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Ecoliteracy and environmental citizenship: a systematic review of the literature in basic and secondary education

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Abstract

The planet faces increasingly complex environmental challenges, creating an urgent need to educate citizens who are aware of their relationship with the environment. In this context, ecoliteracy emerges as a transformative educational approach that promotes understanding of ecosystems and their interactions. This study presents a systematic literature review with the objectives of: (1) identifying and categorizing educational strategies used to develop ecoliteracy in primary and secondary students; (2) analyzing pedagogical approaches in ecological education aimed at sustainable development; and (3) examining the influence of cultural contexts on environmental competencies. Using the PRISMA methodology, 199 scientific articles published between 2014 and 2024 in the Scopus and Web of Science databases were analyzed. The results show that most studies were conducted in the United States, highlighting interdisciplinary strategies and the use of emerging technologies to foster ecological awareness. In addition, the findings emphasize the importance of adapting ecoliteracy to cultural diversity and the need for more rigorous evaluation. Thus, this study contributes to the field as it provides an updated systematization of practices and proposes inclusive and contextualized educational models. The findings have implications for curriculum design, teacher training, and public policy. It is suggested to advance toward intercultural approaches adapted to the socio-territorial realities of Latin America

Ecoalfabetización y ciudadanía ambiental: una revisión sistemática de la literatura en la educación básica y secundaria

Resumen

El planeta enfrenta problemáticas ambientales cada vez más complejas, lo que genera una necesidad urgente de formar ciudadanos conscientes de su relación con el entorno. En este contexto, la ecoalfabetización surge como un enfoque educativo transformador que promueve la comprensión de los ecosistemas y sus interacciones. Se presenta una revisión sistemática de literatura con los objetivos de: (1) identificar y categorizar estrategias educativas utilizadas para desarrollar la ecoalfabetización en estudiantes de primaria y secundaria; (2) analizar enfoques pedagógicos de educación ecológica orientados al desarrollo sostenible; y (3) examinar la influencia de contextos culturales en las competencias ambientales. Utilizando la metodología PRISMA, se analizaron 199 artículos científicos publicados entre 2014 y 2024 en las bases de datos Scopus y Web of Science. Los resultados muestran que la mayoría de los estudios se realizaron en Estados Unidos, destacando estrategias interdisciplinarias y el uso de tecnologías emergentes para fomentar la conciencia ecológica. Además, resaltan la importancia de adaptar la ecoalfabetización a la diversidad cultural y la necesidad de una evaluación más rigurosa. Así, este estudio contribuye al campo al ofrecer una sistematización actualizada de prácticas y al proponer modelos educativos inclusivos y contextuales. Los hallazgos tienen implicaciones para el diseño curricular, la formación docente y las políticas públicas. Se sugiere avanzar hacia enfoques interculturales adaptados a las realidades socio-territoriales de América Latina.

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1. Introducción

Currently, planet Earth is facing major and diverse environmental issues, such as air, water, and soil pollution, erosion, hazardous waste, global warming, biodiversity loss, deforestation, climate change, and resource depletion, all of which have accelerated environmental degradation (Kabir et al., 2023; Kuşkaya, Aldieri, Sharma and Balsalobre-Lorente, 2022; Ni, 2022; Sadulaeva, 2023; Timmis and Verstraete, 2022).

This crisis essentially originates from ecological illiteracy due to a deficient environmental education, reflected in the lack of knowledge about the complexity and the interactions between the natural and human systems that make up the planet (Tarté, 2012). Therefore, given the increasing difficulty in understanding the relationship between ecosystems, life, and the Earth's balance, it becomes urgent to position ecoliteracy as a viable and effective path or strategy to educate under the notion of sustainability and respect for the environment. It must be taken into account that the understanding humans have of ecology is fundamental to achieving sustainability, and that comprehension of nature is only possible through respect, cooperation, and dialogue, rather than through domination (Capra, 2006).

