024). Toward diversifying higher education sustainability competency scholarship: findings and implications from a bibliometric analysis. *International Journal of Sustainability in Higher Education*, 25(2), 221–237. <https://doi.org/10.1108/IJSHE-08-2022-0250>
- Misiaszek, G. W. (2020). Ecopedagogy: teaching critical literacies of ‘development’, ‘sustainability’, and ‘sustainable development’. *Teaching in Higher Education*, 25(5), 615–632. <https://doi.org/10.1080/13562517.2019.1586668>
- Mngomezulu, H., & Ramaila, S. M. (2025). Integrating Environmental Education into Grade 11 Life Sciences Classrooms: Challenges and Pedagogical Opportunities. *International Journal of Learning, Teaching and Educational Research*, 24(7), 376–401. <https://doi.org/10.26803/ijlter.24.7.19>
- Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics*, 106(1), 213–228. <https://doi.org/10.1007/s11192-015-1765-5>
- Passas, I. (2024). Bibliometric Analysis: The Main Steps. *Encyclopedia*, 4(2), 1014–1025. <https://doi.org/10.3390/encyclopedia4020065>
- Pompeii, B., Chiu, Y.-W., Neill, D., Braun, D., Fiegel, G., Oulton, R., Ragsdale, J., & Singh, K. (2019). Identifying and Overcoming Barriers to Integrating Sustainability across the Curriculum at a Teaching-Oriented University. *Sustainability*, 11(9), 2652. <https://doi.org/10.3390/su11092652>
- Saarna, R., & Laius, A. (2025). The sustainability literacy assessment instruments: a systematic literature review. *International Journal of Sustainability in Higher Education*. <https://doi.org/10.1108/IJSHE-01-2025-0048>
- Sanchez, S. J., Ballen, J., RUEDA VARON, M., & Robertson, D. (2024, June 23). Associating Sustainability Literacy with educational level of Industrial Engineering Students. *2024 ASEE Annual Conference & Exposition Proceedings*. <https://doi.org/10.18260/1-2--46626>
- Sanchez, S. J., Guzman, Y. P., Molano, J. S., Robertson, D., Ahern, S., & Garza, T. (2025). Systematic literature review: a typology of Sustainability Literacy and Environmental Literacy. *Frontiers in Education*, 10, 1–11. <https://doi.org/10.3389/educ.2025.1490791>
- Santiani, S., Reffiane, F., & Winarto, W. (2024). Science interdisciplinary learning approach: a study interdisciplinary thinking skills and literacy environment. *Journal of Education and Learning (EduLearn)*, 18(4), 1454–1459. <https://doi.org/10.11591/edulearn.v18i4.21416>
- Sari, N. K., Heliawati, L., & Rubini, B. (2024). Analysis of Sustainable Awareness of Junior High School Students on Biotechnology Material. *Journal of Innovation in Educational and Cultural Research*, 5(4), 556–567. <https://doi.org/10.46843/jiecr.v5i4.1911>
- Shutaleva, A. (2023). Ecological Culture and Critical Thinking: Building of a Sustainable Future. *Sustainability*, 15(18), 13492. <https://doi.org/10.3390/su151813492>
- Small, H. (2004). On the shoulders of Robert Merton: Towards a normative theory of citation. *Scientometrics*, 60(1), 71–79. <https://doi.org/10.1023/B:SCIE.0000027310.68393.bc>

- Sohae, N., & Farsad, R. (2025). *Innovative Pedagogies for Sustainability Education* (pp. 221–237). https://doi.org/10.1007/978-3-031-80380-2_11
- Sule, O. F., & Greig, A. (2017). *Embedding Education for Sustainable Development (ESD) Within the Curriculum of UK Higher Educational Institutions (HEIs): Strategic Priorities* (pp. 91–107). https://doi.org/10.1007/978-3-319-47883-8_6
- Surendar, Dr. A., Veerappan, S., Sindhu, S., & Arvinth, N. (2024). A Bibliometric Study of Publication- Citations in a Range of Journal Articles. *Indian Journal of Information Sources and Services*, 14(2), 97–103. <https://doi.org/10.51983/ijiss-2024.14.2.14>
- Tafese, M. B., & Kopp, E. (2025). Education for sustainable development: analyzing research trends in higher education for sustainable development goals through bibliometric analysis. *Discover Sustainability*, 6(1), 51. <https://doi.org/10.1007/s43621-024-00711-7>
- Tahamtan, I., & Bornmann, L. (2022). The Social Systems Citation Theory (SSCT): A proposal to use the social systems theory for conceptualizing publications and their citations links. *El Profesional de La Información*, 13(4), 1–17. <https://doi.org/10.3145/epi.2022.jul.11>
- UNESCO. (2017). *Education for Sustainable Development Goals: learning objectives*. UNESCO. <https://doi.org/10.54675/CGBA9153>
- Veres, C., Tănase, M., Bacos, I. B., & Kardos, M. (2025). Sustainable Universities: A Bibliometric and Thematic Analysis in Higher Education. *Sustainability*, 17(5), 1817. <https://doi.org/10.3390/su17051817>
- Widiyatmoko, A., Taufiq, M., Purwinarko, A., Wusqo, I. U., & Darmawan, M. S. (2022). The Effect of Environmental Pollution Game-Based Learning on Improving Students' Conceptual Understanding and Environmental Awareness. *Journal of Innovation in Educational and Cultural Research*, 3(4), 691–700. <https://doi.org/10.46843/jiecr.v3i4.344>
- Yang, H., Chang, Y.-C., & Zhu, K. (2025). The relationship between environmental knowledge and environmental behavior among university students in Guangxi, China: The mediating effects of environmental risk perception and environmental attitude. *Environment and Social Psychology*, 10(5). <https://doi.org/10.59429/esp.v10i5.3690>
- Yarime, M., Takeda, Y., & Kajikawa, Y. (2010). Towards institutional analysis of sustainability science: a quantitative examination of the patterns of research collaboration. *Sustainability Science*, 5(1), 115–125. <https://doi.org/10.1007/s11625-009-0090-4>
- Zamora-Polo, F., & Sánchez-Martín, J. (2019). Teaching for a Better World. Sustainability and Sustainable Development Goals in the Construction of a Change-Maker University. *Sustainability*, 11(15), 1–15. <https://doi.org/10.3390/su11154224>