Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

April 2025. Vol. 13, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 233-253

Botanical Literacy in the Last Ten Years: Insights from Scopus

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Received: March 2025; Revised: April 2025; Published: April 2025

Abstract

This systematic literature review examines the evolution of botanical literacy research over the last decade, based on 32 Scopus-indexed studies. Nine research questions (RQs) explore publication trends, geographical distribution, subject areas, funding sponsors, co-occurring keywords, influencing factors, effective strategies, and emerging themes. Data collection followed the PRISMA protocol, with bibliometric analysis and VOSviewer used to explore trends, while Scopus AI facilitated thematic and content analysis. The analysis identified a sevenfold increase in publication volume from 2017 to 2024, with notable peaks in 2022 (n=7) and 2024 (n=7). These findings reflect a growing academic recognition of the crucial role plants play in tackling global environmental challenges. The United States and the United Kingdom lead in research, while Asian countries such as Indonesia remain underrepresented (less than 5% of total publications), highlighting the need for a more inclusive, global approach. The study also reveals the interdisciplinary nature of botanical literacy, encompassing environmental sciences, agriculture, social sciences, and fields like computer science and psychology. Key factors influencing botanical literacy include lack of interest, poor educational materials, and ineffective teaching methods. Effective strategies identified include inquiry-based learning and integrating botanical education into daily life. Emerging themes emphasize "Scientific Literacy in Environmental Contexts" as a recurring focus, reinforcing the relevance of botanical literacy in environmental education.

Keywords: Botanical literacy; Environmental education; Global; Scopus; Student

How to Cite: Husamah, H., Permana, T., & Rahardjanto, A. (2025). Botanical Literacy in the Last Ten Years: Insights from Scopus. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *13*(2), 233-253. doi:https://doi.org/10.33394/j-ps.v13i2.15160

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INTRODUCTION

Botanical literacy—the understanding of plant biology, ecology, and their role in ecosystems (Arif et al., 2025; Uno, 2009)—is fundamental in addressing contemporary socio-ecological challenges, such as biodiversity loss, climate change, and food security (Krosnick & Moore, 2024; Neves, 2024; Stroud et al., 2022). Despite its importance, studies reveal a concerning decline in botanical knowledge among students, a phenomenon often termed "plant blindness" or Plant Awareness Disparity (PAD) (Pedrera et al., 2024; Uno, 2009; Wells et al., 2021). This gap in understanding limits students' ability to engage with environmental issues and pursue careers in plant sciences. Given the critical role of plants in sustaining life, improving botanical literacy is an urgent educational priority (Balding & Williams, 2016; Batke et al., 2020; Stroud et al., 2022).

Recent research highlights various factors influencing botanical literacy, including curriculum design, teaching methodologies, and student engagement strategies. Studies suggest that integrating botanical education into standardized curricula (Hall & Sawey, 2014; Krosnick & Moore, 2024) and employing inquiry-based, hands-on learning approaches can enhance students' interest and comprehension (Corbacho-Cuello et al., 2024; M. S. Sari & Mawaddah, 2021). Additionally, innovative tools such as digital platforms and experiential learning have shown promise in mitigating PAD (Arango-Caro et al., 2025; Berezowitz et al., 2015; Pany et al., 2019; Parsley et al., 2022; Stagg et al., 2025). However, despite these advancements, a systematic synthesis of evidence-based strategies remains underexplored.

While previous reviews such as (Beasley, Hesterman, MacCallum, et al., 2023) and Amprazis and Papadopoulou (2020) have mapped pedagogical strategies and conceptual frameworks in botanical literacy, they often emphasize conceptual evolution or education-focused interventions without providing detailed bibliometric analysis across global regions. Similarly, although Arif et al (2025) explores botanical literacy in Indonesia, it is limited to qualitative insights and lacks a comparative bibliometric synthesis. Thus, there is a clear gap in literature reviews that consolidate trends, strategies, and thematic development using Scopus-exclusive, AI-supported methods—especially those highlighting underrepresented regions such as Asia. This review fills that gap by offering a global yet regionally sensitive synthesis that integrates both bibliometric and content-based insights.

While existing studies emphasize the need for improved botanical education, there is a lack of comprehensive reviews that consolidate findings from high-quality, peer-reviewed research. Most literature focuses on specific interventions or regional case studies, leaving a gap in understanding global trends and best practices. Furthermore, the role of teacher training and institutional support in sustaining botanical literacy initiatives requires deeper investigation.

This systematic literature review aims to (1) analyze the research trends (based on documents by year, documents by country, documents by subject area; document by funding sponsor, and cooccurrance of keywords) of botanical literacy among students based on Scopus-indexed studies; (2) identify factors influencing and effective strategies to enhance botanical literacy; and (3) evaluate the concept map and emerging themes which is related as a form of evolution and development of botanical literacy studies globally.

By synthesizing data from Scopus and Scopus AI using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, this study provides a rigorous, evidence-based overview of botanical literacy research. The findings will inform educators, policymakers, and researchers on effective strategies to address PAD, ultimately contributing to a more botanically literate generation capable of tackling global environmental challenges.

METHOD

Research Questions (RQs)

We formulated nine RQs to achieve the set goals. Based on the formulation related to Research Trends Analysis, the following RQs were determined: **RQ1**: How has the number of Scopus-indexed publications on botanical literacy among students evolved over time (by year)? **RQ2**: Which countries contribute the most to botanical literacy research, and what patterns exist in global research distribution? **RQ3**: What are the dominant subject areas in botanical literacy studies, and how do they intersect with other disciplines? **RQ4**: Who are the major funding sponsors supporting botanical literacy research, and what trends exist in funding patterns? **RQ5**: What are the most frequent and co-occurring keywords in botanical literacy research, and how do they reflect thematic focus?

To explore *factors and strategies* in botanical literacy: **RQ6**: What are the key factors influencing botanical literacy among students? **RQ7**: What educational strategies have been most effective in enhancing botanical literacy? Meanwhile, regarding *conceptual mapping and emerging themes*, we asked: **RQ8**: How do concept maps illustrate the relationships between core themes in botanical literacy research? **RQ9**: What are the emerging themes and future directions in the evolution of botanical literacy studies globally?

Data Collection & PRISMA Protocol

The data source for this study is the Scopus database, using a refined search strategy centered on the term "botanical literacy". The initial query string was: ALL ("botanical literacy") AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (OA, "all")) AND (EXCLUDE (EXACTKEYWORD, "Article") OR EXCLUDE (EXACTKEYWORD, "Northeast Brazil") OR EXCLUDE (EXACTKEYWORD, "Niger [West Africa]") OR EXCLUDE (EXACTKEYWORD, "Niger Republic") OR EXCLUDE (EXACTKEYWORD, "Malawi") OR EXCLUDE (EXACTKEYWORD, "India") OR EXCLUDE (EXACTKEYWORD, "Brazil") OR EXCLUDE (EXACTKEYWORD, "Australia") OR EXCLUDE (EXACTKEYWORD, "Document Analysis")) AND (EXCLUDE (PREFNAMEAUID, "da Silva, S.M.#56451478300")).

