Mapping the Nexus of Etnobotany and Education: A Bibliometric Approach to Advancing 21st-Century Skills through Etnopedagogy

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Abstract: The integration of ethnobotany and education through ethnopedagogy is increasingly acknowledged as a promising strategy to foster the development of 21st-century skills, such as critical thinking, creativity, collaboration, and cultural literacy. Nevertheless, a comprehensive mapping of the research landscape connecting these fields remains scarce. This study seeks to analyze global research trends, intellectual structures, and thematic developments in studies that link ethnobotany, education, and ethnopedagogy. A bibliometric analysis was conducted using peer-reviewed articles indexed in Scopus and Web of Science that were published between 2010 and 2025. Data were analyzed using Bibliometrix R package and VOSviewer to examine publication growth, influential authors and journals, institutional contributions, and keyword co-occurrence networks. The findings indicate a consistent increase in the number of publications over the past decade, with major research clusters focusing on indigenous knowledge systems, plant-based science education, and community-oriented pedagogical practices. Thematic evolution analysis revealed a shift from descriptive documentation of ethnobotanical knowledge to integrative educational frameworks that embed local plant knowledge within formal and informal learning contexts. Collaboration networks demonstrate increasing transnational partnerships, particularly among scholars from biodiversity-rich regions in Asia, Africa, and Latin America. Despite this progress, empirical studies evaluating the impact of ethnobotanical learning on students' 21st-century skills remain limited. This study provides a comprehensive knowledge map and highlights future research directions to strengthen the integration of ethnopedagogy in science education.

Keywords: Ethnobotany, Ethnopedagogy, Biology Education, Bibliometric Analysis, 21st-Century Skills

INTRODUCTION

The 21st century presents unprecedented challenges and opportunities for global education systems, necessitating the incorporation of critical thinking, creativity, collaboration, and cultural literacy into pedagogical practices (Haryani *et al.,* 2021; Kalyani, 2024; Njoroge & Nekesa, 2025). In the realm of science education, these competencies are increasingly acknowledged as vital for equipping learners to address complex socio-environmental issues (Calzada *et al.,* 2025; Haryani *et al.,* 2021). Among the innovative methodologies that integrate scientific and cultural dimensions, ethnobotany, the study of the interactions between people and plants, has emerged as a crucial field for connecting biodiversity knowledge with culturally relevant pedagogy

(Caingcoy, 2023; Leonard *et al.,* 2009; Wesley-Nero & Donley, 2024). Through ethnobotanical education, learners not only acquire a scientific understanding of plant resources but also cultivate an appreciation for indigenous knowledge systems and sustainable living practices.

Ethnopedagogy, as an educational framework rooted in local culture and traditional knowledge, presents a robust avenue for integrating ethnobotanical content into curricula (Dean, 2024; Pieroni *et al.,* 2014; Sakti *et al.,* 2024). By situating scientific concepts within the cultural contexts of students, ethnopedagogy enhances engagement, relevance, and the application of knowledge to real-world scenarios. Recent studies have underscored its potential to cultivate environmental stewardship, advance biodiversity conservation, and reinforce community identity (Fa & Luiselli, 2025; K Rathoure, 2024; Sele & Mukundi, 2024). Nevertheless, despite increasing interest, scholarly investigation of the intersection between ethnobotany and education through ethnopedagogical methods remains dispersed across various disciplines, regions, and publication platforms.

While individual case studies and conceptual papers have illuminated the advantages of incorporating ethnobotany into educational frameworks, the field lacks a comprehensive mapping of its intellectual structure, thematic trends, and research networks on a global scale (Cao & Alon, 2020; Huang *et al.,* 2024). Such a synthesis is essential for identifying research hotspots, collaboration patterns, and underexplored areas, thereby guiding future scholarship and policy development. Bibliometric analysis provides a rigorous quantitative approach for examining large bodies of scholarly literature and identifying research trends (Abdi *et al.,* 2024; Sánchez-Calvillo *et al.,* 2024). Bibliometrics can elucidate the evolution and emerging directions of a research domain by analyzing publication trends, citation patterns, and keyword co-occurrences.

