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REVIEW

Environmental Education as a Strategy for Ecosystem Conservation: A Bibliometric Analysis of Global Trends

Educación Ambiental como Estrategia para la Conservación de Ecosistemas: Un Análisis Bibliométrico de Tendencias Globales

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ABSTRACT

Environmental education has emerged as a fundamental tool to promote ecosystem conservation in the face of crises such as climate change and biodiversity loss. This study analyzes recent scientific production on environmental education as a conservation strategy through a bibliometric analysis of articles in Spanish and English in Scopus (2020-2024). VOSviewer was used to examine annual productivity, thematic networks, and keyword co-occurrence. Three dominant thematic axes were identified: pedagogical approaches, community participation, and emerging technologies. It is concluded that environmental education has evolved towards more inclusive and technologically supported models, although challenges persist in scaling up and evaluating long-term impact. This analysis provides a roadmap for future research and policies that link education, technology, and collective action in ecosystem protection.

Keywords: Environmental Education; Ecosystem Conservation; Sustainability; Community Participation; Educational Technologies.

RESUMEN

La educación ambiental se ha consolidado como una herramienta fundamental para promover la conservación de ecosistemas frente a crisis como el cambio climático y la pérdida de biodiversidad. Este estudio analiza la producción científica reciente sobre educación ambiental como estrategia de conservación, mediante una bibliometría de artículos en Scopus (2020-2024) en español e inglés. Se empleó VOSviewer para examinar productividad anual, redes temáticas y co-ocurrencia de palabras clave. Se identificaron tres ejes temáticos dominantes: enfoques pedagógicos, participación comunitaria y tecnologías emergentes. Se concluye que la educación ambiental ha evolucionado hacia modelos más inclusivos y tecnológicamente apoyados, aunque persisten desafíos en su escalamiento y evaluación de impacto a largo plazo. Este análisis proporciona una hoja de ruta para futuras investigaciones y políticas que vinculen educación, tecnología y acción colectiva en la protección de ecosistemas.

Palabras clave: Educación Ambiental; Conservación de Ecosistemas; Sostenibilidad; Participación Comunitaria; Tecnologías Educativas.

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INTRODUCTION

Environmental education (EE) has emerged as an essential transdisciplinary field to face ecological challenges, from biodiversity loss to climate change.[1,2] EE has evolved from naturalistic approaches to critical perspectives, integrating social, political, and cultural dimensions.[3,4] Its role transcends the mere transmission of ecological knowledge, positioning itself as a strategy to foster values, skills, and collective actions oriented towards sustainability. In a context of global environmental crisis, AE is revealed not as an option, but as an educational and civilizational urgency.[5,6]

As complex webs of life, ecosystems require conservation strategies that go beyond traditional approaches based on protected areas or punitive regulations.[7] Here, EA bridges ecological science and social action by facilitating the understanding of human-nature interdependencies.[8,9] Well-designed educational programs have proven effective in changing behaviors, such as reducing plastic consumption or promoting habitat restoration. However, its real potential lies in its ability to transform worldviews by cultivating a biocentric ethic that recognizes the intrinsic value of ecosystems beyond their human utility.[10,11]

Globally, AE manifests itself at multiple scales, from school systems that integrate sustainability into their curricula to community initiatives that rescue traditional knowledge. These approaches are particularly relevant in megadiverse regions, where indigenous and rural communities combine ancestral knowledge with modern tools for territorial management.[12,13] Significant challenges remain, however.

Nevertheless, significant challenges remain. EA often faces marginalization in educational policies, reduced to sporadic activities without continuity.[14,15] Furthermore, there is a gap between theoretical advances and their practical implementation, especially in contexts of inequality where access to educational resources is limited.[16] Ruiz-Mallén[17] and Shui[18] point out that the most successful programs are those that adopt situated approaches, by considering the specific cultural and ecological realities of each territory, instead of standardized models.