To improve the clarity of the keyword co-occurrence network and remove unrelated or misleading metadata, some terms were excluded using the filter EXACTKEYWORD. We excluded terms such as “India,” “Brazil,” “Australia,” and “Niger” not because research from these countries was omitted, but because in preliminary searches these terms appeared as keywords even when they were not central to the article content. These geographic names were often used as affiliation markers or field tags, which disrupted the accuracy of conceptual keyword mapping. Therefore, such terms were excluded only from the visual keyword analysis, not from the inclusion of the articles themselves.

All relevant articles, including those originating from or discussing India, Brazil, Australia, and other countries, were retained in the dataset and analyzed. These exclusions only applied to the co-occurrence keyword visualizations, ensuring that the resulting concept maps reflected core academic themes rather than incidental metadata.

The search process began with 109 articles and resulted in 32 final articles included for full analysis. This selection is illustrated in a detailed PRISMA flow diagram (Figure 1), which outlines the steps of identification, screening, eligibility, and inclusion.

Performing keyword search using Scopus AI is as follows: ("botanical literacy" OR "plant literacy" OR "plant knowledge" OR "botany education") AND ("education" OR "learning" OR "teaching" OR "curriculum") AND ("environmental education" OR "nature study" OR "outdoor education" OR "science education") AND ("student engagement" OR "curricular integration" OR "pedagogy" OR "educational outcomes").

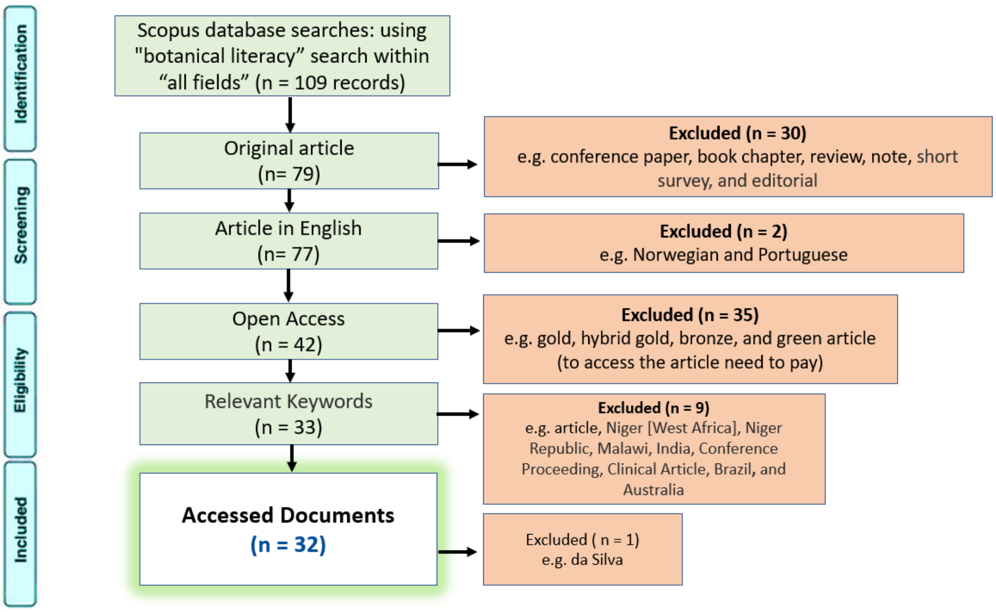

Figure 1. PRISMA diagram visualizing the identification, screening, eligibility, and inclusion stages

Regarding the query structure in Scopus, we acknowledge the concern about the exclusion of terms such as “India” and “Australia.” We clarify that the use of country names as exact keywords is inconsistent with the conceptual purpose of keyword indexing in scientific databases. A keyword, by its nature, should represent a concept, theme, or focus area of the research, rather than a geographic location, unless the study explicitly centers on a geographical case. In several preliminary searches, country names appeared in the keyword field not as conceptual categories but as metadata or affiliation artifacts, which skewed the co-occurrence network by inflating non-conceptual nodes. Therefore, terms like “India” and “Australia” were excluded from the exact keyword filter solely during co-occurrence mapping to ensure that only thematically relevant keywords were visualized.

Moreover, the exclusion does not affect the inclusion of articles in the corpus itself; all articles from or about India, Australia, or any other country were still part of the dataset and were included during full-text screening and analysis. The exclusions apply only to the visual representation of keyword co-occurrences, not to the systematic literature selection process.

We recognize the importance of transparency in systematic reviews and have included a PRISMA flow diagram (Figure 1) to clarify the number of records at each stage of identification, screening, eligibility, and inclusion. This ensures that the data selection process remains replicable, unbiased, and robust.

Data analysis

The Bibliometric Analysis (for RQ1–RQ5) was conducted using Scopus Analyze Results and VOSviewer, while Thematic and Content Analysis (for RQ6–RQ9) was assisted by Scopus AI. To enhance validity and minimize interpretive bias, an Expert Check was conducted involving consultations with experts in science and botanical education, supported by internal team discussions.

RESULTS AND DISCUSSION

Documents by year (RQ 1)

Articles related to botanical literacy tend to be the focus of experts since 2017. Although decreasing in 2019 (one article) and 2023 (four articles), articles reached their highest number in 2022 and 2024 (seven articles each). This can be clearly seen in Figure 2.

From Figure 2, we can see a fluctuating trend in the publication of articles on botanical literacy. The number of documents increased by seven times from 2017 (1 article) to 2024 (7 articles), with noticeable dips in 2019 and 2023. The decrease in those years may be due to shifts in global research focus or funding priorities.

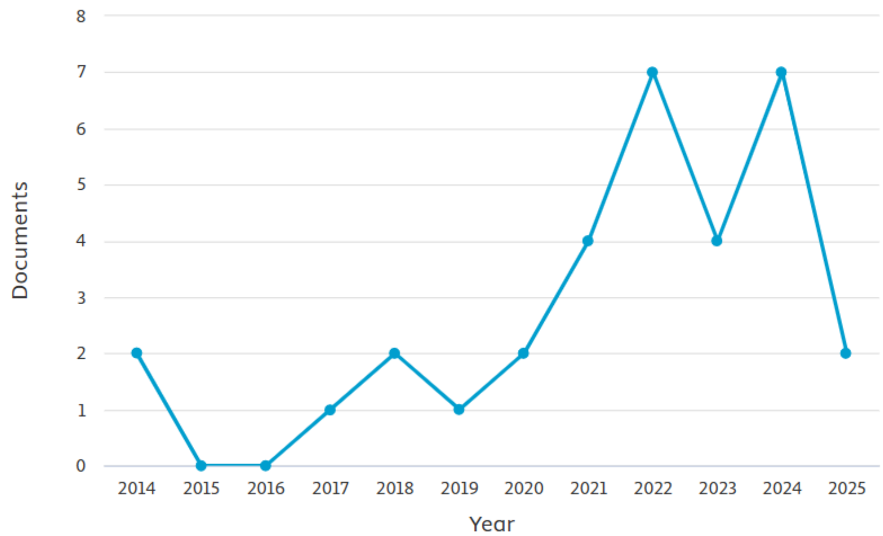

Figure 2. Documents by year

The upward spikes in 2022 and 2024 suggest intensified academic concern, likely influenced by the growing urgency to address climate change, biodiversity loss, and environmental education reforms. This aligns with the urgency to improve botanical literacy among students (Arif et al., 2025; Gutiérrez-García et al., 2024).