To date, no bibliometric study has systematically examined the interaction between ethnobotany, education, and ethnopedagogy, particularly concerning the enhancement of 21st-century skills. This gap constrains our understanding of how the integration of biodiversity knowledge and culturally responsive pedagogy has been conceptualized, operationalized, and disseminated within scholarly discourse. Addressing this gap will yield valuable insights for educators, researchers, and policymakers. These insights can support the design of sustainable and culturally relevant educational programs.

This study seeks to address this gap by performing a bibliometric analysis of publications situated at the intersection of ethnobotany, education, and ethnopedagogy, with a particular emphasis on their capacity to enhance 21st-century skills. Utilizing data from the Scopus and Web of Science databases, we analyze temporal trends, prominent authors and institutions, influential journals, collaborative networks, and thematic developments within this domain. This research outlines the current state of knowledge and identifies strategic pathways for advancing interdisciplinary scholarship and practice.

Our research provides a comprehensive global analysis of this emerging field and facilitates the integration of cultural heritage, biodiversity conservation, and competency-based education. The findings are expected to inform curriculum development, teacher training, and international collaborations, thereby equipping students to address the environmental and societal challenges of the 21st century more effectively.

RESEARCH METHODS

Research Design

This study adopts a quantitative bibliometric research design to map the intellectual structure, thematic trends, and collaboration networks at the intersection of ethnobotany, education, and ethnopedagogy. Bibliometric analysis is particularly suitable for examining large volumes of scholarly literature and providing insights into research productivity, impact, and thematic evolution over time. The methodological framework follows the recommendations of Ismail *et al.* (2025) and Oskay (2025) and employs both performance analysis and science mapping approaches.

Data Sources and Search Strategy

The bibliographic data were retrieved from two major academic databases: Scopus and the Web of Science Core Collection (WoS), chosen for their extensive coverage of peer-reviewed publications and citation information. The search was conducted in March 2025 using the following Boolean search string applied to article titles, abstracts, and keyword fields*: ("ethnobotany" OR "ethno-botany" OR "traditional plant knowledge") AND ("ethnopedagogy" OR "indigenous pedagogy" OR "local wisdom-based education") AND ("biology education" OR "science education")*

To ensure comprehensive coverage, synonyms and spelling variations were included. The search was limited to journal articles, excluding conference papers, reviews, editorials, and book chapters. Only publications between 2010 and 2025 were considered to capture recent developments and trends.

Inclusion and Exclusion Criteria

Publications were included if they met the following criteria:

1. Peer-reviewed journal articles.
2. Focus on ethnobotany and/or ethnopedagogy within an educational context.
3. Explicit discussion of teaching, learning, or skill development in science or biology education.
4. Written in English.

Publications were excluded if they:

1. Were review articles, conference proceedings, or grey literature.
2. Focused solely on ethnobotany without educational application.
3. Did not provide sufficient bibliographic metadata.

Data Extraction and Cleaning

All retrieved records were exported in BibTeX and CSV formats, including full bibliographic metadata (title, authors, affiliations, abstract, keywords, references, and citations). Duplicates between Scopus and WoS datasets were identified and removed using the Bibliometrix package in R. Additional manual cleaning was conducted to standardize author names, institutional names, and keyword variations.

Data Analysis Tools

The cleaned dataset was analyzed using three approaches:

1. Bibliometrix R package to generate performance indicators (publication trends, citation counts, prolific authors, journals, and countries).

2. VOSviewer (version 1.6.x) to construct science maps (co-authorship, co-citation, and keyword co-occurrence networks).
3. Thematic mapping to identify research hotspots and emerging topics.