In contemporary studies, ecoliteracy is regarded as a transcendental path in environmental education, given its potential to foster processes of understanding in human beings about the need to care for and protect the environment (Sharma, 2023). It is presented as a holistic approach, rooted in ecosystemic knowledge and the principles of ecological organization, which drives sustainable development. Its aim is to empower and transform individuals, fostering a society that recognizes humanity's dependence on nature (Sharma, 2023; da Silva Antunes de Souza, Ferrer and Stein, 2020), considering it as a system of complex connections where human beings inhabit (Orr, 1992).

Thus, ecoliteracy leads to an understanding of human connections with environmental processes, fostering awareness and developing the capacity to solve environmental problems (Jordan, Singer, Vaughan and Berkowitz, 2009; Rosyid, Budiaman and Hasanah, 2019). It therefore encompasses five components related to ecology: knowledge, awareness, ethics, behavior, and emotions (Ha and Dong, 2023). Hence, a robust and effective ecoliteracy requires the pedagogical integration of these elements, promoting experiential, critical, and participatory learning that empowers individuals to become agents of change toward a more just and sustainable future.

Ecoliteracy emerges as a pedagogical possibility that can help social actors of all ages gain a deeper understanding of the composition and function of ecosystems; and perhaps, from that awareness, envision and implement actions aimed at environmental care and the strengthening of ecological consciousness. Ultimately, it is a process that may prove to be highly relevant in the educational sphere. However, it must begin with a critical reflection on how ecoliteracy is being approached, and from that analysis, forge pathways that foster greater awareness, sensitivity, and empathy toward environmental stewardship (Ramírez-Gómez, Pascuas-Rengifo and Mora-Penagos, 2023).

From diverse theoretical and methodological perspectives, numerous publications have integrated research findings related to ecoliteracy. Within this framework, studies have examined the implementation of this approach in prospective biology teachers (Bilianska and Yaroshenko, 2020), the readiness of the educational system to foster ecoliterate individuals (da Silva Antunes de Souza, Ferrer and Stein, 2020), ecolinguistic studies (Ha, 2023), its articulation with digital media in early childhood (Ninsiana, Septiyana and Suprihatin, 2024) and innovations in ecoliteracy, such as the TECO application developed by Pascuas-Rengifo, Perea-Yara and García-Quigora (2020) who designed a gamified didactic-technological mediation aimed to transform the relationship with electronic waste in the Colombian Amazon.

Based on the foregoing, it is necessary to point out that this study aimed to analyze the educational strategies, pedagogical approaches, and the influence of the cultural context on ecoliteracy, as reflected in the scientific literature of the last decade. Achieving this objective it becomes possible, through the

findings and results, to establish certain foundations that may contribute to the inclusion of ecoliteracy as an effective strategy for environmental education and sustainability.