Botanical literacy has a significant impact on students, especially in the context of environmental awareness and sustainability. Looking at the trend of article publications, academic interest in botanical literacy tends to increase, indicating that more research and learning is focused on the importance of understanding plants and their role in the ecosystem. This is in line with the urgency to improve botanical literacy among students (Arif et al., 2025; Gutiérrez-García et al., 2024; Saraiva et al., 2024; Zelenika et al., 2018).

As the number of articles increases, it is apparent that researchers are increasingly focusing on the importance of integrating botanical literacy into education. When students understand the role of plants in sustaining life, they are better prepared to face increasingly complex environmental challenges. This knowledge is not only important for developing ecological awareness, but also for opening up career opportunities in plant science and conservation that can contribute to solving environmental problems (Pany et al., 2024; Stroud et al., 2022).

Given the spikes in 2022 and 2024, it is possible that this increase in publications coincides with increased educational efforts to address plant blindness and the gap in students' understanding of plants. Therefore, it is important for educators to integrate botanical literacy into the curriculum so that students can better understand their interactions with the natural world, deepen their understanding of the function of plants in living systems, and encourage them to pursue careers in plant science, which are increasingly needed to address pressing environmental issues.

Documents by country (RQ 2)

Based on the country of origin, it can be seen that the United States and the United Kingdom are two countries that have concerns in botanical literacy research and publication. Based on continent, there are four continents that are the origin of publications, namely America, Europe, Australia, and Asia. Interestingly, Asia is only represented by one country, namely Indonesia. Complete data can be seen in Figure 3.

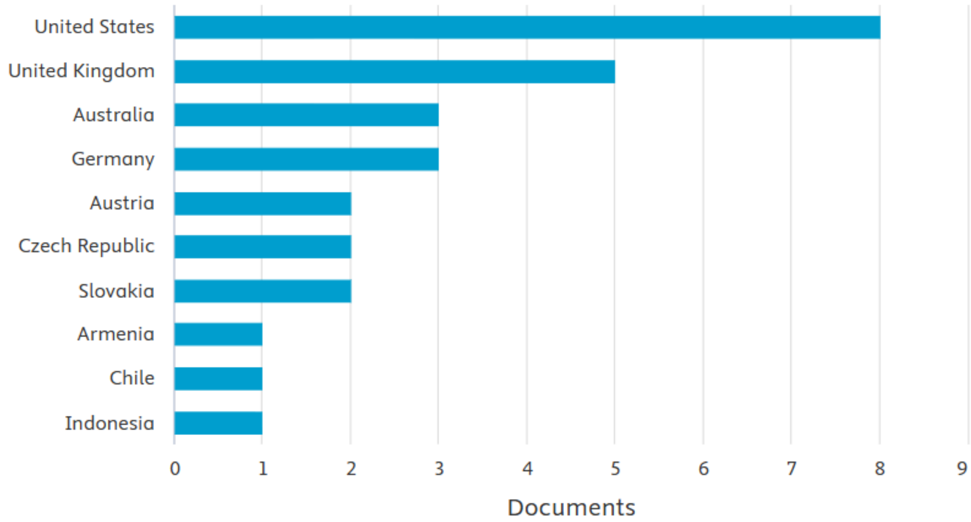

Figure 3. Documents by country

To provide a more comparative view, Table 1 presents country-wise document counts normalized by population (per 10 million people) and estimated number of higher education institutions.

Table 1. Country-wise document counts normalized by population (per 10 million people) and estimated number of higher education institutions

Country	Articles	Per 10M Pop.	Approx. HEIs	Articles per HEI
USA	10	0.3	~5,000	0.002
UK	7	1.0	~165	0.042
Australia	3	1.1	~43	0.070
Indonesia	1	0.04	~4,700	~0.0002

This reveals that although Indonesia appears in the dataset, botanical literacy research is relatively underdeveloped across Asia when adjusted for population and institutional capacity. Countries like India, Japan, and China are notably absent despite their active environmental research sectors—possibly due to different terminology use, indexing limitations, or thematic prioritization. Thus, the lack of representation from Asia may not solely indicate a lack of interest, but rather a misalignment between publication indexing systems and local research terminologies or institutional output patterns.

We can observe from the Figure 3 that the United States and the United Kingdom are the two nations with the highest interest in botanical literacy research and publication. This may be an indicator that these nations have evolved or set up research institutions in botanical research, aimed at raising awareness of why plants are vital in the environment. This is because they have highly advanced academic and scientific communities that cherish environmental education and sustainability.

Geographically, the articles are dispersed over four continents: America, Europe, Australia, and Asia. Such worldwide dispersal indicates the growing acknowledgment of the significance of botanical literacy all over the world. However, it can be observed that Asia is represented only by Indonesia, which can imply that there is a gap in research and publication of botanical literacy in other Asian countries. This can be a challenge for the initiation of research endeavors in Asia, particularly in nations where environmental and sustainability education is still in its initial stage.

Perhaps the reason the United States and the United Kingdom are leading the way in botanical literacy studies is that they have well-funded educational and scientific institutions that are more capable of producing significant publications and research on the subject. This is an example of how developed countries may have more resources to channel into environmental literacy, whereas other regions are still building their capacity in this respect. The only inclusion of Indonesia from the Asian region in botanical literacy books is surprising and raises several questions. One of the reasons may be the lesser awareness or lower prioritization of plant sciences in the majority of Asia. Although countries like India, Japan, and China have developed in the field of environmental studies, botanical literacy per se may not be a priority (Amprazis et al., 2021; Marcos-Walias et al., 2023). The inclusion of Indonesia might mirror the nation's expanding ecological concerns, particularly due to its high biodiversity and the extreme significance of plants in its ecosystems (Sun et al., 2024). It may also be the beginning of enticing other Asian nations into botanical literacy research, thereby facilitating additional publications and an appreciation of the plant's role in life sustenance.

Documents by subject area (RQ 3)

Botanical literacy is approached through social sciences (37.3%) and agricultural and biological sciences (20.3%). This theme is also approached through other subject areas such as environmental sciences, computer science, psychology, biochemistry, arts and humanities, health professions, economics, and energy. This is as presented in Figure 4.

