

SUSTAINABILITY LITERACY IN EDUCATION: A BIBLIOMETRIC REVIEW AND SYSTEMATIC ANALYSIS OF HIGHLY CITED STUDIES

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Abstract

Sustainability literacy has become an essential educational priority for preparing learners to address complex environmental, social, and economic challenges. Despite growing research interest, the intellectual development and major research contributions in this field remain insufficiently synthesized. This study aimed to map the global research landscape of sustainability literacy in education through a bibliometric analysis complemented by a systematic review of highly cited studies. Bibliographic data were retrieved from the Scopus database using the search query TITLE-ABS-KEY ("sustainability literacy" AND "education") for publications from 2016 to 2026. Following the PRISMA 2020 screening process, 172 articles were analyzed using Bibliometrix (Biblioshiny), VOSviewer, and Microsoft Excel. The findings reveal a steady increase in publication output, peaking in 2025, with the United States, the United Kingdom, and China as the leading contributors. International Journal of Sustainability in Higher Education and Sustainability were the leading publication sources, while Mokos Melita was the most productive author. Research has shifted from foundational sustainability literacy toward the Sustainable Development Goals, competency development, and innovative pedagogical approaches. The systematic review identified four major themes: sustainability literacy assessment, knowledge and behavior gaps, competency-based education, and pedagogical innovation. These findings provide a comprehensive understanding of the field's evolution and offer valuable directions for future research, educational practice, and policy development.

Keywords: sustainability literacy; education; SDGs; ESD

1. Introduction

Sustainability has become one of the defining priorities of the twenty-first century as the world faces increasingly complex environmental, social, and economic challenges. This urgency is driven by escalating environmental degradation, climate change, and unsustainable patterns of consumption and production, all of which continue to threaten the resilience of ecological, economic, and social systems worldwide (Arora & Mishra, 2023; Glavič, 2021). To address these challenges, the United Nations adopted the 2030 Agenda for Sustainable Development, comprising 17 Sustainable Development Goals (SDGs) that provide a shared global framework for achieving environmental, social, and economic sustainability (United Nations, 2015). As a universal framework, the SDGs provide an integrated roadmap for governments, institutions, industries, and communities to address global challenges while ensuring long-term sustainability.

Education is widely recognized as a key driver of sustainable development, as it equips future generations with the knowledge and competencies needed to respond to complex sustainability challenges (Cebrián et al., 2021). As sustainability issues become increasingly complex and interconnected, education is expected not only to provide knowledge but also to develop the competencies needed to understand sustainability issues and make informed decisions for a more sustainable future. In this context, sustainability literacy has emerged as a fundamental educational outcome that enables individuals to comprehend sustainability challenges (Panakaje et al., 2024), think critically about their implications (Chen et al., 2022), and make informed decisions that contribute to sustainable development (Hakam et al., 2025). Consequently, sustainability literacy has become an increasingly important focus of educational research, reflecting its central role in preparing individuals to contribute to a more sustainable future.

Although the body of literature on sustainability literacy has grown substantially over the past

decade, the overall development of this research field remains insufficiently understood. Existing studies have predominantly focused on evaluating educational interventions, assessing learners' sustainability literacy, and developing measurement frameworks, whereas relatively limited attention has been devoted to examining the intellectual structure, thematic evolution, and global research trends of the field (Omazic & Zunk, 2021). Consequently, there is still a lack of comprehensive evidence regarding how sustainability literacy research has evolved, who the leading contributors are, which themes have shaped its development, and where future research opportunities lie. Addressing these questions is essential for providing a clearer understanding of the current state of knowledge and informing future research and educational practice.

To address these gaps, this study provides a comprehensive bibliometric review complemented by a systematic analysis of highly cited studies on sustainability literacy in education. Using publications indexed in the Scopus database from 2016 to 2026, the study maps publication trends, leading countries, influential authors, productive sources, and keyword co-occurrence networks, as well as overlay visualization to identify thematic evolution. Furthermore, a systematic analysis of the most highly cited studies is conducted to synthesize prevailing research themes, methodological characteristics, and future research directions. By combining bibliometric techniques with an in-depth review of influential studies, this research offers a comprehensive overview of the knowledge landscape of sustainability literacy and provides valuable insights for researchers, educators, and policymakers. Accordingly, this study addresses the following research questions.

1. What are the publication trends of research on sustainability literacy in education over the past decade?
2. Which countries, authors, and sources have contributed most significantly to this field?
3. What are the dominant research themes and their evolution based on keyword co-occurrence and overlay visualization?
4. What are the key research themes, methodological characteristics, and findings emerging from the most highly cited studies on sustainability literacy in education?

2. Literature Review

2.1. Sustainability Literacy

Sustainability literacy is defined as the integrated knowledge, skills, and values that enable individuals to understand the interconnections among environmental, social, and economic systems, critically evaluate complex sustainability challenges, and make informed decisions and responsible actions that contribute to sustainable development. Unlike conventional forms of literacy that primarily emphasize the acquisition of disciplinary knowledge, sustainability literacy adopts a holistic perspective by integrating cognitive, affective, and behavioral dimensions (Demirci et al., 2025; Hermawan et al., 2022). Consequently, sustainability literacy is concerned not only with what individuals know about sustainability but also with how they interpret sustainability related issues (Kazazoglu, 2025), develop ethical perspectives, and translate their understanding into meaningful actions (Qureshi, 2020). This holistic orientation reflects the growing recognition that addressing contemporary sustainability challenges requires a combination of knowledge, competencies, values, and responsible behavior rather than isolated disciplinary expertise.

Furthermore, sustainability literacy extends beyond a solely environmental perspective by recognizing the interdependence of environmental, social, and economic dimensions of sustainable development (Hariram et al., 2023). Rather than addressing these dimensions independently, sustainability literacy promotes an integrated understanding of how ecological integrity, social well-being, and economic prosperity influence one another in shaping sustainable societies (Dvulit et al., 2024). Such a holistic perspective enables individuals to recognize the complexity of sustainability challenges and appreciate the need for balanced and context sensitive solutions. Given its multidimensional nature and its central role in advancing sustainable development, sustainability literacy has become an increasingly prominent focus of research across diverse educational contexts and is widely regarded as an essential competency for the twenty-first century.

