

Botanical Literacy and Learning Media: What Can Scopus AI Tell Us?

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Abstract

Botanical literacy, crucial for addressing biodiversity and sustainability challenges, is declining due to ineffective traditional learning media. This review utilizes Scopus AI to analyze trends in botanical literacy research and the role of innovative learning media. Key insights include: (1) traditional textbooks are insufficient, while emerging tools such as augmented reality (AR) and interactive games enhance engagement and comprehension; (2) research is concentrated on assessment methods, learning tools, and educational approaches, with immersive technologies addressing Plant Awareness Disparity (PAD) and bridging gaps in experiential learning; and (3) technologies like virtual field trips and AI applications are transforming botanical education by promoting ecological awareness and higher-order thinking. The review emphasizes the need for technology-integrated, student-centered pedagogies and identifies gaps in AI-driven research synthesis. Future directions include longitudinal studies on AR/VR effectiveness, AI-customized tools, teacher training, and cross-cultural assessments. By synthesizing Scopus AI's data-driven insights with manual analysis, this review provides a roadmap for developing evidence-based learning media that cultivate plant-literate generations capable of addressing global environmental challenges.

Keywords: Augmented Reality; Botanical Literacy; Learning Media; Science Education; Scopus AI

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INTRODUCTION

Botanical literacy, defined as the understanding of plant biology and its ecological significance (Arif et al., 2025; Beasley et al., 2021; Uno, 2009), is essential for addressing global challenges such as biodiversity loss and sustainable agriculture (Beasley et al., 2021; Cappelli et al., 2022; Chen & Sun, 2018; Mercan, 2025; Stroud et al., 2022). Botanical literacy is essential for understanding plant-related global challenges and fostering scientific competence (Beasley et al., 2023; Pedrera et al., 2024). Effective botanical education requires high-quality instructional materials that promote inquiry-based learning and conceptual understanding (Pedrera et al., 2024; Uno, 2009).

Even though it is important, studies have revealed that students and the public are losing interest and there is a lack of knowledge in botany. Traditional learning

media, i.e., textbooks and classroom lecture, fail to capture the student (Buck et al., 2019; Gubo & Schiffli, 2022; Lindemann-Matthies et al., 2024; Marcos-Walias et al., 2023; Peter Batke et al., 2020; Stagg et al., 2025). Because of this, teachers and researchers resort to new learning media, i.e., computer resources, virtual labs, and intelligent systems, to enhance botanical education (Aldya & Arifendi, 2021; Liang, 2024; Potkonjak et al., 2016). Yet, how well these tools work and are used in educational environments is underresearched, leaving some ground for further investigation.

Recent advances in learning technology have introduced AI-powered tools like Scopus AI, capable of sifting through massive scientific databases to ascertain research trends, gaps, and changing themes (Aguilera-Cora et al., 2024; ETH Zurich, 2025; LibCognizance, 2024; Mariani et al., 2023; Ofosu-Ampong, 2024). Unlike traditional bibliometric methods that primarily focus on quantitative metrics such as citation counts or simple keyword analysis, Scopus AI allows for a more nuanced understanding by identifying emerging trends, latent research gaps, and the evolution of themes over time. Scopus AI offers the promise of distinguishing insights into learning media and botany literacy by processing peer-reviewed literature, citation patterns, and keyword growth (concept map and emerging themes). Meanwhile, contemporary learning media such as AR plant identification software and interactive e-modules have been discovered to boost interest and learning retention (AlGerafi et al., 2023; Dritsas & Trigka, 2025; Lampropoulos & Kinshuk, 2024; Sung et al., 2016; Won et al., 2023). Despite these developments, the synthesis of the role of AI-driven analyses in shaping and refining botany learning tools remains insufficient. Such developments aside, synthesis of the role of AI-driven analyses in shaping and refining botany learning tools is wanting.