The data reveals that botanical literacy is predominantly studied within the fields of social sciences and agricultural and biological sciences. This indicates that a large portion of research focuses on understanding the relationship between humans, plants, and ecosystems, especially from a societal or ecological perspective. Social sciences often emphasize the cultural, historical, and socio-economic aspects of botanical knowledge, which helps frame plant-related issues within human behavior, policy, and society. Agricultural and biological sciences, on the other hand, likely explore the practical and scientific aspects of plants, such as their growth, role in ecosystems, and their applications in agriculture and biotechnology.

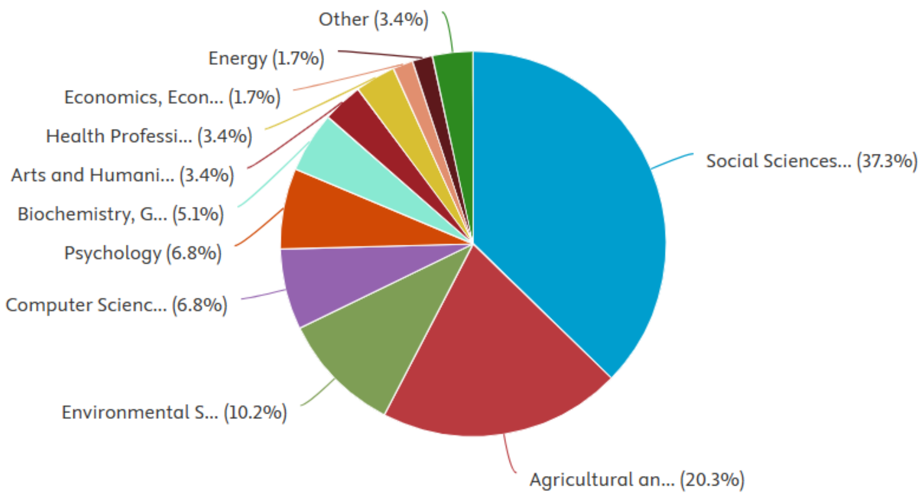

Figure 4. Documents by subject area

Interestingly, botanical literacy is also explored in a variety of other fields, including environmental sciences, computer science, psychology, biochemistry, arts and humanities, health professions, economics, and energy. This broad range of disciplines reflects the interdisciplinary nature of botanical literacy, emphasizing that the importance of plants extends far beyond traditional agricultural or biological studies. For instance, in environmental sciences, the focus might be on the role of plants in ecosystems and sustainability, while in computer science, research could explore the use of digital tools to model plant growth or analyze environmental data. In psychology, studies may look at how exposure to plants impacts mental health and well-being. Each of these perspectives highlights the diverse ways in which botanical literacy is relevant to various aspects of life and society.

The inclusion of botanical literacy in a wide range of disciplines underlines its importance as a cross-cutting theme in education and research (Amprazis & Papadopoulou, 2020; Balding & Williams, 2016; Sanders, 2019). While the social sciences and agricultural sciences remain the core areas for exploring botanical knowledge, the growing recognition of plants' role in other fields reflects their broader significance in addressing global challenges. For example, in health professions, understanding the therapeutic uses of plants or the mental health benefits of greenery in urban environments is increasingly vital. Meanwhile, in economics, research on plant-based industries, such as the agricultural or pharmaceutical sectors, can inform sustainable practices and economic growth.

The involvement of fields like computer science and biochemistry also signals the emergence of new technological and scientific approaches to studying plants. With the advancement of technology, botanical literacy may extend to innovative areas such as biotechnology (in biochemistry) and big data analytics (in computer science), opening up new frontiers for plant research and environmental conservation. Furthermore, the mention of arts and humanities suggests that there is a cultural and aesthetic aspect to botanical literacy, possibly involving the representation of plants in literature, art, and cultural practices.

Documents by funding sponsor (RQ 4)

The National Science Foundation (NSF) is an institution that has concern and consistency in funding research and publications around the theme of botanical literacy. The amount funded is very prominent, which is four articles, compared to nine other institutions which only have one article each. This is as presented in Figure 5.

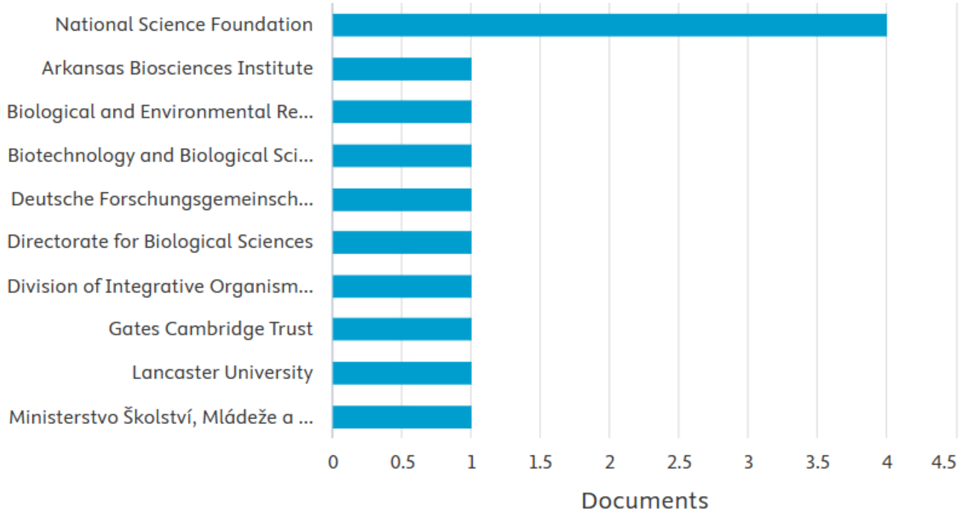

Figure 5. Documents by funding sponsor

The National Science Foundation (NSF) is identified as a leading institution in terms of funding research and publications focused on the theme of botanical literacy. The NSF's commitment to supporting this area of study is demonstrated by the significant funding it has provided for four articles. This is notably higher compared to nine other institutions, each of which has funded only one article. This disparity in funding highlights the NSF's prominent role in advancing research related to botanical literacy, making it a key player in the field. The data presented in Figure 5 emphasizes the NSF's sustained dedication to this particular theme, positioning it as a major source of financial support for botanical literacy research.

The fact that the NSF has funded four articles on botanical literacy, compared to the other institutions that have funded only one, illustrates the institution’s priority and emphasis on this area of research. The NSF’s prominent role in this field likely stems from its broader mission to support science and education, including environmental literacy and sustainability. Botanical literacy is crucial in understanding ecosystems, biodiversity, and the importance of plants in sustaining life, which aligns with the NSF’s goals of fostering scientific knowledge and addressing environmental challenges (National Science Foundation, 2022; Spears, 2015).

The disparity in funding levels between the NSF and other institutions could be indicative of the varying priorities among funding bodies. While other institutions may also be interested in botanical literacy, their financial commitments may be less substantial, possibly due to competing research agendas or limited resources. The NSF, on the other hand, appears to recognize the long-term value of investing in botanical literacy, potentially as a way to address global environmental issues, enhance ecological education, and promote sustainability.