Beyond its conceptual definition, sustainability literacy is reflected in a set of interrelated competencies that enable individuals to respond effectively to complex sustainability challenges. These competencies include systems thinking, collaboration, and reflective decision-making, all of which are essential for understanding the interconnected nature of environmental, social, and economic issues and for developing context-sensitive solutions (Baharuddin, Saefudin, & Kusnadi, 2025; Zizka & Varga, 2021). Rather than functioning independently, these competencies complement one another by enabling individuals to critically evaluate sustainability issues, appreciate multiple perspectives, collaborate with

others, and translate their understanding into informed and responsible action (Ribeiro et al., 2023). Accordingly, sustainability literacy should be viewed not as a static body of knowledge, but as a dynamic and continuously evolving competency that develops through learning, reflection, and active engagement with sustainability challenges across diverse educational and societal contexts.

2.2. Sustainability Literacy in Educational Contexts

Over the past decade, research on sustainability literacy has expanded considerably, reflecting the increasing recognition of its importance in preparing individuals to address contemporary sustainability challenges (Saarna & Laius, 2025). Existing studies have investigated sustainability literacy across a wide range of educational settings, including primary and secondary schools (Anderson, 2024), higher education (Fošner, 2025), teacher education (Muñoz-Losa et al., 2025), vocational education (Ihsan et al., 2025), and community based learning (Yemini et al., 2025). This diversity reflects the understanding that sustainability literacy should be cultivated throughout the educational field, with each educational context addressing distinct learner characteristics, societal needs, and sustainability challenges. Consequently, educational institutions are increasingly expected to embed sustainability principles into curricula and learning experiences that prepare learners to contribute to sustainable development within their respective communities.

In addition to examining different educational settings, researchers have explored a variety of pedagogical approaches for fostering sustainability literacy, including Education for Sustainable Development (ESD), project-based learning, problem-based learning, experiential learning, place-based education, and digital learning environments (Fathurohman et al., 2023; Kamil et al., 2020). Although these approaches differ in their instructional design, they consistently emphasize active participation, interdisciplinary inquiry, collaboration, and engagement with authentic sustainability issues. Such student centered pedagogies encourage students to connect theoretical knowledge with real world experiences, thereby promoting deeper conceptual understanding and responsible action (Baharuddin, et al., 2025; McLean et al., 2022; Parry & Metzger, 2023).

The growing emphasis on sustainability literacy has encouraged researchers to adopt diverse methodological approaches to examine its development, assessment, and influencing factors (Ariza et al., 2021; Kuehl et al., 2021). Quantitative studies frequently employ questionnaires, competency-based scales, and knowledge assessments, whereas qualitative and mixed-methods studies provide deeper insights into learners' experiences, values, and decision-making processes (Nautiyal & Goel, 2021). Collectively, these methodological approaches provide complementary perspectives on sustainability literacy, enabling researchers to capture both measurable learning outcomes and the complex processes through which sustainability competencies are developed. This methodological diversity highlights the multidimensional nature of sustainability literacy and underscores the challenges of assessing a construct that encompasses cognitive, affective, and behavioral dimensions.

3. Research Methods

This study employed a bibliometric methodology using data retrieved from the Scopus database, followed by a systematic analysis of highly cited studies to provide a comprehensive overview of sustainability literacy research in education. Bibliometric analysis has become a widely adopted approach for quantitatively evaluating the development of scientific knowledge. This approach enables researchers to identify influential publications, leading contributors, and thematic developments through the objective analysis of bibliographic data, thereby offering a comprehensive understanding of a research domain's evolution, current state, and underlying knowledge structure (Omer & Dong, 2025; Öztürk et al., 2024). To complement this quantitative mapping, the study also conducted a systematic analysis of highly cited studies, focusing on their methodological characteristics, dominant research themes, and substantive findings. Integrating bibliometric mapping with a systematic review of influential literature thus provides a more holistic perspective, capturing not only how sustainability literacy research has evolved, but also which scholarly contributions have most shaped its development.

3.1. Data Source and Search Strategy

The bibliographic data used in this study were retrieved from the Scopus database in July 2026. Scopus was selected as the sole data source because it is one of the largest multidisciplinary citation databases, providing extensive coverage of high-quality peer-reviewed literature and standardized bibliographic metadata suitable for bibliometric research. The database offers comprehensive bibliographic information, including publication year, authors, affiliations, countries, abstracts, author keywords, citations, and source titles, thereby facilitating both bibliometric performance analysis and science mapping. The literature search was conducted using the TITLE-ABS-KEY field to identify publications explicitly focusing on sustainability literacy in education. To ensure transparency and reproducibility, the search strategy was defined using predetermined inclusion criteria, including the

database, search field, publication period, search query, language, document type, publication stage, and export format. The complete search strategy is presented in **Table 1**.

Table 1. Search strategy and eligibility criteria.

Aspect	Criteria
Database	Scopus
Search field	TITLE-ABS-KEY
Publication period	2016-2026
Search query	(TITLE-ABS-KEY("Sustainability Literacy" AND "Education"))
Language	English
Document type	Article
Publication stage	Final
Data export format	CSV, RIS, and BibText

3.2. Data Processing and Screening

The retrieved records were screened following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework, as illustrated in **Figure 1**. The screening process was conducted to ensure that only publications meeting the predefined eligibility criteria were included in the final dataset. Records were evaluated based on publication period, language, document type, and publication stage, with only English language journal articles published in their final stage retained for analysis. Following the screening process, the final dataset was exported from Scopus in BibTeX, CSV, and RIS formats to ensure compatibility with the software applications used in this study.