While there have been studies on botany education and e-learning media in isolation (Corbacho-Cuello et al., 2024; Febrianti et al., 2024; Huang et al., 2010; Varisa & Fikri, 2022), fewer studies utilize AI-based bibliometric software like Scopus AI to visualize patterns in research or identify under-studied research topics. This review offers a comparative perspective by showing how Scopus AI uncovers nuanced trends and gaps that traditional bibliometric methods miss, particularly in identifying the evolution of new technologies and pedagogical approaches in botanical education. With most reviews derived from qualitative synthesis of literature manually, these miss capturing more abstract trends or latent themes. Also missing is catching up with innovation in technology from the AI frontier to applied plant pedagogy. This difference represents a demand for an integrative approach that brings together AI-guided analysis and education research to support botanic literacy efforts.

This mini-review attempts to explore what Scopus AI reveals about trends, gaps, and opportunities in botanical literacy and learning media. Specifically, it attempts to (1) review the nature of learning media in allowing botanical literacy; (2) concept map as pattern the promise of Scopus AI in identifying prominent themes and underdeveloped themes, and (3) determine emerging themes that are crucial for advancing botanical education through technology integration, such as AI-driven tools and immersive learning environments.

By leveraging Scopus AI, this review provides a data-driven summary of botanical literacy research, a fresh integration of trends and gaps that traditional reviews may not capture. The findings can guide educators, researchers, and

developers in designing more effective, evidence-based learning tools. This research also demonstrates the transformative power of AI in education research, revealing how machine-assisted analyses can more effectively help us understand pedagogical problems and innovations.

In botanical education, the application of advanced technologies such as cloud technologies, augmented reality (AR), and adaptive gamification holds significant promise to enhance learning effectiveness. Papadakis et al (2023) highlight that computer simulations and cloud-based technologies enable global access to educational materials, facilitating flexible and open learning environments. These technologies support both independent and collaborative learning, allowing students to engage with content in real-time, which is highly relevant for creating more interactive and accessible botanical learning media. Furthermore, the synergy between cloud technologies and AR, as discussed by Papadakis, Kiv, Kravtsov, Osadchyi, Marienko, Pinchuk, Shyshkina, Sokolyuk, Mintii, Vakaliuk, Azarova, et al., (2023) offers great potential to enrich the learning experience. AR, by providing visual and interactive elements, can deepen students' understanding, such as through virtual plant identification, making botanical education more engaging and immersive. Additionally, Zourmpakis et al (2023) emphasize that adaptive gamification in science education increases student motivation and engagement by integrating customized game elements. This gamification approach can be particularly effective in making botanical learning more enjoyable and interactive, especially when applied to challenges such as plant identification or botanical experiments. Overall, these technologies, which can be further analyzed and synthesized using AI-based bibliometric tools like Scopus AI, open up significant opportunities for innovation in botanical learning media, making it more effective, interactive, and aligned with contemporary educational needs.

METHOD

Research Framework

This study uses a mini-review approach, a concise yet comprehensive integration of the literature, to analyze trends and gaps in botanic literacy and learning media (Grant & Booth, 2009). In contrast to systematic and scoping reviews, which typically involve exhaustive searches and a rigorous quality assessment of studies, mini-reviews are more focused and are suitable for rapidly evolving fields like botanical education (Aromataris, E. & Munn, 2020). To enhance objectivity and efficiency, this review leverages Scopus AI, an artificial intelligence-powered tool integrated into the Scopus database that uses natural language processing (NLP) and machine learning to analyze research trends, identify influential works, and map knowledge domains (Elsevier, 2024). By combining manual analysis with Scopus AI's data-driven insights, this study aims to provide a balanced perspective on how technology shapes botanical literacy and botanical education while highlighting future research directions.

Performing keyword search

The search history in 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"). This search strategy ensures a broad yet relevant capture of the literature. However, further clarity on the inclusion/exclusion criteria, the publication date range, and the types of documents reviewed would enhance transparency and reproducibility in future studies. This history can be a reference for further researchers to continue or test the truth of the process we have done.