Keywords (RQ 5)

Figure 6 presents a Co-occurrence keywords map related to botanical literacy. From the figure, it is apparent that certain keywords have a dominant presence in the network, represented by larger nodes. These dominant keywords include plant blindness, environmental education, plant awareness, education, botany, botanical literacies, and science education.

To enhance clarity, Figure 7 provides a keyword heatmap that displays the frequency of key terms across the 32 analyzed documents. This visualization shows that “plant blindness” (18 mentions), “environmental education” (15), and “plant awareness” (13) are the most frequently co-occurring terms, underscoring their central role in current botanical literacy discourse.

Less frequent terms such as "early childhood education," "climate," and "scientific literacy" suggest emerging yet underexplored areas, particularly in cross-stage education and global environmental frameworks.

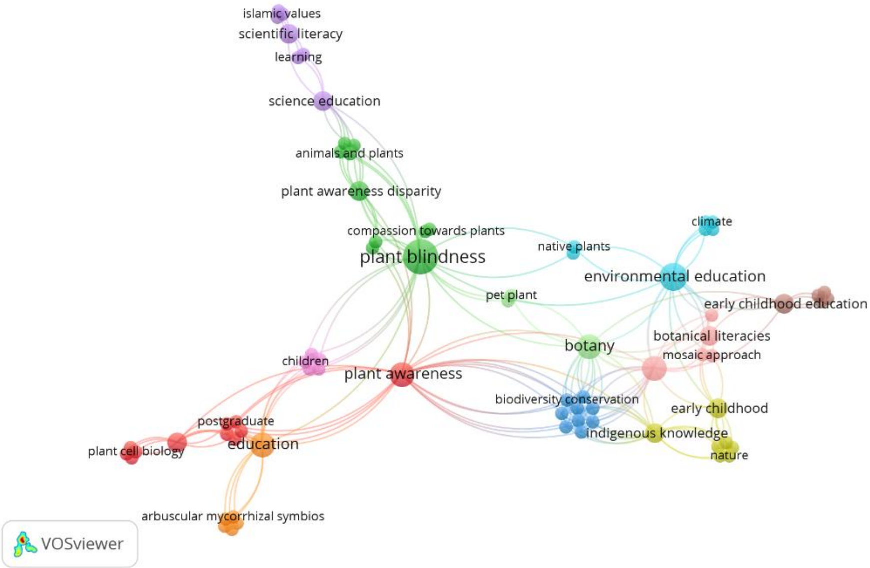

Figure 6. Cooccurrence keywords

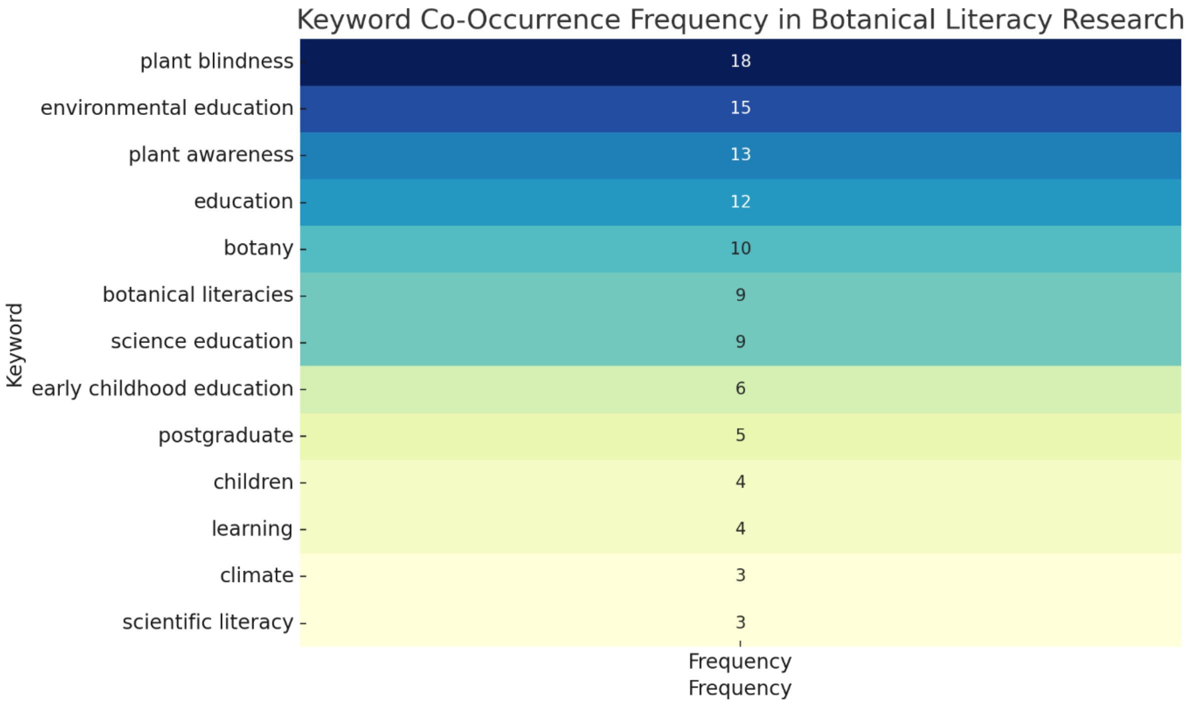

Figure 7. Heatmap visualisation

The prominence of terms like plant blindness, environmental education, and plant awareness suggests that botanical literacy is closely tied to efforts in raising awareness about the importance of plants and addressing the issue of plant blindness, where individuals fail to recognize the significance of plants in their daily lives. The strong link between education, botany, and science education also highlights the importance of integrating botanical literacy into formal education systems, promoting an understanding of plant life as part of broader environmental and scientific education.

The inclusion of terms like early childhood education and postgraduate suggests that botanical literacy is being considered across various educational stages. While it is often emphasized at the primary or secondary school levels, there is also a growing interest in integrating botanical literacy in early childhood education to instill foundational knowledge and values about plants and nature. Additionally, postgraduate education could reflect the need for advanced studies in botanical sciences and their applications in research or conservation efforts (Arif et al., 2025; Beasley et al., 2021; Beasley, Hesterman, & Lee-Hammond, 2023; Pongsophon & Jituafua, 2021).

Smaller nodes such as climate and scientific literacy indicate that botanical literacy is often viewed in relation to broader environmental issues like climate change, where plants play a crucial role in sustaining ecosystems and mitigating climate impacts. The focus on scientific literacy further underscores the importance of botanical education as a key component of broader scientific understanding, helping individuals connect the dots between plants, ecosystems, and global environmental challenges.