2. Method

This systematic literature review consisted of searching for existing scientific evidence from the last decade on the several ways and approaches in which ecoliteracy has been addressed. To this end, the Preferred Reporting Items for Systematic Reviews (PRISMA) method was implemented, which is recognized for its high academic credibility, has been the subject of numerous contemporary studies, and allows for adaptation to the development of reviews in the educational context (Sánchez-Serrano, Pedraza-Navarro and Donoso-González, 2022). The following figure presents the different stages carried out in this research (see Figure 1).
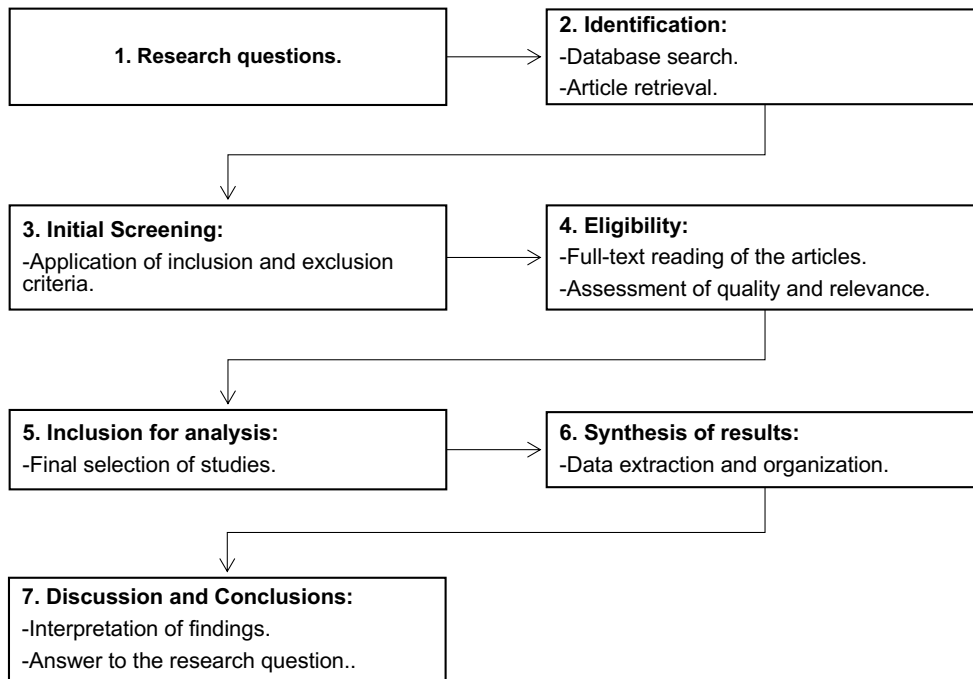
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┌─────────────────────────────┐      ┌─────────────────────────────┐
│                             │      │ 2. Identification:          │
│  1. Research questions.     │ ───> │ -Database search.           │
│                             │      │ -Article retrieval.         │
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│ 3. Initial Screening:       │      │ 4. Eligibility:             │
│ -Application of inclusion    │ ───> │ -Full-text reading of the   │
│  and exclusion criteria.    │      │  articles.                  │
│                             │      │ -Assessment of quality and  │
│                             │      │  relevance.                 │
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│ 5. Inclusion for analysis:  │      │ 6. Synthesis of results:    │
│ -Final selection of studies. │ ───> │ -Data extraction and        │
│                             │      │  organization.              │
└─────────────────────────────┘      └─────────────────────────────┘

┌─────────────────────────────┐
│ 7. Discussion and           │
│    Conclusions:             │
│ -Interpretation of findings. │
│ -Answer to the research      │
│  question..                 │
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Figure 1. Stages of the Review Process.
Note: own elaboration based on Page et al. (2021) and Sánchez-Serrano et al. (2022).

The process began with the following guiding questions: (RQ1) What scientific evidence on ecoliteracy exists in recent academic literature? (RQ2) With which terms has ecoliteracy been associated in scientific production, and what thematic patterns emerge from these relationships? (RQ3) What educational strategies have been implemented to promote ecoliteracy in primary and secondary education? (RQ4) What approaches in ecological education have been proposed within the framework of ecoliteracy to foster sustainable development? (RQ5) What influence does the cultural context have on the development of environmental competencies through ecoliteracy?

In the identification stage, the databases Web of Science (WoS) and Scopus, since they disseminate scientific articles that have undergone a peer-review process certifying their quality, granting these publications international reach, and positioning them as significant contributions to research processes in the field of education (Stahlschmidt and Stephen, 2022). In addition to declaring the sources, it is necessary to note that the search in these databases was conducted in February 2025.

The search strategy was based on publications that included the terms "ecoliteracy" or "ecological literacy" in the title, abstract, or keywords. Accordingly, the search strings used were as follows: in the WoS database, the search equation applied was "ecoliteracy" OR "ecological literacy" (Title) or "ecoliteracy" OR "ecological literacy" (Abstract) or "ecoliteracy" OR "ecological literacy" (Author Keywords). For the Scopus database, the equation applied was: TITLE-ABS-KEY ("ecoliteracy" OR "ecological literacy").

To ensure the rigor and relevance of this systematic literature review, inclusion and exclusion criteria were established during the initial screening stage to guide the selection of studies. These criteria made it possible to delimit the documentary corpus based on parameters consistent with the objectives of the study, thereby ensuring the thematic, methodological, and contextual pertinence of the publications considered. Consequently, Table 1 presents the criteria applied during the selection process.