Analyzing scientific production on EA and ecosystem conservation is crucial in this scenario to identify trends, gaps, and opportunities. This article is justified by the need to synthesize the knowledge generated in recent years, marked by the acceleration of ecological crises and innovation in educational strategies. This study aims to analyze, through a bibliometric approach, the global academic production (2020-2024) on environmental education as a strategy for ecosystem conservation**.**

METHOD

This study employed a bibliometric approach to systematically analyze the scientific production on environmental education as a strategy for ecosystem conservation. The Scopus database was selected for its broad coverage of scientific literature in ecological sciences, education, and interdisciplinary studies, with special emphasis on high-impact publications. Data processing was carried out using VOSviewer software, a tool specialized in network analysis and visualization of conceptual relationships in the academic literature.[19,20]

Phase 1. Definition of search criteria and data collection

The process began with the formulation of a search strategy that integrated three conceptual dimensions: environmental education (“environmental education”), conservation strategies (“ecosystem conservation”), and pedagogical approaches (“environmental pedagogy”, “sustainability education”). The search was limited to 2020-2024 and was executed in the title, abstract, and keyword fields, using Boolean operators to optimize the results. The structured search string was:

(TITLE-ABS-KEY (“environmental education” OR “environmental education”) AND TITLE-ABS-KEY (“conservation” OR “ecosystem conservation”) AND TITLE-ABS-KEY (“sustainability” OR “sustainability education”) AND PUBYEAR > 2019 AND PUBYEAR < 2026) AND (LIMIT-TO (DOCTYPE, “ar”)).

Phase 2. Data extraction and filtering.

The initial results were subjected to a three-stage filtering process. First, non-relevant documents (editorial reviews, conferences) were excluded; only original research articles were retained. Second, a language filter was applied, selecting publications in Spanish and English. Third, a manual review of titles and abstracts was performed to verify thematic relevance, and studies that did not explicitly address the relationship between environmental education and ecosystem conservation were eliminated. This process generated a refined corpus of documents for the analysis.

Phase 3. Bibliometric analysis with VOSviewer

The refined sample was analyzed using VOSviewer software, which allowed us to examine various aspects of scientific production. This analysis included evaluating annual productivity, mapping collaborative country networks, and identifying thematic patterns through keyword co-occurrence analysis. Visualization through bibliometric maps revealed the conceptual structure of the field of study by highlighting the relationships between the different research topics and their temporal evolution.

Phase 4. Interpretation and synthesis of results

A qualitative analysis complemented the quantitative findings to contextualize the identified patterns. The thematic clusters were organized along three principal axes: pedagogical approaches, community participation, and emerging technologies. This integration allowed us to assess gaps between theoretical research and practical applications in different social-ecological contexts.

This methodology provided a robust framework for characterizing the state of the art in environmental education and

conservation research. This offered insights into both dominant trends and neglected areas that require further development in the future.[21,22]

RESULTS

A total of 557 research studies related to environmental education as a strategy for ecosystem conservation were identified. The highest number of publications was produced in the last two years, with 22 % and 28 %, respectively. These findings indicate that the body of research on this topic is growing and that the scientific community is showing increasing interest in studying environmental education and its application in ecosystem conservation (figure 1).

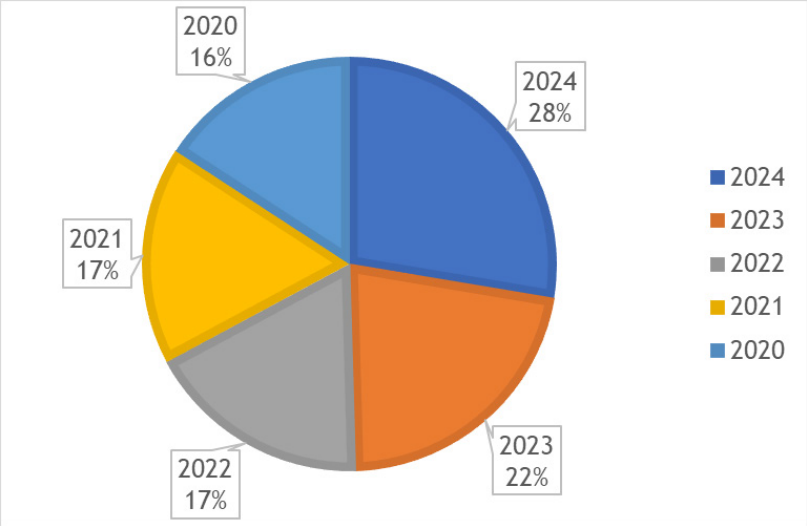

Figure 1. Research distributed by year of publication. Based on VOSviewer data

The analysis of the distribution of countries with the highest academic production on the subject reveals that the United States, China, and Brazil are at the forefront. This indicates that the developed countries in the West and the East are engaged in developing strategies and coping mechanisms for ecosystem conservation, focusing on environmental education (figure 2).

In addition, a co-occurrence analysis of the most critical keywords in the literature was carried out, which revealed a multidimensional panorama with environmental education as a strategy for the conservation of ecosystems as its central axis. As can be seen in figure 3, three predominant thematic axes were identified that show interactions between pedagogical approaches, community participation, and emerging technologies, which constitute the main lines of research in this field.