Factors Influencing Botanical Literacy (RQ 6)

Table 2 presents the findings of Scopus AI regarding Factors Influencing Botanical Literacy. The Table 2 identifies three key factors that influence botanical literacy: lack of interest and exposure, educational materials, and teaching methods. Lack of Interest and Exposure: This factor indicates that students often do not develop a strong interest in plants or plant science due to limited exposure before entering college. The lack of early engagement in the study of plants can significantly hinder their understanding and appreciation of botanical concepts. As noted by Uno (2009) and Wells et al (2021), students may not see plants as relevant to their daily lives, which contributes to a reduced interest in learning about them.

Table 2. Factors Influencing Botanical Literacy

No	Factors	Important information	References
1	Lack of Interest and Exposure	Students often lack interest in plants and have limited exposure to plant science before college	(Uno, 2009; Wells et al., 2021)
2	Educational Materials	The quality of instructional materials, such as textbooks, can impact botanical literacy. Many textbooks promote superficial learning and fail to foster deep understanding	(Pedrera et al., 2024)
3	Teaching Methods	Traditional teaching methods may not effectively engage students or develop their botanical literacy	(Corbacho-Cuello et al., 2024; Uno, 2009)

Educational Materials: The quality of educational resources, such as textbooks, is another important factor. As highlighted by Pedrera et al (2024), textbooks and other materials often present plant science in a superficial manner, which can lead to shallow learning experiences. This limited depth of content prevents students from fully understanding the complex interconnections within ecosystems and the critical role plants play in sustaining life.

Teaching Methods: Traditional teaching methods may fail to actively engage students or encourage the development of botanical literacy. According to Corbacho-Cuello et al (2024) and Uno (2009), conventional methods might not emphasize hands-on or inquiry-based learning, which are essential for fostering a deeper understanding of plants and their significance. As such, more innovative teaching approaches that go beyond passive learning are needed to enhance botanical literacy.

The data presented emphasizes several challenges in improving botanical literacy, particularly at the educational level. The lack of interest and exposure to plants before higher education suggests that early education programs may need to incorporate more plant-related content to spark curiosity and engagement. This would help establish a foundation for deeper botanical knowledge as students progress in their academic careers.

In terms of educational materials, the reliance on textbooks that provide superficial content is a major barrier. Textbooks need to evolve to encourage critical thinking and exploration of plant science, moving beyond basic facts to integrate real-world applications and ecological concepts. This shift could help students develop a more meaningful connection to the subject matter, enhancing their understanding of plants as part of broader environmental and scientific issues.

Finally, the teaching methods highlighted in the table point to the need for more interactive, student-centered approaches to learning. Inquiry-based and experiential learning methods, such as fieldwork, plant identification, or experiments with plant growth, could be more effective in engaging students. These approaches would not only promote active learning but also allow students to apply botanical concepts to real-life situations, reinforcing the relevance of plants in their daily lives and fostering a deeper appreciation for the natural world.

Effective Strategies to Enhance Botanical Literacy (RQ 7)

Table 3 presents the effective strategies to enhance botanical literacy. Table 2 presents various strategies that can effectively enhance botanical literacy, categorized into inquiry-based and hands-on learning, scaffolding information literacy, personal connections and relevance, and innovative educational tools. Each category emphasizes active engagement and the development of deeper, more relevant understanding in students regarding plants and botany.

Table 3. Effective Strategies to Enhance Botanical Literacy

No	Factors	Important information	References
1	Inquiry-Based and Hands-On Learning		
1a	Botanical Inquiry Trails	Engaging students in hands-on activities like plant identification and understanding local vegetation can significantly improve their botanical knowledge and interest	(Corbacho-Cuello et al., 2024)
1b	Native Garden Planting	Activities such as planting native species can enhance students' understanding and appreciation of plants and biodiversity	(Wells et al., 2021)
2	Scaffolding Information Literacy		
2a	Structured Learning	Implementing scaffolding techniques in botany education can improve botanical literacy among prospective biology teachers, enabling them to transfer this knowledge effectively to their students	(M. S. Sari & Mawaddah, 2021)
3	Personal Connections and Relevance		
3a	Herbarium Projects	Connecting students to their botanical heritage through herbarium curation can foster a deeper interest in botany and citizen science	(Krosnick & Moore, 2024)
3b	Everyday Connections	Encouraging students to explore their daily interactions with plants, such as analyzing food items or local field trips, can broaden their understanding and interest in botany	(Fadiman, 2014)
4	Innovative Educational Tools		
4a	Mobile Technologies	Developing interactive apps that align with the botany curriculum can provide dynamic learning experiences and enhance botanical literacy	(Pettit et al., 2014)

Inquiry-Based and Hands-On Learning: (1a) Botanical Inquiry Trails: Engaging students in hands-on activities like plant identification and exploring local vegetation can significantly enhance their botanical knowledge and spark interest in plant science. According to Corbacho-Cuello et al (2024), such inquiry-based activities are crucial for helping students connect theoretical knowledge to real-world experiences. (1b) Native Garden Planting: Activities that involve planting native species provide students with direct exposure to plants and biodiversity, which is crucial for fostering a deeper understanding of local flora. Wells et al (2021) suggest that such activities help students appreciate plants not only for their scientific importance but also for their ecological and cultural value.

Scaffolding Information Literacy i.e. Structured Learning: Implementing scaffolding techniques in botany education helps students progressively build their botanical knowledge, allowing them to absorb complex concepts in manageable steps. This method is particularly effective in preparing future educators, such as biology teachers, by enabling them to transfer botanical knowledge more effectively to their students. M. S. Sari and Mawaddah (2021) emphasize the importance of structured learning in enhancing botanical literacy, especially for educators.

Personal Connections and Relevance: (3a) Herbarium Projects: Engaging students in herbarium curation allows them to connect with their botanical heritage and engage in citizen science, which can foster a stronger interest in botany. According to Krosnick and Moore (2024), herbarium projects help students develop a personal connection to plants and deepen their understanding of plant science. (3b) Everyday Connections: Encouraging students to explore how plants are relevant to their everyday lives—through food, medicine, or local field trips—can enhance their understanding of botany. Fadiman (2014) suggests that these everyday connections broaden students' perspectives and reinforce the relevance of plants in their lives.

Innovative Educational Tools i.e. Mobile Technologies: The development of interactive mobile apps that align with the botany curriculum offers dynamic and engaging learning experiences. Pettit et al (2014) note that mobile technologies can facilitate an interactive approach to learning, making botanical education more accessible and enjoyable for students.

The strategies outlined in Table 2 focus on actively engaging students in the learning process, ensuring that they not only gain knowledge but also develop a lasting interest in botany. Inquiry-based and hands-on learning is highlighted as a core strategy. Activities like botanical inquiry trails and native garden planting not only engage students with the subject matter but also give them a direct connection to the natural world, helping them appreciate the significance of plants in real-life contexts. This aligns with research that shows hands-on learning boosts student motivation and retention.

The scaffolding of information literacy is also critical, particularly for future educators. By ensuring that botany concepts are taught in a structured, step-by-step manner, students can build a comprehensive understanding of plant science, which they can then pass on to others. This strategy is essential for preparing the next generation of biology teachers and researchers, who will play a crucial role in advancing botanical literacy.