Table 1.
Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
Studies conducted from 2014 to 2024.	Publications prior to 2014.
Categories WoS: education & educational research, and education, scientific disciplines. Scopus: social sciences.	Categories WoS: other than education & educational research, and education, scientific disciplines. Scopus: other than social sciences.
The full text is open access.	There is no open access to the full text.
The articles are written in English or Spanish.	Articles written in languages other than English or Spanish.
The articles are published in indexed journals.	Correspond to conference proceedings, books, or book chapters.
Publications that are not systematic reviews and/or bibliometric analyses.	Publications that are systematic reviews and/or bibliometric analyses.
Students are the studied population.	The considered population is different from students.
Conducted at the primary and/or secondary education levels.	The educational level involved is different from primary and secondary education.

Note: Own elaboration.

After obtaining the articles from each database, the results were merged using Rstudio, a development environment that allows data analysis. Duplicate records were removed, and the database was then exported in xlsx format. A final screening of the publication titles was carried out, eliminating any remaining duplicates, resulting in a total of 154 documents. Then, the file was imported into Biblioshiny. This application was chosen because it offers a simple and intuitive interface, supports data retrieved from both Scopus and WoS, and generates graphical representations of the data.

Subsequently, the open access availability criterion was applied, resulting in 71 records. These were screened by title and abstract according to the inclusion and exclusion criteria, yielding 23 articles. Finally, a full-text screening was conducted, leading to the selection of 14 publications that met the established eligibility criteria for in-depth analysis. The phases of the selection process are detailed in the flow diagram presented in Figure 2.

Using Biblioshiny, the visual analysis of tables, graphs, and figures revealed key patterns to address RQ1 and RQ2, highlighting: the average number of citations per year, scientific production by country, and the distribution of key concepts according to frequency and thematic category. The graphs and tables were visually refined with Microsoft Excel. Based on the selected tables and figures, the interpretation of the findings was carried out through both statistical and conceptual analysis.

In the eligibility stage, a Microsoft Excel spreadsheet was created, and a template was designed to analyze the articles selected for in-depth review. This allowed for the extraction of relevant data, including authors, year of publication, country, objective, educational strategy, cultural linkage, and relationship to

sustainability. In the inclusion stage, aimed at answering RQ3, RQ4, and RQ5, the following categories were established: educational strategies, sustainability, and the cultural component. This analysis made it possible to identify the main educational action plans implemented to foster ecoliteracy, the approaches employed to teach sustainability through ecoliteracy in primary and secondary education, and, ultimately, the development of competencies grounded in students' cultural context.
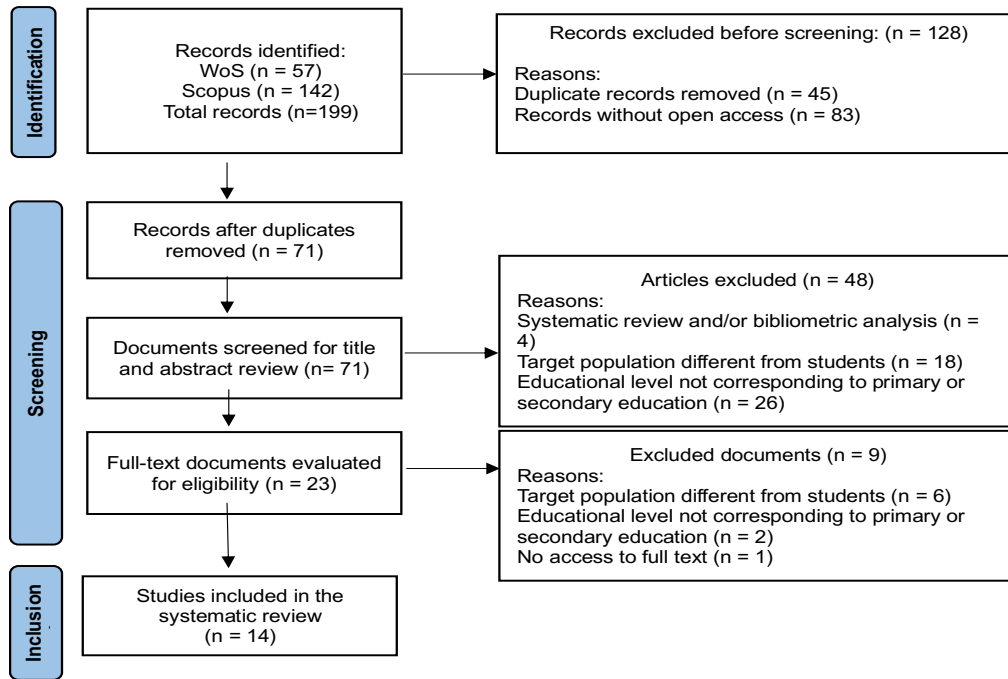

Figure 2. Flowchart
Note: Own elaboration based on Page et al. (2021).