The BibTeX file was imported into the Bibliometrix package through the Biblioshiny interface to perform bibliometric performance analysis and science mapping. The RIS file was imported into VOSviewer to construct and visualize bibliometric networks, including co-authorship, co-occurrence, and citation relationships, while the CSV file was used for data management and descriptive analyses in Microsoft Excel. In addition to the bibliometric analysis, the retrieved publications were ranked according to their total citation counts in the Scopus database. The most highly cited articles were subsequently selected for systematic qualitative analysis to examine their methodological characteristics, principal research themes, and scholarly contributions. This complementary analysis enabled a deeper understanding of the intellectual foundations and influential developments that have shaped sustainability literacy research in education.

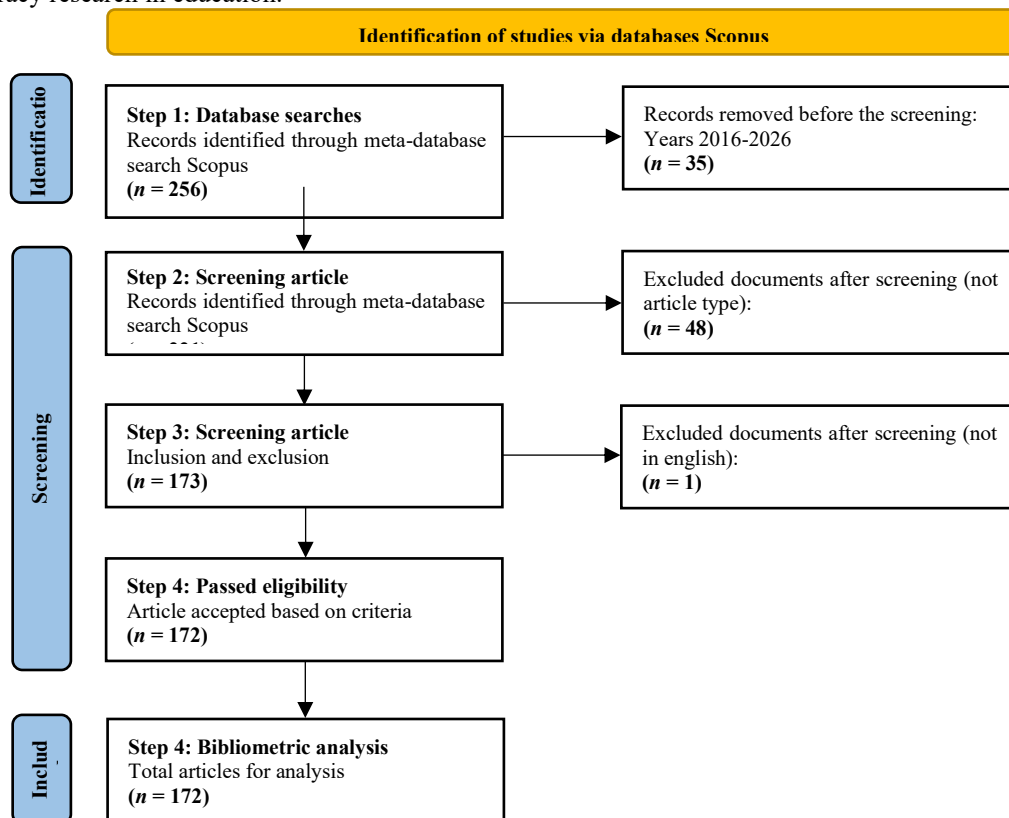


Figure 1. PRISMA flow diagram of the literature search and study selection process

4. Results and Discussion

Following the PRISMA 2020 screening process, the final dataset comprised 172 English-language journal articles on sustainability literacy in education published between 2016 and 2026. These publications formed the basis for the bibliometric analyses conducted in this study. The results are presented in a sequential manner, beginning with publication trends, followed by the identification of the most influential sources, authors, institutions, and countries, as well as analyses of thematic evolution. The section concludes with a systematic analysis of the highly cited studies to provide deeper insights into the dominant research themes and scholarly contributions that have shaped the field.

4.1. Publication Trends Over Time

The annual distribution of publications on sustainability literacy in education between 2016 and 2026 as presented in **Figure 2** highlighting the growth and fluctuations in research output over the study period. The early period (2016–2019) was characterized by relatively low publication activity, with annual outputs ranging from 5 to 9 articles. The number of publications increased from 5 articles in 2016 to 9 articles in both 2017 and 2018, followed by a slight decline to 7 articles in 2019. During the middle period (2020–2022), research output increased steadily from 12 articles in 2020 to 18 articles in both 2021 and 2022, representing the first sustained period of higher publication activity. This trend was followed by a temporary decline to 11 articles in 2023, before recovering slightly to 13 articles in 2024. The most recent period (2025–2026) recorded the highest publication output throughout the study period, reaching 38 articles in 2025, while 32 articles had been indexed in 2026 at the time of data retrieval. Overall, the trend indicates a gradual increase in scholarly attention to sustainability literacy in education over the past decade, with a marked acceleration in publication output beginning in 2025. In 2026, 32 documents were recorded, however, this figure may still increase as the year was not yet complete at the time of data retrieval.

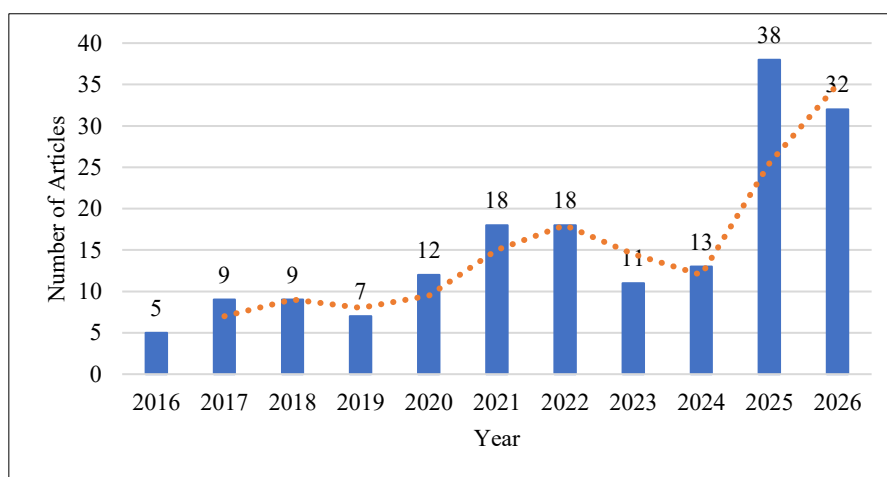


Figure 2. Annual scientific production on sustainability literacy in education (2016-2026)