Personal connections and relevance are also vital for enhancing students' interest and engagement with botany. Projects such as herbarium curation and activities that link everyday life to plant science help students understand that botany is not just an academic subject but an essential part of their daily lives. This personal connection can drive students to pursue careers in botany, conservation, or related fields.

Concept map (RQ 8)

A concept map visually represents the relationships and key themes within a body of research. It illustrates how different concepts, keywords, and topics are interconnected, offering a clear depiction of the structure and flow of knowledge in a particular field of study (Figure 7).

However, this categorization overlaps conceptually with broader educational discourses such as “Environmental Education.” For instance, both “scientific literacy” and “place-based learning” are frequently used in environmental education literature, suggesting that botanical literacy is part of a nested subset rather than a distinct field.

The use of AI-generated mapping (via Scopus AI) is beneficial for identifying patterns but also carries methodological limitations. Language model biases, reliance on keyword co-occurrence, and potential exclusion of gray literature may affect thematic validity. Moreover, some overlaps—like "art and botany" versus "student engagement"—require manual thematic triangulation to avoid misclassification.

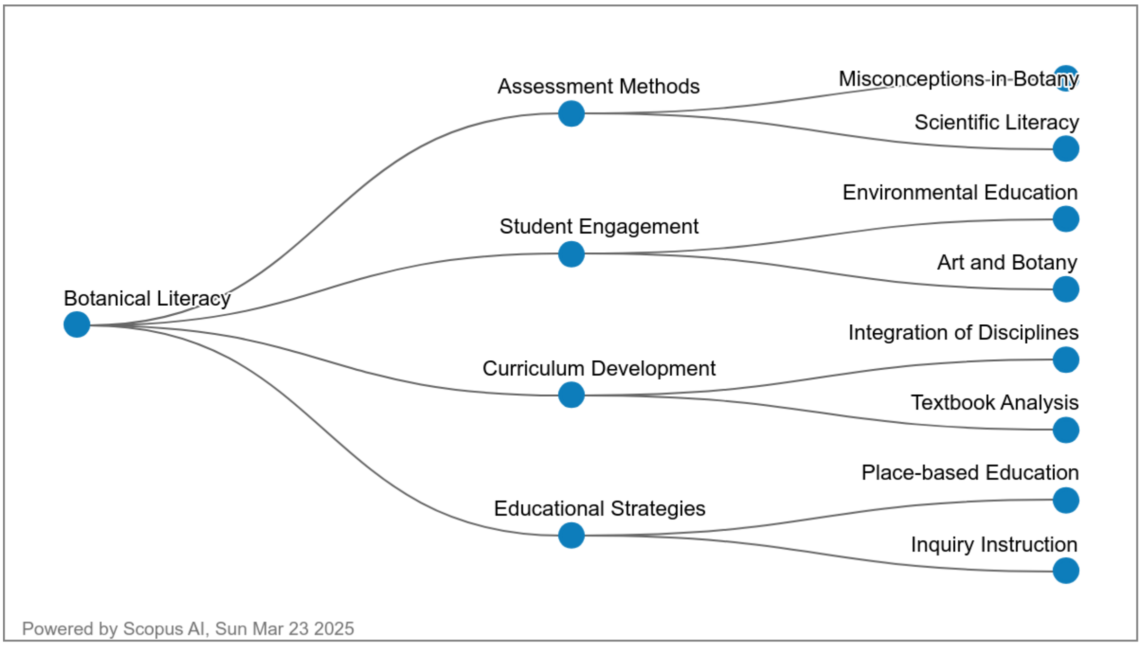

Figure 7. Concept map of botanical literacy

To aid comprehension, Table 4 provides a summary of the four central clusters identified in the concept map along with their subthemes.

Table 4. Summary of the four central clusters identified

Core Theme	Subthemes
Assessment Methods	Misconceptions in botany, Scientific literacy
Student Engagement	Environmental education, Art and botany
Curriculum Development	Interdisciplinary integration, Textbook analysis
Educational Strategies	Place-based education, Inquiry instruction

Based on Figure 7, it can be seen that in the concept map, botanical literacy is related to four things, namely assessment methods, student engagement, curriculum development, and educational strategies. These four things each branch into two things, namely assessment methods related to misconceptions in botany and scientific literacy; student engagement related to environmental education and art and botany, curriculum development related to integration of disciplines and textbook analysis, and educational strategies related to place-based education and inquiry instruction.

The concept map in Figure 7 outlines key areas where botanical literacy intersects with broader educational frameworks. By examining the relationships between assessment methods, student engagement, curriculum development, and educational strategies, it becomes clear that enhancing botanical literacy requires a multifaceted approach that addresses both content and pedagogy (Arif et al., 2025; Beasley, 2023; Beasley, Hesterman, & Lee-Hammond, 2023).

For example, addressing misconceptions in botany through more effective assessment methods is essential to improving how students grasp plant-related concepts. This is especially important in cultivating scientific literacy, as plants are fundamental to understanding natural sciences, ecosystems, and biodiversity. Therefore, strengthening botanical literacy will contribute to more holistic scientific education.

In terms of student engagement, the connection to environmental education emphasizes that learning about plants and ecosystems can directly influence students' awareness of and interest in pressing global environmental challenges. Integrating art and botany provides a creative outlet for students, making botanical knowledge more accessible and enjoyable. This could also encourage students who might not be initially interested in science to engage with the subject through a different lens (Çil, 2015; Gurnon et al., 2013).

Curriculum development should prioritize integration of disciplines. Botanical literacy should not be isolated in biology classes but woven into interdisciplinary curricula, making it more relevant to students' lives. In addition, analyzing and improving textbooks ensures that the material is not only accurate but also engaging and reflective of the interconnectedness of plants with other subjects like climate science, health, and agriculture (Dimon et al., 2019; Hemingway et al., 2011).

Adopting educational strategies like place-based education and inquiry instruction offers a practical, hands-on approach to learning. By connecting students to local ecosystems and encouraging them to explore botanical concepts through questions and investigations, these strategies foster active learning and help students form a personal connection to the subject matter.

Emerging themes (RQ 9)

Scopus AI identifies “Scientific Literacy in Environmental Contexts” as a consistent theme across 31 articles. However, this theme’s distinction from “Environmental Education” remains conceptually blurred. While scientific literacy emphasizes students’ capacity to apply scientific reasoning to real-world problems, environmental education often focuses on awareness, values, and behaviors. Several articles (e.g., Bórquez-Sánchez, 2024; Luzyawati et al., 2025) use both terms interchangeably, which raises challenges in drawing boundaries across the literature.

Additionally, while digital tools and citizen science are emerging sub-themes, fewer studies examine structural enablers—like national policy, curriculum mandates, or teacher capacity—which points to a research gap in systems-level intervention analysis. These observations call for future reviews to use mixed-method thematic extraction that combines AI-driven clustering with manual coding to ensure higher conceptual precision.