In this article, the authors employ the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method to ensure a structured and transparent approach to synthesizing literature. The PRISMA methodology is widely used in systematic reviews and meta-analyses to improve the quality and reproducibility of research by providing a clear framework for conducting reviews. In this article, the PRISMA method guides the selection, evaluation, and synthesis of studies (Husamah et al., 2022, 2023; Page et al., 2021; Shamseer et al., 2015; Sukadari et al., 2023) related to botanical literacy and learning media. We present a flow diagram summarizing the screening and selection process in Figure 1, ensuring transparency in the study selection. The process begins with a comprehensive search for relevant studies across multiple databases, followed by an assessment of the eligibility of these studies based on predefined inclusion and exclusion criteria. However, we acknowledge the need for a clearer justification regarding the small number of articles reviewed in this study.

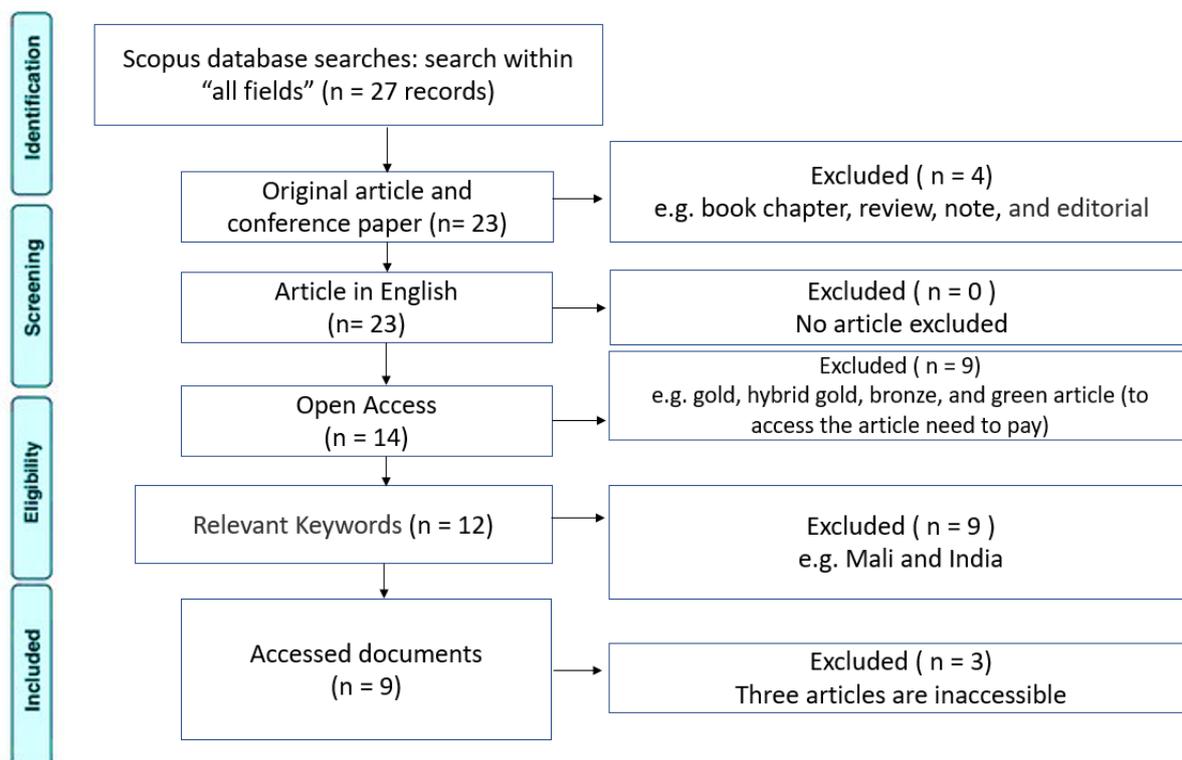


Figure 1. PRISMA process

We have defined specific inclusion and exclusion criteria to guide the selection of articles for this review. Articles included were those that focused on botanical literacy or learning media, involved educational technology, and were published in peer-reviewed journals between 2015 and 2025. Excluded were articles not primarily

focused on botanical literacy, reviews without primary data, and studies published outside the specified time frame. This systematic approach ensures that the review captures a broad range of relevant literature, thereby reducing bias and enhancing the validity of our findings. Figure 1 shows the PRISMA process that visually summarize the article screening and selection process based on those criteria.