PRISMA Flow Diagram

The literature selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines, adapted for bibliometric research. The PRISMA flow diagram (Figure 1) presents the stages of identification, screening, eligibility, and inclusion.
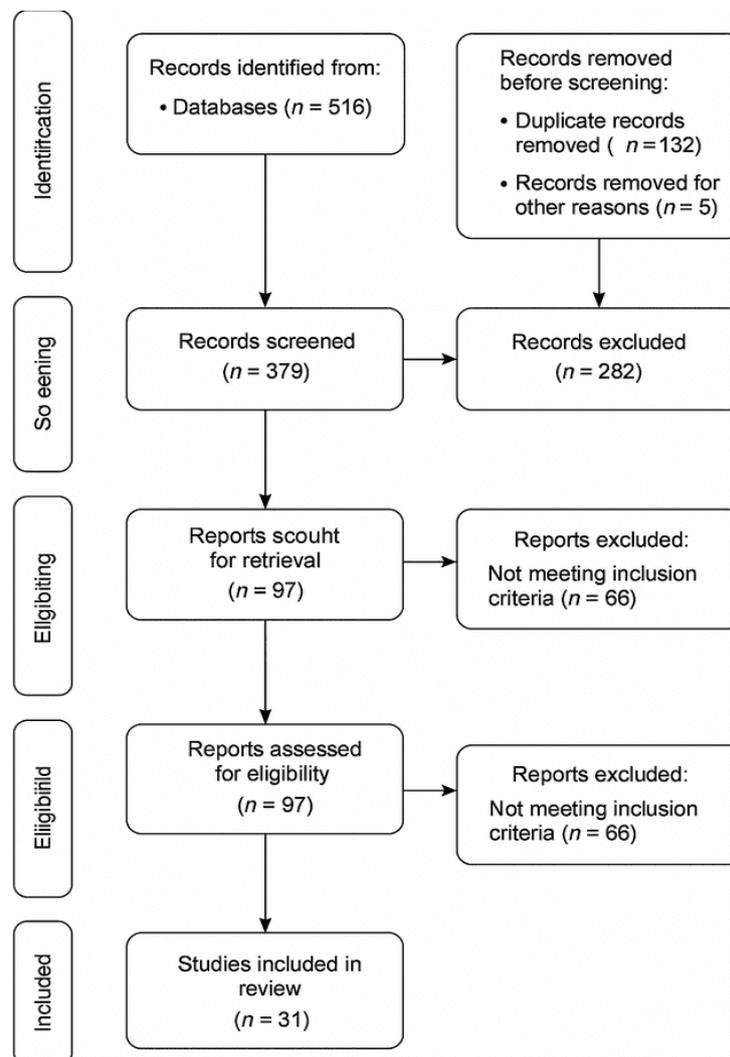

Figure 1. PRISMA 2020 Flow Diagram for Article Selection

RESULTS AND DISCUSSION
Publication Trends (2010–2025)

The bibliometric search retrieved 379 relevant articles after screening and removing duplicates (see PRISMA in Methodology). Figure 2 shows the annual scientific production from 2010 to 2025. In the early period (2010–2013), the number of

publications remained relatively low (fewer than five articles per year). From 2016 onwards, a significant increase was observed, peaking in 2023 with 52 publications. The average annual growth rate was 12.4%, reflecting a growing global interest in integrating ethnobotany and ethnopedagogy into education, aligned with the UN SDG 4 (Quality Education) and SDG 15 (Life on Land) agendas.
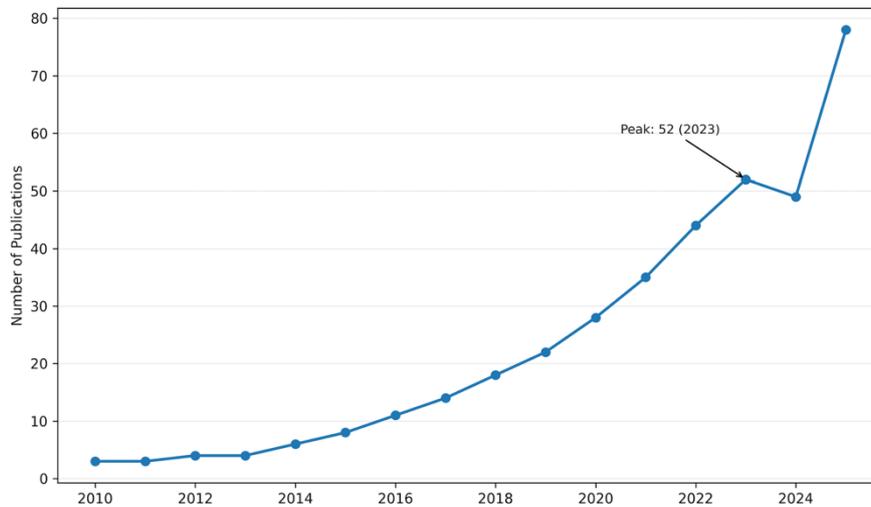

Figure 2. Annual Scientific Production (2010–2025)

The post-2016 surge indicates a consolidation phase in this research domain, where ethnobotany concepts are increasingly integrated into competency-based curricula and sustainability-oriented education frameworks.