Based on the analysis of 31 articles related to this study, Scopus AI identified that “Scientific Literacy in Environmental Contexts” is “Consistent Theme”. The consistent presence of clusters focusing on scientific literacy, particularly in environmental contexts, indicates a sustained interest in understanding and improving how students engage with and comprehend scientific concepts related to the environment. This theme encompasses various educational strategies and assessment tools aimed at enhancing students' scientific literacy, with a notable emphasis on environmental issues such as ecosystems, biodiversity, and climate change ((Afidah & Juanengsih, 2024; Aini et al., 2024; Badaruddin et al., 2024; Baltikian et al., 2024; Barrutia et al., 2024; Bórquez-Sánchez, 2024; Clark et al., 2024; Coppi et al., 2023, 2024; Dewi & Wibawa, 2024; Halhaji, 2024; Haris & Hakim, 2024; Hartono et al., 2023; Junanto et al., 2024; Lee, 2023; Lestari et al., 2024; Luzyawati et al., 2025; Morgacheva et al., 2023; Mulyono et al., 2024; Pratama et al., 2024; Quinde-Ramos et al., 2025; Santoso et al., 2023; P. M. Sari, 2024; Sidauruk et al., 2025; Stahl et al., 2024; Sumarni & Wahyuni, 2023; Suryani et al., 2023; Syukur et al., 2023; Tran et al., 2024; Wati et al., 2024; Wright et al., 2024; Wulaningsih et al., 2024).

The analysis reveals that “Scientific Literacy in Environmental Contexts” emerges as a dominant and consistent theme across 31 Scopus-indexed studies (2023–2025), reflecting a global scholarly focus on integrating botanical and ecological concepts into science education. This trend underscores the urgency of fostering students’ ability to critically engage with environmental challenges—such as biodiversity loss, climate change, and ecosystem dynamics—through scientific inquiry (Afidah & Juanengsih, 2024; Barrutia et al., 2024; Clark et al., 2024). Notably, studies like those of Baltikian et al (2024) and Hartono et al (2023) highlight how curricula increasingly link plant literacy to broader environmental stewardship, suggesting a pedagogical shift toward contextualized learning that bridges theory and real-world applications.

The theme's consistency is further evidenced by recurring methodological approaches, including place-based learning (Bórquez-Sánchez, 2024; Luzyawati et al., 2025) and interdisciplinary assessments (Stahl et al., 2024; Tran et al., 2024). Geographically, contributions span diverse regions—from Indonesia (e.g. Mulyono et al., 2024; Suryani et al., 2023) to Europe (Coppi et al., 2023) and Latin America (Quinde-Ramos et al., 2025) — indicating universal recognition of environmental scientific literacy as a cornerstone of modern education. However, regional variations exist; for instance, Indonesian studies (e.g., Lestari et al., 2024; Wati et al., 2024) emphasize local biodiversity, while European works (Morgacheva et al., 2023) focus on climate change frameworks.

Despite the theme's prominence, gaps persist in scaling interventions and measuring long-term impacts. Emerging studies (Pratama et al., 2024; Wright et al., 2024) advocate for innovative tools like digital platforms and citizen science projects to sustain student engagement. Yet, fewer articles address systemic barriers—such as teacher preparedness or policy support—suggesting a need for future research on implementation strategies (Halhaji, 2024; Sidauruk et al., 2025). Collectively, these findings position environmental scientific literacy as an evolving field, demanding collaborative, cross-disciplinary efforts to translate research into actionable educational practices. While some studies (e.g., Pratama et al., 2024; Wright et al., 2024) promote tools like digital platforms and citizen science to engage learners, few articles explore structural enablers such as teacher preparedness, national curriculum policies, or institutional capacity. This points to the need for future reviews that incorporate mixed-method thematic extraction—combining AI-generated clusters with manual coding—for improved analytical depth and reduced thematic bias.

To align with science education frameworks, this theme can be mapped to curriculum goals such as the "Next Generation Science Standards (NGSS)" in the U.S., which emphasize cross-cutting concepts, scientific practices, and ecological awareness. Similarly, in Indonesia, the Kurikulum Merdeka's "Profil Pelajar Pancasila" incorporates environmental literacy as a core competency—making botanical literacy highly relevant for curriculum designers.

CONCLUSION

This systematic literature review provides comprehensive insights into the evolution and expansion of botanical literacy research over the past decade, based on Scopus-indexed publications. The analysis reveals a clear upward trend in scholarly attention, particularly after 2017, with notable peaks in 2022 and 2024. This growth reflects a heightened global recognition of the critical role plants play in addressing pressing environmental challenges such as sustainability, biodiversity loss, and climate change.

Findings show that botanical literacy is increasingly integrated across diverse academic disciplines—ranging from social sciences and agricultural studies to environmental science, computer science, and psychology—demonstrating its interdisciplinary relevance. While the United States and the United Kingdom lead in research output, a significant gap remains in Asian representation, with Indonesia as the sole contributor from the region. This highlights the urgent need for broader international collaboration and more inclusive global research efforts.

The concept map analysis emphasizes the importance of a multifaceted approach to advancing botanical literacy, which involves not only content development but also innovative pedagogy and assessment strategies. Effective strategies include inquiry-based learning, scaffolding information literacy, and establishing real-life connections to students' everyday experiences with plants—each fostering deeper student engagement and long-term retention.

Emerging themes identified through Scopus AI highlight "Scientific Literacy in Environmental Contexts" as a dominant focus, reinforcing the alignment between botanical education and broader environmental literacy goals. This consistent thematic presence across regions underlines the value of integrating botanical literacy into school curricula and science education frameworks.

In light of these findings, policymakers and education stakeholders should consider incorporating botanical literacy more explicitly into curriculum guidelines and teacher training programs. Promoting professional development that equips educators with interdisciplinary strategies—especially in underrepresented regions—will be essential to fostering a globally informed, ecologically literate generation capable of addressing 21st-century environmental issues.

RECOMMENDATION

Future research on botanical literacy should focus on expanding studies in underrepresented regions, particularly in Asia, to address the existing gap and foster global participation, engaging countries like India, China, and Japan, where plants play vital roles in ecosystems and cultures. Additionally, exploring the integration of botanical literacy into interdisciplinary curricula across subjects such as climate science, health, agriculture, and the arts is essential to make learning more holistic and relevant to students. Pedagogical innovations, like place-based education and inquiry instruction, should be further researched to enhance student engagement. There is also a need to investigate innovative assessment methods that address misconceptions in botany and encourage critical thinking. Incorporating technology and digital platforms, such as mobile apps and citizen science projects, can make botanical education more interactive and accessible, especially for students with limited access to physical botanical environments. Furthermore, research into teacher preparedness and policy support is crucial to ensure educators are equipped with the necessary tools and training, and to explore how policies can facilitate the inclusion of botanical literacy in curricula, particularly in regions where environmental education is still developing.

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