4.2. Scientific Production by Country

Figure 3 presents the top 10 contributing countries in sustainability literacy research in education, with the number of publications contributed by each country indicated in parentheses. The United States ranked first, contributing 66 publications (27%), followed by the United Kingdom with 42 publications (17%) and China with 41 publications (10%). Together, these three countries accounted for approximately 54% of the total publications among the top 10 contributing countries. Indonesia ranked fourth with 21 publications (9%), followed by India with 17 publications (7%). Malaysia and Spain each contributed 16 publications (6%), while Australia and Turkey each produced 15 publications (6%). Sweden completed the top 10 with 12 publications (5%). Overall, the distribution indicates that research productivity was concentrated in a limited number of countries, although contributions were also observed across diverse geographical regions.

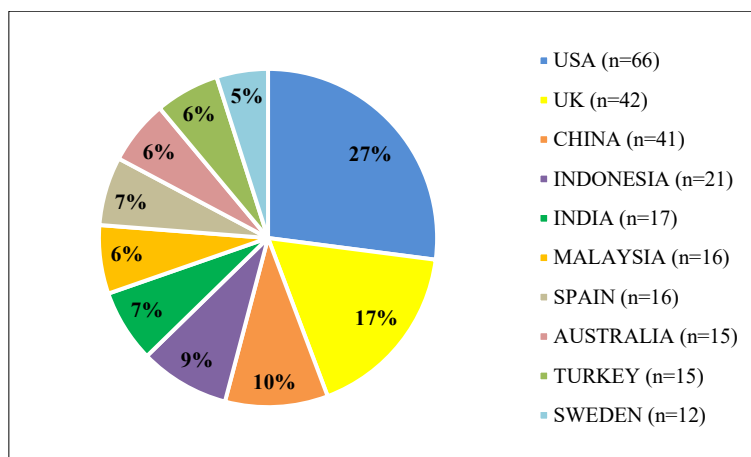


Figure 3. Distribution of publications by the top 10 contributing countries

4.3. Leading Publication Sources

Figure 4 presents the leading publication sources in sustainability literacy research in education, ranked according to the number of published articles. The International Journal of Sustainability in Higher Education was the most productive source, publishing 26 articles, followed closely by Sustainability (Switzerland) with 24 articles. World Sustainability Series ranked third with 12 articles, whereas Discover Sustainability and Sustainable Development Goals Series each contributed 3 articles. The remaining publication sources, including Environment, Development and Sustainability, Frontiers in Sustainability, Higher Education, Skills and Work-Based Learning, Journal of Cleaner Production, and Language Learning in Higher Education, each published 2 articles. Overall, the distribution indicates that sustainability literacy research has been disseminated across a range of publication sources, although a substantial proportion of the literature is concentrated in a small number of leading journals.

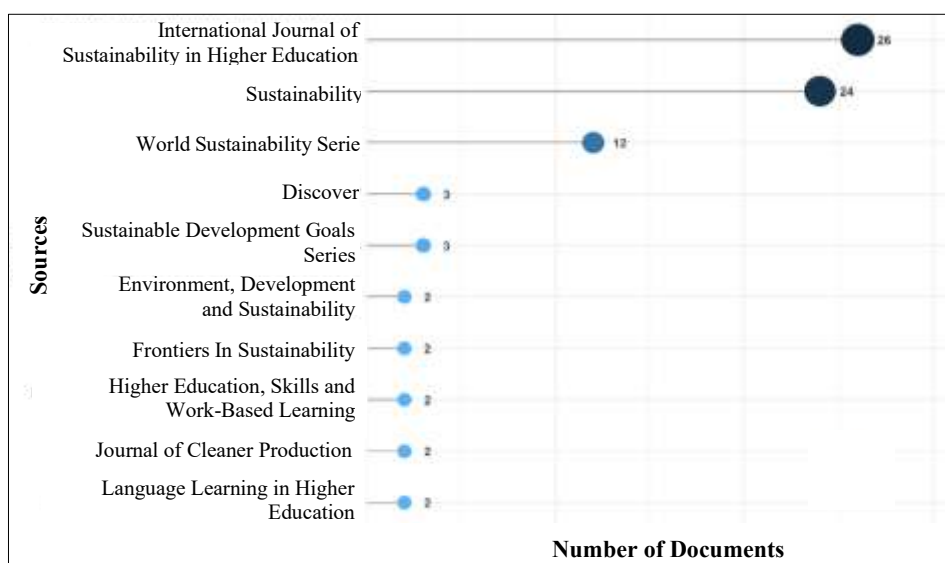


Figure 4. Leading publication sources in sustainability literacy research in education.

4.4. Most Productive Authors

Figure 5 presents the top 10 most productive authors in sustainability literacy research in education, ranked according to the number of published articles. Mokos Melita was the most productive author, contributing 5 articles, followed by Realdon Giulia and Pek Lim Seong, each with 4 articles. Mogias Athanasios, Eilks Ingo, and Boubonari Theodora each published 3 articles, demonstrating consistent contributions to the field. The remaining authors, including Chinn Pauline Wu, Cano-Ortiz Ana, Cano Eusebio, and Armstrong Rachel, each contributed 2 articles. Overall, the publication output among the leading authors shows a relatively balanced distribution, with no single author contributing a disproportionately large share of the literature. Instead, research productivity appears to be distributed

across multiple scholars, indicating that the development of sustainability literacy research in education has been supported by contributions from a diverse group of researchers.