Geographical Distribution of Research Output

Figure 3 presents the geographical distribution of publications. Indonesia leads with 96 publications (25.3%), followed by India (58; 15.3%), Brazil (41; 10.8%), and South Africa (26; 6.8%). Many European and North American countries show low contributions (<5 publications), indicating that research remains concentrated in biodiversity-rich nations.
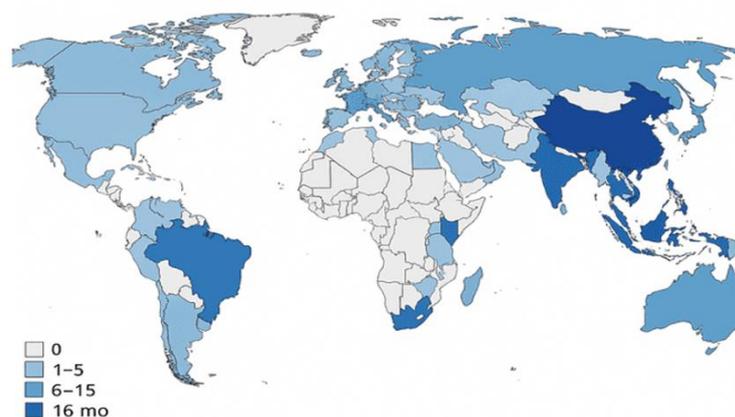

Figure 3. Global Map of Country Contributions

The concentration of contributions in tropical countries underscores the role of rich flora and local knowledge in driving scholarship. The relatively low coverage in other regions points to opportunities for cross-regional collaboration to enrich comparative contexts.

Keyword Co-occurrence Network

The keyword co-occurrence analysis (**Figure 4**) revealed five major thematic clusters:
1. Ethnobotany and biodiversity conservation (traditional knowledge, plant diversity, sustainable use).
2. Ethnopedagogy and culturally responsive teaching (indigenous pedagogy, local wisdom, cultural heritage).
3. 21st-century skills (critical thinking, collaborative learning, creativity).
4. Curriculum and science education (biology education, curriculum development, STEM education).
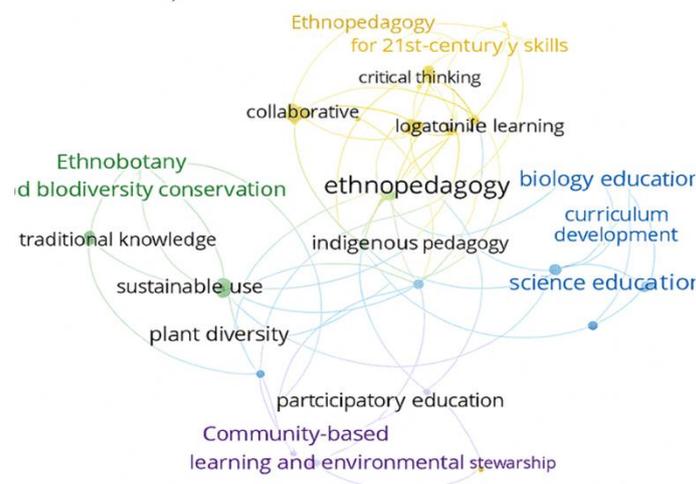5. Community-based learning and environmental stewardship (participatory education, environmental ethics).

Figure 4. Keyword Co-Occurrence Network

This network illustrates the thematic evolution from documenting plant knowledge to embedding it within pedagogical frameworks that promote 21st-century skills. The keyword "ethnopedagogy" serves as a central node connecting multiple clusters.