Articles analyzed

Based on the findings of Scopus AI, there are nine articles that are in accordance with the topic that is the focus of this study. The nine articles are presented in Table 1. The small number of articles included in the review is primarily due to the specific focus of this mini-review on cutting-edge research, where studies using AI-based bibliometric tools like Scopus AI are still emerging. However, the inclusion of only nine articles does limit the comprehensiveness of the findings and requires further justification. Meanwhile, to find or formulate Emerging themes, Scopus AI analyzed the 10 most recent articles published in 2024-2025 (Bacon, 2024; Corbacho-Cuello et al., 2024; Hartanti et al., 2024; Karima, 2024; Krosnick & Moore, 2024; Macneill et al., 2024; Pedrera et al., 2024; Rubiales et al., 2024; Sidauruk et al., 2025; Vančugovienė et al., 2024).

Table 1. Data of articles analyzed

No	References	Aims/Focus	Media Type Used	Outcome	Sample Size
1	(Chowdhury et al., 2015)	Examines how video-mediated learning enhances farmers' knowledge, attitudes, and practices regarding botanical pesticides and facilitates farmer-to-farmer learning beyond structured programs like Farmer Field Schools in rural Bangladesh.	Video-mediated learning	Enhanced knowledge, attitudes, and practices in botanical pesticide usage and farmer-to-farmer learning	Rural farmers in Bangladesh
2	(Andarini et al., 2016)	Aims to develop an interactive edutainment-based CD learning game about plants for elementary school students (grades 1-3) to	Interactive CD learning game	Improved cognitive development and critical thinking skills in elementary students	Elementary school students

No	References	Aims/Focus	Media Type Used	Outcome	Sample Size
3	(Dijaya et al., 2018)	foster fun yet informative learning while supporting cognitive development and critical thinking skills. Aims to develop an Augmented Reality (AR)-based 3D interactive learning media using flashcards to enhance the recognition and understanding of 20 medicinal plants among orthopedagogic students with hearing and speech impairments.	AR-based 3D interactive media	Enhanced recognition and understanding of medicinal plants among students with hearing and speech impairments	Orthopedagogic students
4	(Chien et al., 2019)	Aims to evaluate the effectiveness of AR-based learning materials in enhancing third-grade students' scientific literacy and higher-order cognitive skills in botany.	AR-based learning materials	Increased scientific literacy and cognitive skills in plant observation and identification	Third-grade students
5	(Pongsophon & Jituafua, 2021)	Develops and validates a learning progression model for botanical literacy to improve Thai pre-service science teachers' botanical knowledge through a 15-week garden-	Garden-based education	Significant learning gains in botanical knowledge and understanding of plant biology	Pre-service science teachers

No	References	Aims/Focus	Media Type Used	Outcome	Sample Size
6	(Anggraeni & Sriyati, 2021).	based education course. Aims to develop and evaluate CBG-based teaching materials using the ADDIE method to enhance plant literacy and classification skills among 10th-grade students.	CBG-based teaching materials	Enhanced plant literacy and classification skills among 10th-grade students	10th-grade students
7	(Sari & Mawaddah, 2021).	Examines the impact of information literacy scaffolding on botanical literacy among prospective biology teachers.	Information literacy scaffolding	Significant enhancement in botanical literacy and understanding among prospective biology teachers	120 prospective biology teachers
8	(Corbacho-Cuello et al., 2024)	Investigates the effectiveness of a botanical inquiry trail in enhancing botany education among prospective teachers.	Botanical inquiry trail	Increased knowledge and deeper engagement with local vegetation, fostering active learning and critical thinking	Prospective teachers
9	(Pedrera et al., 2024)	Evaluates how seven Spanish secondary biology textbooks address the Scientific Model of Plant Nutrition (SMPN).	Spanish secondary biology textbooks	Enhanced understanding of the Scientific Model of Plant Nutrition (SMPN) and overcoming Plant Awareness Disparity (PAD)	Seven Spanish textbooks