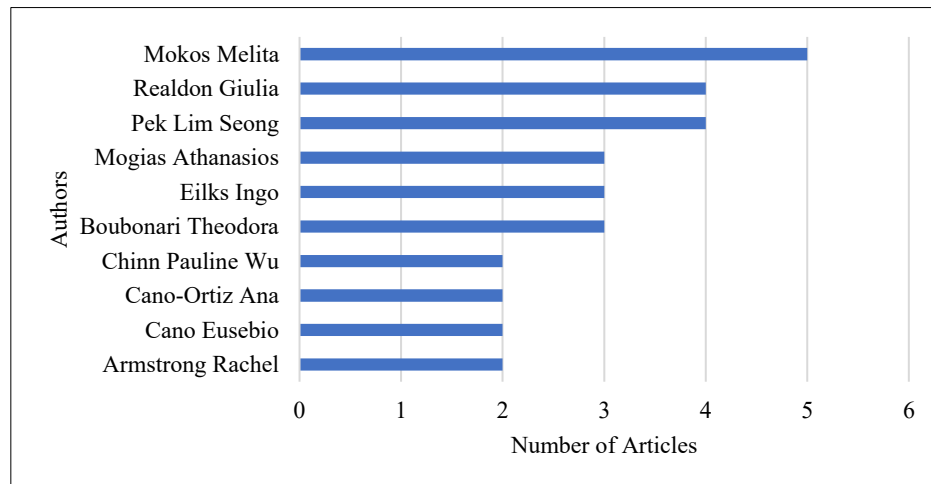


Figure 5. Top 10 most productive authors on sustainability literacy in education

Figure 6 presents the author co-authorship density visualization generated using VOSviewer, illustrating the distribution of collaboration among authors in sustainability literacy research in education. The visualization indicates a relatively fragmented collaboration pattern, characterized by several small author groups rather than a single, highly interconnected research network. Areas of higher density are observed around authors such as Lee, S., Chen, X., Li, J., Yu, J., Afifah, S., Rashidi, N., and Crampton, A., indicating comparatively stronger collaboration activity within these localized groups. In contrast, many authors, including Décamps, A., Emblen-Perry, K., Puntha, H., Erguvan, I.D., Permanasari, A., Viswanathan, M., Gabaudan, O., and Chinedu, C.C. appear as individual density hotspots without forming larger collaborative structures. Overall, the visualization suggests that collaboration within this research field remains dispersed, with research activities occurring primarily in small collaborative groups rather than through an extensive international author network. Interestingly, the most productive authors identified in the publication analysis do not appear among the prominent collaboration groups shown in the visualization, suggesting that high publication productivity in this field is not necessarily associated with extensive co-authorship networks meeting the visualization threshold.

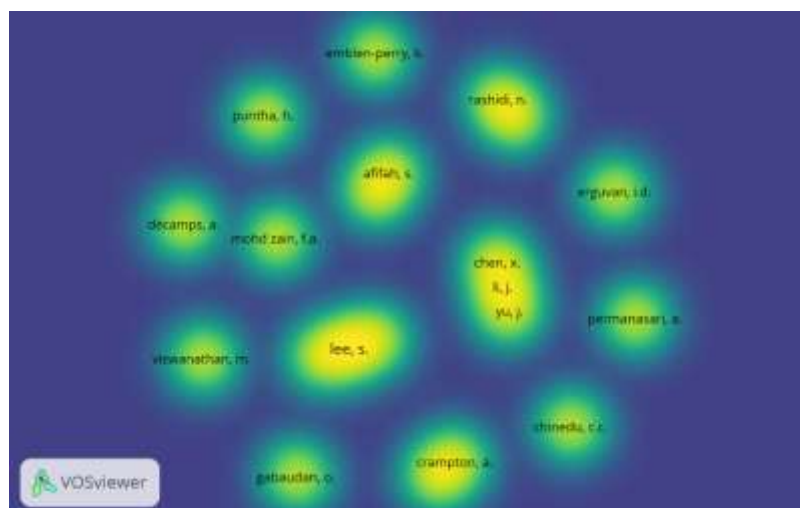


Figure 6. Density visualization of the author co-authorship network

4.5. Keyword Co-occurrence Network and Thematic Evolution

The network visualization in **Figure 7** maps the relationships between key terms in sustainability literacy education research, with "sustainability literacy" and "sustainability" emerging as the two largest and most central nodes, connected to concepts such as "sustainable development," "higher education," and "literacy." Four main clusters can be identified by color: the blue cluster centers on "sustainability"

and "literacy," linking to "curriculum," "education," and "climate change"; the red cluster centers on "sustainable development," connecting to "united nations," "teaching," and "higher education institutions"; the green cluster centers on "sustainability literacy" and "sustainability education," linking to "environmental education" and "experiential learning"; and the yellow cluster centers on "higher education," connecting to "SDGs" and "sustainable development goal".

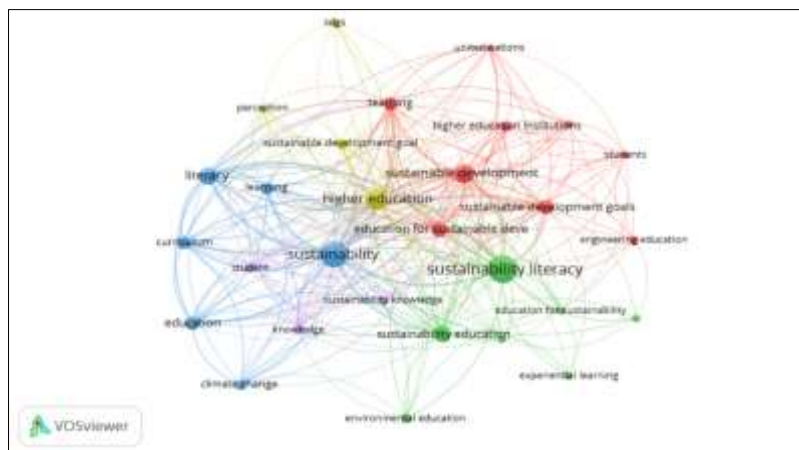


Figure 7. Keyword co-occurrence network visualization

The dense interconnections across clusters suggest that sustainability literacy research spans multiple interrelated themes, ranging from institutional and policy-driven perspectives to pedagogical and curricular approaches. The recurring presence of terms such as "SDGs," "united nations," and "sustainable development goals" reflects a strong link between sustainability literacy scholarship and global policy frameworks, while the appearance of "experiential learning" and "environmental education" points to an emphasis on active, applied pedagogical approaches within the field.