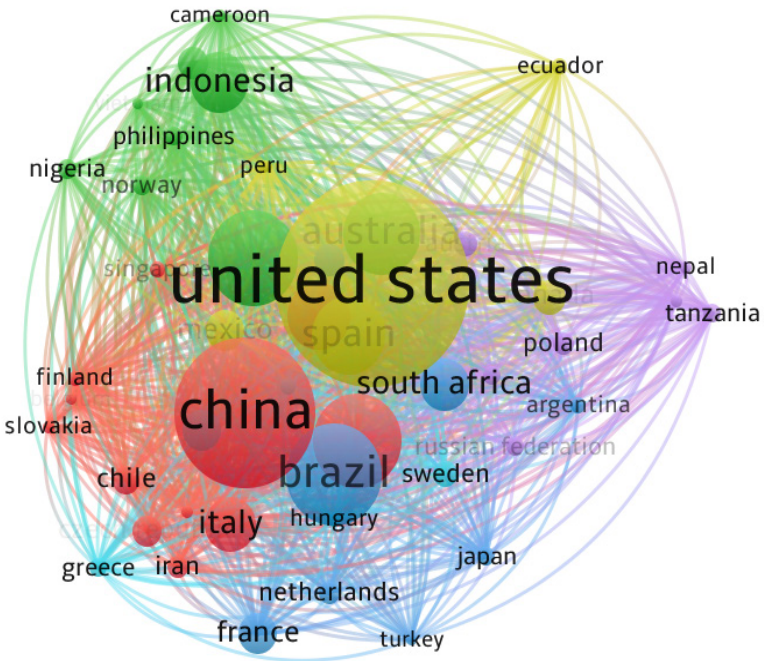

Figure 2. Scientific production network by country. Based on VOSviewer data

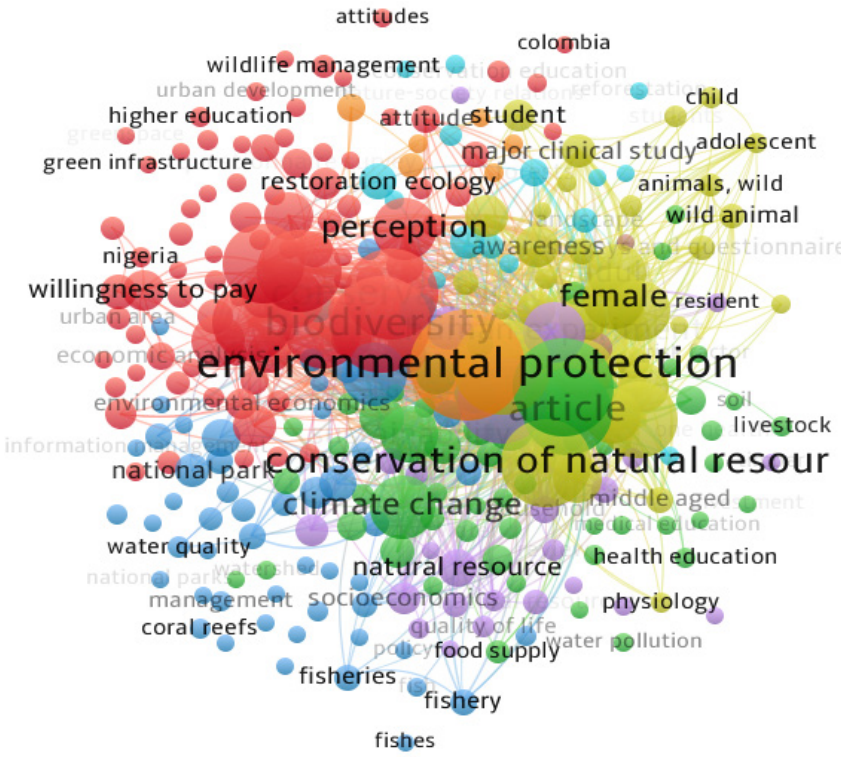

Figure 2. Keyword co-occurrence network. Based on VOSviewer data

Innovative Pedagogical Approaches

Cheung[23] highlights a significant evolution in pedagogical approaches to environmental education, moving from traditional models of knowledge transmission to more critical and participatory proposals. Lladó-Farrulla[24] and Ensmann[25] show a growing interest in active pedagogies such as project-based learning, where students investigate and act on real environmental problems in their communities. This approach is more effective in developing environmental competencies than traditional expository methods, particularly when linked to concrete conservation actions.[26,27]

Hampson[28] and Jalalian[29] emphasize the importance of contextualizing educational content according to each territory's ecological and cultural characteristics. In regions with high biodiversity, such as Latin America, successful experiences have been documented that integrate scientific knowledge with the traditional knowledge of Indigenous communities, generating more relevant and meaningful educational proposals.[30,31] However, challenges persist in teacher training, as many educators lack the pedagogical tools and resources necessary to implement these innovative approaches.