Ethical Considerations

This review article does not involve human or animal subjects, as it synthesizes secondary data from publicly accessible sources. We clarify that no primary data were collected for the purposes of this review. All data used were derived from peer-

reviewed articles, databases, and other publicly available literature. This clarification ensures transparency in our research process and aligns with good research practices.

RESULTS AND DISCUSSION

Learning Media

Learning media that are related to botanical literacy based on articles in the Scopus database are presented in Figure 2. Figure 2 should clearly present the relationship between various learning media and their impact on botanical literacy, including the technologies and pedagogies that have emerged in recent research.

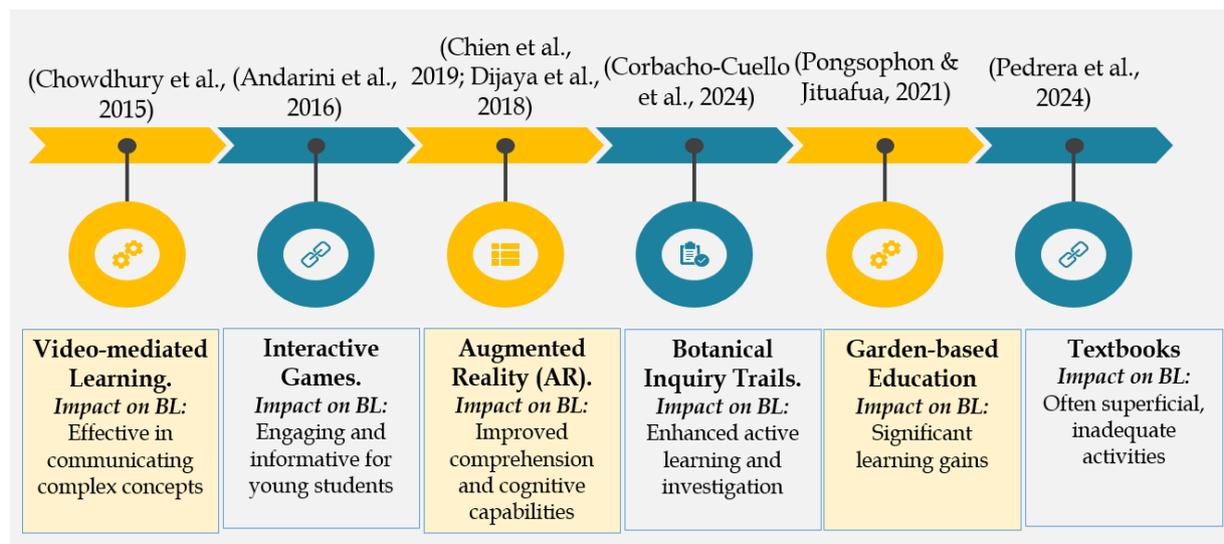


Figure 2. Learning media and their impact on botanical literacy (Source: authors own elaboration based on Scopus AI data).

Botanic literacy is highly challenged by low-quality teaching materials, particularly traditional textbooks, which usually offer surface-level content and fail to promote deep understanding (Pedrera et al., 2024). However, it is essential to critically examine the limitations of these conventional methods, particularly their static nature and lack of engagement, which hinder deeper cognitive engagement with botanical concepts. Innovative approaches such as garden-based learning materials have been promising in promoting plant literacy and classifying abilities, as shown through the use of the Cibodas Botanical Garden (Anggraeni & Sriyati, 2021). These findings highlight the need to move beyond conventional textbooks and find more efficacious sources that can engross students even more in botanical topics. Active learning pedagogies, such as inquiry-based approaches and hands-on activities, have proven particularly effective in advancing botanical literacy by fostering deeper understanding. Such approaches actively engage students in the learning process and support critical thinking and problem-solving skills.