Figure 8 presents the overlay visualization of author keywords in sustainability literacy research in education, illustrating the temporal evolution of research themes based on the average publication year of each keyword. The color gradient ranges from purple, representing keywords that appeared earlier in the study period, to yellow, indicating more recently emerging topics. Core keywords such as "sustainability," "higher education," "sustainability literacy," and "sustainability education" occupy central positions in the network and remain closely connected to numerous related concepts throughout the study period. Earlier research themes are represented by keywords including "climate change," "higher education," "sustainability education," and "sustainability knowledge," whereas more recent topics are characterized by keywords such as "United Nations," "students," and "sustainable development goal." In addition, keywords including "teaching," "SDGs," "perception," and "higher education institutions" appear as intermediate to recent themes, indicating their increasing prominence within the research landscape. Overall, the overlay visualization demonstrates a temporal progression from foundational concepts of sustainability education toward research emphasizing the implementation of the Sustainable Development Goals and institutional practices in higher education.

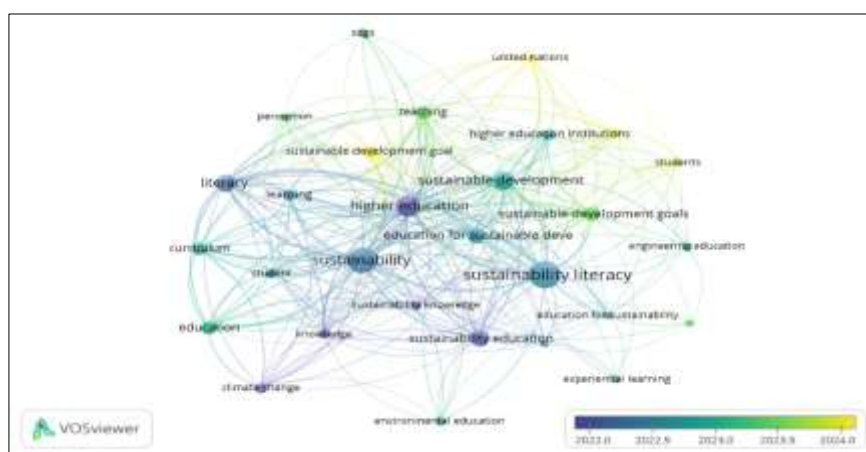


Figure 8. Overlay visualization of keyword evolution

4.6. Top 10 Most Cited Article

Table 2 presents the top ten most cited documents for the analysis period, detailing the authors, titles, journals, publication years, total citations, and normalized citation counts. The ranking lists articles related to sustainability literacy in educational contexts, particularly in higher education. The articles vary in terms of total citations and normalized citations, reflecting the differing impact and influence of each study within the field. Décamps et al. (2017), whose work introduces Sulitest as a collaborative tool to support and assess sustainability literacy in higher education, holds the highest total citation count with 147 citations and a normalized TC of 5.9. This suggests their research has been consistently influential, indicating the significance of standardized assessment tools in advancing sustainability literacy research. Similarly, Leiva-Brondo et al. (2022), examining Spanish university students' awareness and perception of sustainable development goals, recorded a comparably high normalized TC of 5.9 despite being published five years later than Décamps et al., emphasizing the sustained relevance of student awareness studies within a shorter citation window.

Interestingly, the list highlights diverse approaches to examining sustainability literacy, ranging from assessment tool development and awareness surveys to competency frameworks and case studies. The variation in normalized citation counts suggests that while some studies have had a broad and rapid impact on the field, others may be more specialized or have influenced a narrower scope of research. For instance, Caldana et al. (2023), addressing hybrid approaches to sustainable competencies through formal, informal, and non-formal learning, is relatively recent yet has already accumulated a notable normalized TC of 2.7, reflecting its relevance in current academic discussions. On the other hand, older studies such as Clark et al. (2018) on collective action competence show a comparatively lower normalized TC of 1.9, indicating a steady but less pronounced influence over time. This analysis underscores the evolving nature of sustainability literacy research and the varying degrees of impact that different methodological approaches and thematic focuses can have within the academic community.

Table 2. Top 10 most cited articles on sustainability literacy in education

Rank	Authors	Title	Journal	Total Citations	Normalized TC
1	Décamps et al. (2017)	Sulitest: A collaborative initiative to support and assess sustainability literacy in higher education	The International Journal of Management Education	147	5.9
2	Alsaati et al. (2020)	Level of Sustainability Awareness among University Students in the Eastern Province of Saudi Arabia	Sustainability	112	5.8
3	Leiva-Brondo et al. (2022)	Spanish University Students' Awareness and Perception of Sustainable Development Goals and Sustainability Literacy	Sustainability	93	5.9
4	Hansen et al. (2021)	Innovations and challenges in SDG integration and reporting in higher education: a case study from the University of South Florida	International Journal of Sustainability in Higher Education	70	3.8
5	Caldana et al. (2023)	A hybrid approach to sustainable development competencies: the role of formal, informal and non-formal learning experiences	International Journal of Sustainability in Higher Education	46	2.7
6	Radwan et al. (2021)	Knowledge, attitude and practice toward sustainability among university students in UAE	International Journal of Sustainability in Higher Education	45	2.4
7	Chen et al. (2022)	Sustainability Literacy: Assessment of Knowingness, Attitude and Behavior Regarding Sustainable Development among Students in China	Sustainability	42	2.6
8	Álvarez-Nieto et al. (2022)	Developing digital educational materials for nursing and sustainability: The results of an observational study	Nurse Education Today	39	2.4
9	Clark et al. (2018)	Collective action competence: an asset to campus sustainability	International Journal of Sustainability in Higher Education	39	1.9
10	Pfautsch et al. (2022)	Low factual understanding and high anxiety about climate warming impedes university students to become sustainability stewards: An Australian case study	International Journal of Sustainability in Higher Education	38	1.5