3. Findings

The synthesis of results was carried out through the systematic extraction and organization of key data from the selected studies. This rigorous process involved the identification, collection, and categorization of relevant information from each article, guided by predefined categories aligned with the research objectives. This structured organization of the data enabled the identification of emerging relationships, significant contrasts, and cross-cutting patterns among the studies, thus providing a solid foundation for the subsequent interpretative analysis.

3.1. Scientific trends and thematic patterns on ecoliteracy

The impact of ecoliteracy studies, measured through the average number of citations per article, average citations per year, number of documents published per year, and citable years, is shown in Figure 3, evidencing a significant evolution in scientific production. A peak is observed in 2017, the year in which the highest number of publications coincided with the greatest average citations per article, indicating a consolidated academic interest and a high impact in the scientific field. From 2018 onward, although production remains relatively stable, the average citations per article decrease, which may be associated with the recent nature of the publications and the time required to accumulate citations. This trend is particularly evident in 2023 and 2024, where the documents have not yet had a sufficient time window to be cited. These data suggest

that ecoliteracy has sparked sustained interest within the academic community, with a peak of visibility and impact during the 2016–2017 period.

The progressive increase in publications in recent years suggests an expansion both in theoretical research and in the design and implementation of educational experiences in diverse contexts (Koyama and Watanabe, 2023). This trend, in addition to justifying the relevance of this systematic review, provides a quantitative basis that supports the need to continue strengthening the study and application of ecoliteracy in the educational field.
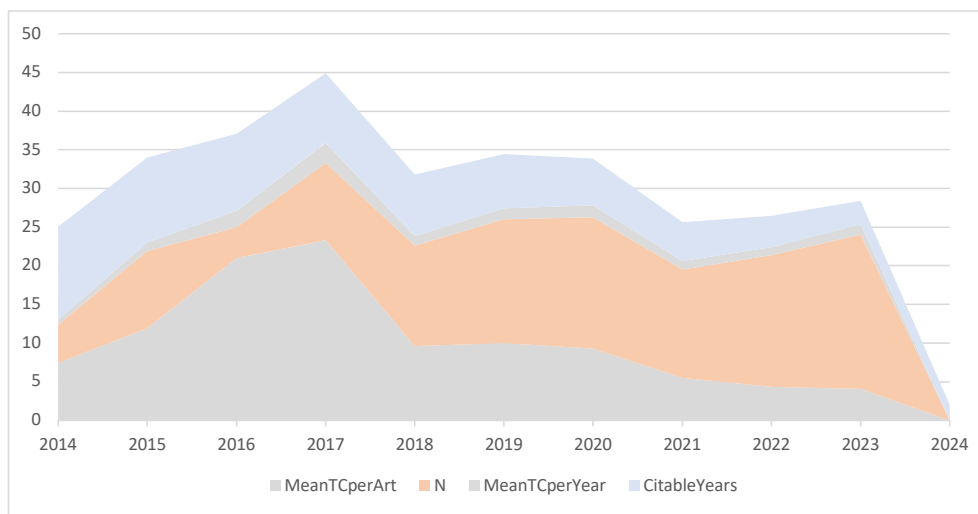
Figure 3. Average citations per year.
Note: Own elaboration.
Evolution of the academic impact of documents related to ecoliteracy.

The distribution by country of the scientific production related to ecoliteracy can be observed in Figure 4. The data show a significant concentration in certain regions, allowing for the identification of both production hubs and geographical gaps around this topic. The highest volume of publications is recorded in the United States, with a total of 42 articles, representing a hegemonic position in research development on ecoliteracy. This leadership may be attributed to the consolidation of educational policies oriented toward sustainability, as well as the presence of academic institutions with specific research lines in environmental education and ecoliteracy. The American researcher Nina Berman (2021) argues that an essential ethical sense of international cooperation should be reflected in the strategies adopted to address environmental issues.