Garden-based education schemes and botanical inquiry streams engage students in experiential research activities, resulting in greater comprehension (Corbacho-Cuello et al., 2024; Pongsophon & Jituafoa, 2021). This suggests that experiential learning approaches offer practical and immersive ways to enhance botanical literacy. Additionally, technology-supported learning such as Augmented Reality (AR) has been shown to promote higher-order thinking skills, allowing students to observe and

identify plant structures more efficiently (Chien et al., 2019; Dijaya et al., 2018). However, it is crucial to assess the accessibility and scalability of AR tools, as they may present barriers for certain student populations. These approaches prioritize experiential learning, which plays a key role in mitigating Plant Awareness Disparity (PAD). Interactive educational media, such as AR-based tools and educational games, offer interactive learning channels for conveying botanical concepts, particularly for preschool students (Andarini et al., 2016; Chien et al., 2019). Moreover, these tools can be particularly beneficial for students with special needs, as they offer adaptive and flexible learning opportunities.

Multimedia learning aids such as video-based learning have also been found effective in delivering complex botanical information. Research on farmer education confirms that classes conducted via video are more effective than workshops in transferring knowledge about botanical pesticide use (Chowdhury et al., 2015). This indicates that visual and interactive presentations can enhance comprehension and memorization of botanical concepts, which could be beneficial in both formal and informal learning settings. To bridge knowledge gaps in botanical literacy, educational developers need to incorporate diverse and interactive media, including AR, video games, and video-mediated learning (Andarini et al., 2016; Chien et al., 2019; Chowdhury et al., 2015). Preparation of teachers in new pedagogical techniques is no less important. Research indicates that scaffolding information literacy makes a radical difference in developing botanical knowledge for future teachers (Sari & Mawaddah, 2021), indicating the efficacy of highly qualified teachers in fostering student abilities.

Lastly, enhancing botanical literacy should move toward more interactive and experiential educational methods. By synthesizing new learning media with best teaching practices, educators can create a scientifically literate citizenry capable of addressing ecological and agricultural issues. However, a more critical discussion of the limitations of these methods, such as teacher readiness and resource availability, is necessary to better assess their widespread implementation.

Concept map

Scopus AI's concept map (Figure 3) illustrates an intelligible development of research on botanical literacy, bifurcating into three key areas: techniques for evaluation, tools for education, and educational strategies for pedagogy. The triadic classification reflects an exhaustive scholarly endeavor to solve Plant Awareness Disparity (PAD) in measurable, pedagogic, and pragmatic terms. The measurement methods division, for instance, calls for a shift from the traditional exam to diversified tools like identification tests (species recognition skill) and questionnaires (quantifying conceptual knowledge and attitude). This shift suggests that a more comprehensive assessment of botanical literacy should focus not only on knowledge acquisition but also on the application and appreciation of botanical concepts—something that traditional exams fail to measure effectively.

The tools for learning department demonstrates the manner in which botanical learning has expanded beyond classical textbooks to multisensory and interactive materials. While herbaria remain to be used in the teaching of plant morphology and taxonomy, their integration with learning games (e.g., AR plant ID apps) indicates a deliberate incorporation of physical and virtual engagement. Significantly, the

mention of textbooks as a sub-branch indicates recurring issues – previous research (e.g., Pedrera et al., 2024) criticizes their static nature, but their mention here indicates continued attempts to restructure them with interactive features. This ambivalence suggests the ongoing tension between traditional and innovative approaches, which has implications for the future of botanical education.