4.7. Discussion

Research Trends in Sustainability Literacy Education

This section discusses key patterns identified in the corpus of articles retrieved and analyzed in this study. These patterns are meaningful as they reveal the trajectory of scholarly attention, the distribution of research capacity, and the conceptual direction of the field, while also pointing toward

areas requiring further development. According to Snyder (2019), understanding the direction and scope of a research field is essential for anticipating how it may adapt to current and future conditions. Publication trends in sustainability literacy in education have shown a generally upward trajectory from 2016 to 2026, with early fluctuations giving way to a marked acceleration beginning in 2025 ($n = 38$), the highest output within the study period. This growth pattern is consistent with the broader expansion of sustainability-related research observed in adjacent fields, where increased global attention to sustainable development has similarly driven publication growth (Kajikawa et al., 2014). The sharp rise coincides with intensified global emphasis on sustainability agendas approaching key SDG milestones, suggesting that shifts in policy attention may correspond with shifts in scholarly output.

Beyond the overall growth trajectory, publication output is not evenly distributed geographically. The country with the highest number of publications is the United States ($n = 66$, 27%), followed by the United Kingdom ($n = 42$, 17%) and China ($n = 41$, 10%). This concentration suggests that research capacity and institutional infrastructure supporting sustainability literacy in education research remain centered in a small number of countries, consistent with broader patterns observed in sustainability education scholarship more generally. At the same time, the presence of contributions from Indonesia, India, Malaysia, Spain, Australia, Turkey, and Sweden indicates that the field is gradually expanding beyond its initial concentration, with regions bringing distinct educational, cultural, and policy perspectives to the study of sustainability literacy. Broader international participation of this kind is important, as cross-country collaboration has been shown to enrich research quality and enable the exchange of methodologies and approaches across contexts (Gilmour, 2024; Sun et al., 2020).

Although the bibliometric analysis demonstrates that sustainability literacy research has expanded across diverse geographical regions, this geographical diversification has not yet been matched by equally strong international collaboration among researchers. The co-authorship network reveals a fragmented collaboration structure, consisting primarily of small, isolated groups rather than a dense and interconnected research network. Notably, none of the most productive authors identified in this study, such as Mokos Melita, Realdon Giulia, and Pek Lim Seong appear among the prominent collaboration groups in the co-authorship network, suggesting that high individual productivity has not necessarily been accompanied by extensive collaborative activity within the visualization threshold. This pattern contrasts with more mature research fields, where increasing publication output is often accompanied by the development of extensive international collaboration networks (Breugelmans et al., 2018; Kwiek, 2021). The limited connectivity observed in this study may indicate that sustainability literacy in education is still developing as a distinct research domain, with scholarly contributions remaining relatively dispersed across institutions and countries. Expanding international and interdisciplinary collaborations could promote greater knowledge exchange (Tu, 2024), methodological diversity (Moshontz et al., 2018), and cross-contextual perspectives (Yao, 2021), thereby contributing to the continued development of sustainability literacy research.

In terms of scholarly influence, the most cited article in this dataset is Décamps et al. (2017), which introduces Sulitest as a collaborative tool for supporting and assessing sustainability literacy in higher education, accumulating 147 citations. This is followed by Alsaati et al. (2020) and Leiva-Brondo et al. (2022), which similarly focus on awareness and perception of sustainability among university students. The prominence of these works suggests that studies offering assessment instruments or empirical insight into student awareness have had a particularly strong influence on the field, mirroring similar patterns observed in other bibliometric reviews where methodologically applied or instrument-based studies tend to accumulate disproportionate scholarly attention (Ullah et al., 2025). Notably, when citations are normalized for publication age, Leiva-Brondo et al. (2022) records a normalized citation score nearly identical to that of Décamps et al. (2017) despite being published five years later, indicating that newer contributions can rapidly accumulate comparable influence within a shorter time frame.

The conceptual structure of the field, as revealed through keyword co-occurrence analysis, further illustrates the multidimensional nature of sustainability literacy research in education. Central terms such as "sustainability literacy" and "sustainability" occupy central positions within four interconnected thematic clusters encompassing sustainability education, higher education, environmental education, curriculum and learning, and the Sustainable Development Goals (SDGs). The overlay visualization further demonstrates the temporal evolution of these themes. Earlier research was characterized by foundational concepts such as "sustainability," "literacy," and "climate change," whereas more recent studies increasingly emphasize keywords including "SDGs," "United Nations," "experiential learning," and "environmental education." Collectively, these findings suggest that the conceptual focus of sustainability literacy research has progressively expanded from establishing foundational literacy concepts toward examining their implementation through global sustainability frameworks and student-centered educational practices. This evolution aligns with the broader transition within sustainability

education from promoting awareness and knowledge acquisition toward developing competencies and supporting the implementation of the Sustainable Development Goals in educational contexts (Rieckmann, 2018; UNESCO, 2017).

Core Findings from High-Impact Literature

The synthesis of the ten most highly cited studies reveals four major intellectual contributions to the development of sustainability literacy research in education: (1) the advancement of sustainability literacy assessment, (2) the identification of persistent knowledge, awareness and behavior gaps, (3) the expansion of sustainability literacy toward competencies and collective action, and (4) the emergence of innovative pedagogical and institutional approaches for sustainability education. A dominant theme across the highly cited literature is the conceptualization of sustainability literacy as a multidimensional and measurable educational construct. Rather than focusing solely on environmental knowledge, influential studies increasingly assess multiple dimensions of sustainability literacy, including awareness, attitudes, behaviors, competencies, and values.