Other countries with notable participation are Canada (8) and Australia (7), both with educational systems that have integrated ecological and sustainable approaches into the school curriculum. In Latin America, Brazil appears with 3 publications, Mexico with 2, and Colombia with 1. The other countries in the region do not have significant publications within this corpus, which suggests an opportunity to strengthen research in Latin American contexts. In Europe, production is dispersed, with moderate presence in countries such as Russia (2), the United Kingdom (2), and France (1). In Asia, China (4) and India (1) stand out, which indicates an emerging interest in the topic, although still limited compared to other regions. Likewise, it can be observed that Africa and a large portion of the Middle East do not have prominent research or studies, which restricts their inclusion in this systematic literature review and highlights the low visibility of scientific research associated with ecoliteracy in these regions.

The data presented in Figure 4 shows that research on ecoliteracy is not a homogeneous phenomenon; rather, there are marked differences in the number of reported studies, leading to a predominance of Engli-

sh-speaking countries located in the Northern Hemisphere. This prevailing trend should be understood as a need, or even an urgency, to weave paths of visibility and strengthen research in countries of the Global South, particularly in Latin America, Africa, and even in some Asian nations. Without a doubt, this comparison can serve as a significant contribution for future studies aimed at carrying out territorial contrasts and promoting the creation of context-based strategies for ecoliteracy (Van Rheenen and Melo, 2021).

Figure 4. Scientific production by countries.
Nota: Own elaboration based on data analyzed in Power BI.

On the other hand, the idea of sustainability emerges as a fundamental aspect within what can be observed in Figure 5, where it is evident that sustainability is associated with other terms such as education, literacy, learning, and knowledge. This relationship can be understood as a pedagogical and critical aspect in which environmental and civic ethics are embedded, mediated by educational training processes (Ramos and Ramos, 2014). In the same vein, terms such as ecology, environmental education, and sustainable development can be identified, which reaffirm the environmental trend while also constituting concepts clearly associated with and complementary to terms that allude to sustainable development and research, such as citizenship, adulthood, problem-solving, and ethics. In Figure 5, it can also be observed some terms linked to social and cultural ideas, such as citizenship, adulthood, problem-solving, and ethics, which highlight that environmental issues are integrated and interdisciplinary. Finally, there are also mentions of specific countries or places (Australia, China, the United States, and urban areas), evidencing the existence of a perspective that emphasizes territory and allows us to see how ecoliteracy is connected with contextual realities and the particularities of different territories.

In sum, the ideas and terms analyzed such as sustainability, education, society, and territory emerge as key pillars of this study, evidencing a clear connection in which none takes precedence over the others but rather complement one another. For instance, sustainability, understood from its ecological, social, and economic dimensions, constitutes an urgent challenge that must be addressed through education. At the same time, education is recognized as a dynamic arena with a strong capacity to transform society in terms of knowledge, environmental awareness and values, as well as individual and collective practices that positively impact human well-being and the environment. Furthermore, it is important to highlight that all of this is largely shaped by context and territorial realities. Indeed, the notions of sustainability, education, and society are deeply influenced by territorial conditions that not only reflect geographic aspects but also allow for the analysis of ecological, cultural, historical, political, educational, and socioeconomic dynamics, which frame the true challenges of ecoliteracy.

Figure 5. Distribution of key concepts according to frequency and thematic category
Note: Own elaboration with data from the study, visualized with RAWGraphs.
The figure presents a frequency analysis of terms associated with the categories: sustainability (green), education (blue), society (yellow), and territory (fuchsia).

3.2. Educational ecoliteracy

Within the framework of this systematic literature review, the findings were structured into three major categories, represented in Figure 6, where it can be observed that each one addresses ecoliteracy from different perspectives or dimensions. In the first category, educational strategies for ecoliteracy, there is a clear tendency to focus on the pedagogical and methodological approaches implemented to strengthen students' environmental awareness at different educational levels. In this first category, an analysis is also carried out that makes it possible to visualize how institutions or educational centers design and implement different strategies aimed at reinforcing knowledge about sustainability and the harmonious coexistence between human beings and the environment they inhabit.