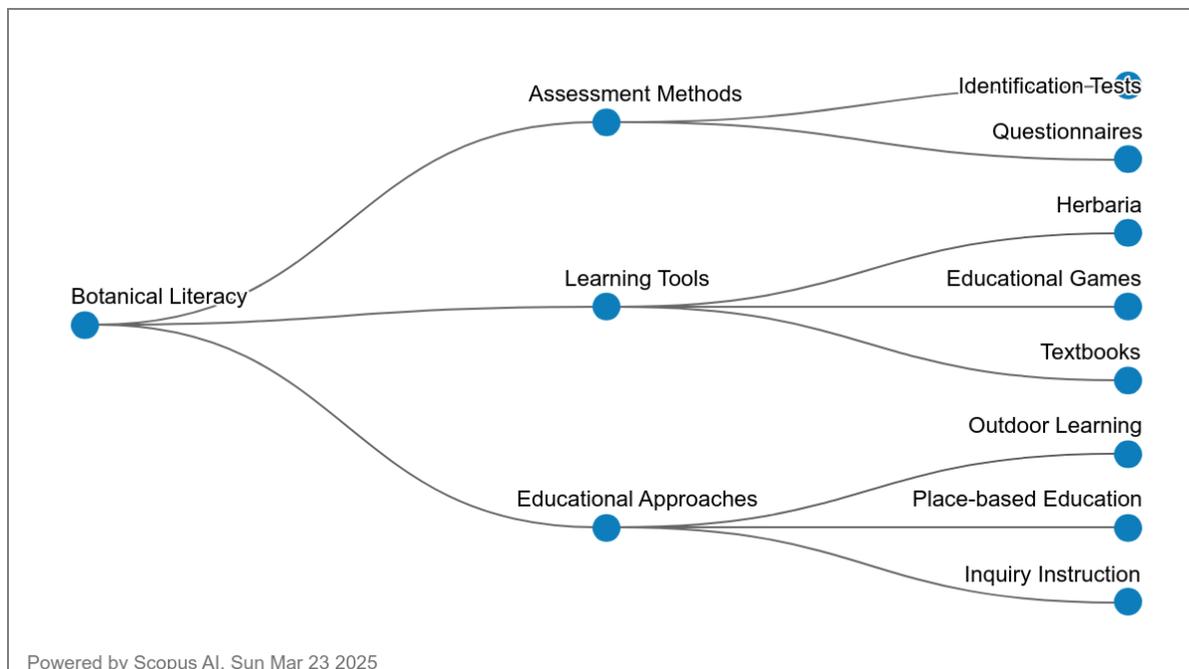


Figure 3. Concept map (powered by Scopus AI).

The branch of educational strategies includes progressive approaches redefining botanic education. Outdoor learning and place-based education focus on environmental immersion, utilizing indigenous plants to anchor theoretical concepts – a practice shown to reduce PAD (Corbacho-Cuello et al., 2024). Meanwhile, inquiry teaching induces higher-level thinking by locating study of plants as investigative processes rather than memorization. These methods not only foster critical thinking but also align with global competencies in environmental stewardship and scientific inquiry. These methods collectively address cognitive and affective barriers to botanic literacy, aligning with global competencies like critical thinking and environmental stewardship. A more critical examination of how these strategies have been implemented across various educational contexts would be beneficial to understand their practical application.

The design of the concept map implicitly resists siloed traditions of research and instead encourages integrative studies that cross-pollinate domains. For example, combining inquiry instruction (approach) with AR games (tool) and identification tests (assessment) might yield whole-system interventions. Future studies might examine how AI-generated concept maps like this one might dynamically track burgeoning trends, such as the development of generative AI for creating customized plant-learning experiences. Furthermore, exploring the potential for AI-generated concept maps to highlight under-explored research areas or emerging trends in botanical education could significantly enhance the analysis of evolving educational tools.

Emerging themes

Scopus AI analysis indicates that "Interactive and Immersive Botanical Learning Tools" has been a reappearing topic in recent botanical education studies. This reappearing cluster of studies indicates persistent academic interest and unrealized potential in leveraging technology to transform plant science education. The consistency of this theme means that these tools are increasingly being seen as fitting solutions to age-old problems in botany education, primarily bridging gaps in addressing Plant Awareness Disparity (PAD) and compensating for the inadequacies of traditional teaching mechanisms that do not address learners appropriately. The study highlights several new tools on the horizon, including virtual tours, interactive botanical trails, and AI-powered mapping applications. These tools represent a shift toward more dynamic and personalized learning experiences, which have the potential to significantly enhance botanical literacy.