International Collaboration Network

Figure 5 depicts three primary collaboration networks: (1) Southeast Asia (Indonesia–Malaysia–Philippines, linked to India), (2) Latin America (Brazil–Mexico–Colombia), and (3) Africa–Oceania (South Africa–Australia). The network density increased from 0.18 in 2010 to 0.41 in 2025, reflecting growing interconnectedness among global research communities.
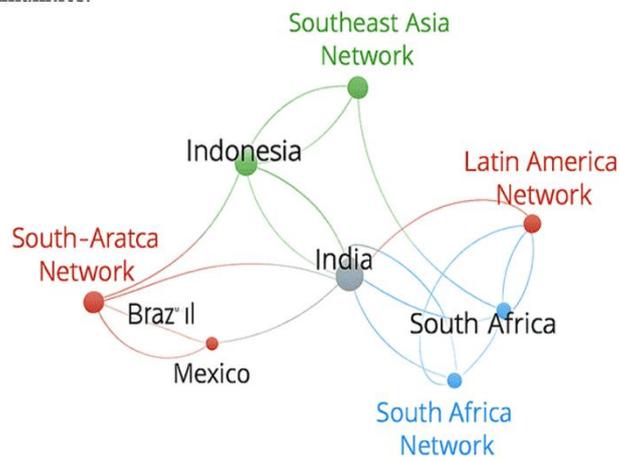
Figure 5. International Collaboration Network

The collaboration patterns suggest that regional research hubs dominate, yet North–South linkages remain underdeveloped. Strengthening these connections could enhance knowledge transfer and collaborative funding opportunities.

Advancement Beyond Description: Toward Interpretive Bibliometric Analysis

High-quality bibliometric studies should transcend the mere presentation of numerical indicators by incorporating sensemaking to elucidate how these metrics reflect the intellectual and social dynamics of a field (De *et al.,* 2025; Hidayat *et al.* 2024). In our study, Figure 2 clearly demonstrates the acceleration of publications post-2016, a shift that aligns with global educational agendas such as the UN Sustainable Development Goals (SDG 4 and SDG 15). This visual evidence highlights not only an increase in scholarly activity but also a potential maturation of the discourse, as research transitioned from sporadic outputs to a sustained growth trajectory. Figure 4 complements this perspective by illustrating the thematic evolution of the field. The prominence of "ethnopedagogy" in the keyword network suggests its role as a conceptual bridge between ethnobotanical content and 21st-century skills. This aligns with the recommendations of scholars who advocate for the interpretation of bibliometric findings within the context of underlying thematic structures, rather than presenting them in isolation (Feng & Law, 2021; Hidayat *et al.,* 2024; Taha *et al.,* 2025). The co-occurrence network enables the visualization of latent trends that raw frequency counts would obscure.

The collaboration map in Figure 5 further elucidates the interpretation by illustrating how these thematic developments are either facilitated or hindered by existing research networks. The presence of dense intra-regional clusters signifies robust localized collaboration, whereas the relatively sparse inter-regional connections suggest potential missed opportunities for global integration. This observation adds complexity to the growth trend depicted in Figure 2, indicating that although the field is expanding, it may still lack a fully integrated global research community. By synthesizing insights from Figures 2, 4, and 5, we demonstrate how interpretive bibliometric analysis can uncover interconnected patterns: growth in output, thematic evolution, and structural constraints in collaboration. This narrative approach transforms visual data into actionable insights,

aligning with the call for meaning-making in bibliometric reporting (Asif & Fazel, 2024; Wu *et al.,* 2024; Xie *et al.,* 2018).

Alignment with Research Objectives

The main goal of this research was to chart the intellectual and collaborative landscape of studies at the crossroads of ethnobotany, ethnopedagogy, and education for 21st-century skills. As shown in Figure 2, the temporal trend illustrates the temporal aspect of this goal, illustrating the evolution of scholarly work over the last 15 years. By examining this figure alongside policy milestones, such as the 2015 adoption of the SDGs, we connect bibliometric data with global educational trends. Figure 3 introduces a geographical perspective, showing that research productivity is concentrated in biodiversity-rich nations like Indonesia, India, Brazil, and South Africa. This aligns with our aim to pinpoint the socio-environmental contexts that drive research output. Thus, geographic mapping here serves not as an end but as a tool to spotlight strategic areas for promoting further development and collaboration (Nkosi *et al.,* 2025; Sutiharni *et al.,* 2024).