A relevant finding is the growing recognition of the role of emotions in environmental learning. Ricardo Jiménez[32] and Powell[33] suggest that direct experiences in nature and emotional contact with ecosystems are fundamental for developing caring and conservation attitudes. This has prompted the development of programs that combine scientific knowledge with experiential and artistic activities, showing promising results in forming environmental values.[34,35]

Community Participation and Environmental Governance

Environmental education has become a catalyst for citizen participation in conservation processes. This citizen science approach has proven particularly effective in protected areas and areas of high ecological value, where local people become guardians of the territory.[36,37]

Guerrero & Janßen[38] stress the importance of addressing social and gender inequalities in these participatory processes. Ardoin[39] argues that conservation strategies are more comprehensive and equitable by including the perspectives of women, youth, and marginalized groups. However, significant challenges are also identified, such as the lack of continuity in participatory processes and difficulty scaling up local experiences to broader public policy.[40,41]

An innovative aspect is the growing interest in collaborative governance systems, where multiple actors (communities, governments, academia) co-design education and conservation strategies. These models have shown potential for resolving socio-environmental conflicts and generating more legitimate and effective agreements to protect ecosystems.[42,43,44]

Emerging Technologies in Environmental Education

New technologies for environmental education present opportunities and challenges. Virtual and augmented reality are revolutionizing the way of teaching about ecosystems by allowing immersive experiences even in urban contexts or with limited access to natural areas.[45,46] These tools have proven to be especially valuable for teaching about fragile or hard-to-reach ecosystems, such as coral reefs or tropical forests.[47]

Digital platforms and mobile applications have facilitated citizen environmental monitoring by allowing people without

specialized scientific training to contribute to the collection of ecological data.[48,49] However, Monte and Reis[50] also warn about risks such as the digital divide and the possible replacement of real experiences in nature with virtual simulations, which could limit the development of emotional bonds with ecosystems.

A promising finding is using artificial intelligence to personalize environmental learning processes by adapting content and strategies to the specific needs of different groups of students. However, these technologies should complement, not replace, pedagogical approaches based on direct experience and community participation.[51,52]

DISCUSSION

The results of this study show that research on environmental education for ecosystem conservation has evolved towards more holistic approaches, overcoming the traditional vision focused only on the transmission of ecological knowledge. Recent literature demonstrates that the most effective programs combine scientific foundations with innovative pedagogical strategies, active social participation, and adaptation to specific local contexts.[24,28,53] However, a troubling disconnect remains between these conceptual advances and their large-scale implementation, particularly in formal educational systems and environmental public policies.[54] This gap significantly limits the transformative potential of environmental education in the face of the current ecological crisis.

A key finding is recognizing that educational processes must be articulated with governance mechanisms to translate learning into sustainable collective action. Research in various contexts shows that conservation results are more profound and lasting when communities actively participate in the design and implementation of educational programs.[36,39,55] However, many projects lack institutional and financial continuity, remaining isolated experiences without the capacity to generate structural changes.[56] This points to the need to develop legal frameworks and public policies that formally integrate environmental education into decision-making processes on territorial management.

Finally, the study reveals the opportunities and risks of new technologies in this field. While digital tools and technological innovations can expand the reach and effectiveness of educational programs, their implementation must be balanced with direct experiences in nature and participatory community processes.[49,51,57] The future challenge is to develop hybrid models that combine the best of both approaches, always keeping the development of an ethical, emotional, and practical relationship between people and their ecosystems as a central objective**.**

CONCLUSIONS

This study shows that environmental education is a fundamental strategy for ecosystem conservation, provided that it transcends merely informative approaches and is articulated with transformative pedagogical processes, effective community participation, and coherent public policies. The results highlight the need to go beyond isolated interventions to develop comprehensive programs that link learning with collective action, adapting to the specific socio-ecological contexts of each territory. Future research should evaluate the long-term impact of different educational strategies on effective ecosystem conservation, develop scalable models that integrate formal and non-formal education, and design institutional frameworks that guarantee the continuity of educational processes beyond specific projects. Only through this systemic approach can environmental education fulfill its potential as a transformative tool for sustainability

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