These technologies offer distinctive advantages over more conventional approaches in that they construct dynamic, experiential learning environments. Virtual field trips build accessible alternatives to actual excursions, allowing students to explore diverse ecosystems remotely. Interactive trails make possible inquiry learning through gamified plant identification exercises, and AI mapping software enables sophisticated visualization of plant distributions and ecological relationships. These tools represent a shift from passive to active learning, emphasizing engagement and conceptual understanding. Such learning tools are not only enhancing student interaction but also helping in greater concept comprehension of complex botanical systems. Fresh evidence validates these interactive tools significantly enhance every aspect of botanical literacy. Recent research indicates them to be significantly effective in their capacity for raising conceptual knowledge, developing scientific investigation skills, and inspiring enhanced plant ecological appreciation (Bacon, 2024; Corbacho-Cuello et al., 2024; Hartanti et al., 2024). However, the specific metrics for evaluating the effectiveness of these tools—such as learning outcomes or engagement levels—should be explored in more detail in future research.

The findings underscore the need for systemic integration of these technologies into science education and emphasize the importance of supporting teacher training programs (Iwan et al., 2023; Widiyatmoko et al., 2023). As the tools become more powerful and accessible, they present tremendous opportunities to rethink botanical education and produce more plant-literate generations that can address critical environmental challenges (Ciloglu & Ustun, 2023; Dimon et al., 2019; Emere et al., 2025).

CONCLUSION

This review integrates Scopus AI's research on botanical literacy and learning media, uncovering several key insights: (1) Traditional textbooks continue to be limited in fostering deep botanical understanding, while emerging media such as garden-based instruction, augmented reality (AR) platforms, and educational games show promise in enhancing engagement and comprehension; (2) The concept map highlights an evolving research landscape focused on evaluating measurement methodologies, pedagogical tools, and teacher training, with novel technologies emerging to bridge gaps in hands-on education and address Plant Awareness Disparity (PAD); and (3) Immersive applications, such as virtual field trips and AI-

powered software, are increasingly explored as effective tools, offering innovative methods to build scientific competence and ecological awareness. The analysis indicates a shift towards incorporating technology-enhanced, student-centered pedagogies, including interactive media, place-based learning, and inquiry-driven instruction, which are beginning to redefine botanical education. While these trends are promising, further research is needed to evaluate their long-term impact and integration into broader educational systems.

RECOMMENDATION

Subsequent research should be guided by interdisciplinary approaches that combine new technologies with effective learning paradigms. Four key research directions are proposed: (1) Longitudinal studies comparing the retention of botanical literacy using experiential media such as AR/VR versus traditional methods, focusing on long-term engagement and cognitive benefits; (2) AI-driven customization of learning media tailored to individual learners' needs, including adaptive games designed for differently-abled students, ensuring accessibility and personalized learning experiences; (3) Teacher training models that integrate technological and pedagogical expertise, empowering educators to effectively implement these tools in diverse classroom settings; and (4) Cross-cultural studies to compare the impact of localized, technology-enabled botanical education on environmental literacy across different global contexts, addressing cultural and regional educational challenges.

Additionally, research could investigate the use of AI in creating personalized plant-learning experiences, such as adaptive virtual plant identification tools and online plant communities. These technologies have the potential to bridge the Plant Awareness Disparity (PAD) gap by providing tailored learning opportunities. Such studies should aim to evaluate the scalability and practical implementation of these tools in real-world educational settings, ensuring that innovations are evidence-based and feasible for widespread adoption.

Author Contributions

Each author has read and approved the published version of the manuscript, has contributed sufficiently to the study, and agrees with the findings and conclusions.

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Conflict of interests

The authors declare no conflict of interest.

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