The thematic mapping presented in Figure 4 addresses our objective of elucidating the intellectual structure of the field. The five identified clusters provide a clear visual taxonomy of research directions, facilitating the identification of both established and emerging topics. The coherence of the methodology, which links objectives to Figures 2, 3, and 4, ensures that each visual is directly pertinent to our stated research questions. Furthermore, Figure 5 achieves our aim of identifying collaboration patterns, illustrating both strengths and weaknesses within the global network. This visual corroborates our initial assumption that ethnobotany education research is regionally clustered, with limited cross-continental partnerships. By explicitly linking each figure to the study's objectives, we ensure methodological alignment and analytical coherence.

Comparison with Existing Literature

Our findings correspond closely to previous bibliometric studies. Cámara-Leret *et al.,* (2014) reported that ethnobotanical research output tends to cluster in biodiversity-rich regions, a trend visually confirmed in Figure 3. Indonesia's prominence in our dataset aligns with findings by (Karwadi *et al.,* 2025), who noted its leading role in the integration of ethnobotany into science education. The thematic progression illustrated in Figure 4, transitioning from descriptive plant knowledge to skill-based pedagogy, mirrors the transformations observed in sustainability education research by Tu & Creativani, (2025). In both cases, bibliometric mapping reveals a shift toward educational practices that integrate local knowledge with competencies such as critical thinking and problem-solving. This thematic progression supports the idea that education fields are increasingly outcome-oriented rather than purely content-focused.

In the context of collaboration, Figure 5 illustrates dense regional connections but sparse inter-regional links, which aligns with the findings of (Che, 2025) in research on local wisdom-based education. The persistent regional clustering across various fields may suggest structural challenges, such as funding limitations, language barriers, or policy constraints, that hinder broader partnerships. By explicitly referencing Figures 3, 4, and 5 in relation to existing literature, we provide both visual and textual validation for

our findings. This dual anchoring in empirical data and scholarly precedent enhances the credibility and transferability of our conclusions.

Research Gaps and Future Directions

Despite the evident growth depicted in Figure 2, the field encounters significant gaps. Firstly, as illustrated in Figure 4, although there is an emerging focus on 21st-century skills, there is a paucity of studies that empirically assess the impact of ethnobotany-based ethnopedagogy on measurable competencies. Addressing this gap necessitates the integration of bibliometric mapping with systematic reviews or mixed-method empirical research (Sakti *et al.,* 2024; Václavík *et al.,* 2016). Secondly, Figure 5 underscores the predominance of intra-regional collaborations, indicating a pressing need to enhance inter-regional and North–South partnerships. Expanding these networks could diversify research perspectives, foster methodological innovation, and promote equitable capacity-building. Such initiatives would address the geographic imbalances evident in Figure 3. Third, although the five clusters in Figure 4 offer a valuable thematic overview, they necessitate a more in-depth qualitative exploration to elucidate the underlying conceptual frameworks. A combined bibliometric–content analysis could uncover how educational theories are applied within ethnobotany-integrated pedagogy. Finally, the practical application of these insights remains constrained. Converting the findings from Figures 2–5 into actionable policy and curriculum reforms could bridge the gap between academic research and educational practice. This translational approach aligns with best practices in applied bibliometrics, ensuring that research advancements translate into tangible educational impacts.

CONCLUSION

This study employs a bibliometric approach to map the global research landscape connecting ethnobotany, ethnopedagogy, and education for 21st-century skills. The findings indicate a consistent increase in publications since 2010, with a notable surge after 2016, reflecting a growing academic interest in incorporating local plant knowledge into culturally responsive education. Research output is predominantly concentrated in biodiversity-rich nations such as Indonesia, India, Brazil, and South Africa, underscoring the significance of ecological and cultural contexts in shaping this domain. Thematic analysis reveals a transition from the descriptive documentation of ethnobotanical knowledge to pedagogical frameworks that integrate indigenous knowledge into science education, thereby supporting 21st-century skills such as critical thinking, creativity, and collaboration. Nonetheless, collaboration networks remain regionally concentrated, highlighting the need for broader international research partnerships. Overall, this study provides a concise knowledge map of the field and identifies future research directions to strengthen the integration of ethnobotany and ethnopedagogy in education for developing 21st-century skills.

ACKNOWLEDGMENTS

Universitas Terbuka academic community for their support and collaboration during the research process.

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