The Sulitest initiative developed by Décamps et al. (2017) represents a landmark contribution by providing a globally standardized assessment framework that enables benchmarking of sustainability literacy across higher education institutions. Similarly, studies by Alsaati et al. (2020) and Chen et al. (2022) demonstrate the applicability of multidimensional assessment frameworks across different national contexts, reinforcing the importance of reliable instruments for evaluating educational outcomes and comparing sustainability literacy among student populations. Together, these studies demonstrate that sustainability literacy assessment has evolved from simple evaluations of environmental knowledge toward comprehensive measurement frameworks that capture cognitive, affective, and behavioral dimensions. This evolution has enabled researchers to generate more holistic evidence regarding students' sustainability competencies and to evaluate the effectiveness of sustainability education initiatives across diverse educational contexts. As a result, standardized assessment has become a fundamental methodological foundation supporting the continued advancement of sustainability literacy research.

Despite advances in assessment, the reviewed studies consistently identify a knowledge–awareness gap among university students (Décamps et al., 2017). Although students generally express positive attitudes toward sustainability and recognize its importance, their factual understanding of sustainability concepts often remains limited (Alsaati et al., 2020). For example, students in Australia exhibited high levels of climate concern while lacking fundamental knowledge regarding the relationship between fossil fuel consumption and climate change (Pfautsch & Gray, 2017). Comparable patterns were observed in Saudi Arabia and Spain, where students reported familiarity with sustainability concepts yet demonstrated limited understanding of renewable resources, sustainable consumption practices, and the practical implementation of the Sustainable Development Goals (SDGs) (Leiva-Brondo et al., 2022). Furthermore, evidence from China suggests that sustainability literacy continues to emphasize environmental issues more strongly than social and economic dimensions, indicating that sustainability education has yet to achieve a fully balanced representation of the three pillars of sustainable development (Chen et al., 2022).

Another recurring finding concerns the gap between sustainability awareness and sustainable action, indicating that increased knowledge and positive attitudes do not necessarily translate into behavioral engagement or active participation in sustainability initiatives. For instance, Spanish university students expressed strong expectations for universities and governments to advance the SDGs while reporting comparatively lower levels of personal commitment (Leiva-Brondo et al., 2022). Similar findings from the United Arab Emirates suggest inconsistencies between students' sustainability knowledge, attitudes, and practices (Radwan & Khalil, 2021). Collectively, these findings reinforce the notion that sustainability literacy extends beyond cognitive understanding and requires educational approaches capable of fostering motivation, personal responsibility, and behavioral change.

To address these challenges, recent influential studies increasingly advocate competency-based and transformative educational approaches. Rather than emphasizing knowledge acquisition alone, sustainability literacy is progressively linked to collective action competence, systems thinking, interdisciplinary learning, and authentic real-world experiences. Clark (2016) highlighted collective action competence as an essential capability for promoting campus sustainability, while Caldana et al. (2021) demonstrated that sustainability competencies are strengthened through the integration of formal, informal, and non-formal learning experiences. Likewise, Álvarez-Nieto et al. (2018) showed that digital educational materials can effectively support sustainability learning in professional education, illustrating the growing role of technology-enhanced pedagogy. At the institutional level, Hansen et al. (2021) further emphasized that meaningful integration of the SDGs requires coordinated curriculum development, institutional commitment, and systematic sustainability reporting.

Taken together, these highly cited studies demonstrate a clear evolution in sustainability literacy research. Early influential work primarily focused on establishing robust assessment frameworks and evaluating students' sustainability literacy, whereas more recent research increasingly emphasizes competency development, behavioral engagement, innovative pedagogical practices, and institutional transformation aligned with the Sustainable Development Goals. Nevertheless, the evidence also reveals a notable concentration of research within higher education settings, with comparatively limited attention devoted to primary, secondary, and vocational education. This imbalance highlights an important direction for future research to examine how sustainability literacy can be effectively developed across diverse educational levels and learning contexts.

4.8. Relevance to Research Objectives

Overall, the findings provide a comprehensive response to the research objectives by providing a comprehensive understanding of the development and intellectual landscape of sustainability literacy research in education. The bibliometric analyses reveal publication growth, leading contributors, collaboration patterns, and the evolving conceptual structure of the field, while the systematic synthesis of the most highly cited studies identifies the key intellectual contributions that have shaped its development, including advances in sustainability literacy assessment, the identification of knowledge and behavior gaps, competency-based education, and innovative pedagogical approaches. Collectively, these findings address the research gap identified in the introduction by moving beyond descriptive publication trends to provide an integrated understanding of the field's research evolution, thematic priorities, and methodological foundations. Consequently, this study offers a comprehensive evidence base that informs future research, educational practice, and policy development aimed at strengthening sustainability literacy across diverse educational contexts.

This study has several limitations that should be considered when interpreting its findings. First, the bibliometric analysis was based exclusively on the Scopus database, which, although comprehensive, may not capture relevant publications indexed in other databases. Second, the search strategy was limited to the terms "sustainability literacy" and "education" within the title, abstract, and keywords, potentially excluding studies addressing similar concepts using alternative terminology. Third, only English-language journal articles published in their final stage were included, which may have limited the representation of research published in other languages or document types. Finally, the systematic analysis focused on the ten most highly cited studies to identify the intellectual foundations of the field, consequently, recent publications with emerging perspectives but lower citation counts may not be fully represented. Future studies could address these limitations by incorporating multiple databases, broader search strategies, and a more extensive qualitative synthesis of the literature.

5. Conclusion

This study provides a comprehensive overview of the evolution of sustainability literacy research in education through a combination of bibliometric analysis and a systematic synthesis of highly cited studies. The findings reveal a marked growth in research output over the past decade, with contributions concentrated in a limited number of countries and publication sources, while international research collaboration remains relatively fragmented. The conceptual structure of the field has evolved from foundational sustainability literacy concepts toward greater emphasis on the Sustainable Development Goals, competency development, and innovative educational approaches. The systematic analysis further highlights that influential studies have primarily focused on sustainability literacy assessment, knowledge and behavior gaps, competency-based education, and institutional integration of sustainability. Collectively, these findings provide valuable insights into the current state and intellectual development of sustainability literacy research and offer a foundation for future studies aimed at strengthening interdisciplinary collaboration, expanding research across diverse educational contexts, and advancing sustainability literacy to support global sustainable development.

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