On the other hand, in category two, ecoliteracy and sustainability, the relationship between ecological knowledge and sustainable practices, carried out individually or collectively, can be observed. In this sense, the analysis highlights how the inclusion of ecoliteracy in teaching and learning processes influences human decisions and behaviors regarding environmental care. Finally, in category three, ecoliteracy and culture, the role of culture in shaping the ecological awareness of human beings is examined (Okyay, Sayin, Demir and Özdemir, 2022). That is, the aim is to establish the degree of influence that aspects related to traditions and cultural practices have on human perceptions or actions concerning the sustainability of the environment. Thus, it can be stated that ecoliteracy could be considered an educational construct or approach aimed at increasing levels of awareness and care for the environment.
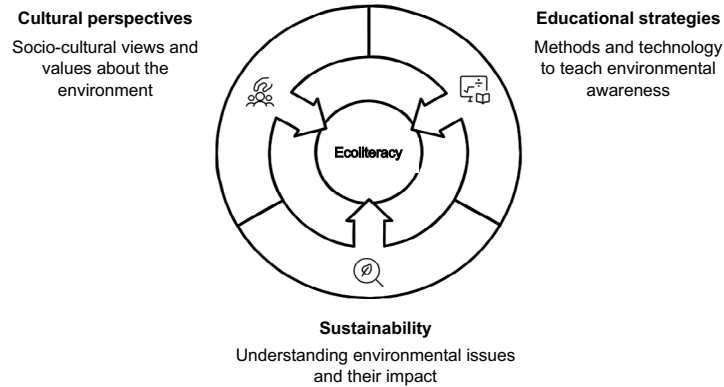
Figure 6. Educational strategies, methods, and technology to foster deep and active environmental awareness
Note: Own elaboration.

Ecoliteracy is a field of research that is in constant evolution. Therefore, the studies reviewed in terms of methodology present a variety of approaches, as shown in Table 2.

Table 2.
Ecoliteracy methodological approaches.

Methodology	Approaches	Authors
Qualitative-Interpretative	Describes the formation of character and environmental behaviors in schools	Daesusi and Asy'ari, 2019; Utomo, Suharti, Sasaongko and Sugiarto, 2023; Rantung, Widiasmoro and Dewi, 2023; García-Rodeja, Vázquez-Lorenzo and Sesto-Varela, 2020; Häggström and Schmidt, 2020
Quasi-Experimental	Evaluates the effectiveness of psychological strategies	Dlimbetova, Abenova, Saykova and Primbetova, 2023
Ethnography	Focuses on human and non-human interactions for the development of ecoliteracy	Persson, Andrée and Caiman, 2024a; Soulé, Nyamekye and Abdoul-Azize, 2022; Berman, 2021
Quantitative Correlational	Analyzes the relationship between ecoliterature and creative thinking skills	Sigit et al. 2023
Quantitative	Identifies the influence of school components on ecoliterature, including the participation of teachers and students, to promote change and continuous improvement	Syah, Hidayat, Yuca, Ardi and Magistarina, 2021; Desfandi, Maryani and Disman, 2017
Action-Research	Involves cycles of planning, action, observation, and reflection to improve educational practices	Chanapimuk, Sawangmek and Nangngam, 2018
Mixed	Create, implement, and refine educational solutions in real world contexts for ecoliteracy	Aguayo y Eames, 2017

Note: Own elaboration.

The execution of research projects in terms of methodology, in some cases, involved dividing participants into control and experimental groups to compare the effects of the proposed intervention. Qualitative projects, on the other hand, employed case studies with small samples, allowing for in-depth investigation but limiting their applicability in other contexts where it might be necessary (Daesusi and Asy'ari, 2019; Utomo et al. 2023; Rantung et al., 2023; García-Rodeja et al., 2020; Häggström and Schmidt, 2020). Quantitative studies used larger samples, often selected through purposive or quota sampling, to analyze the characteristics of a population; in the analyzed studies, action research was structured in reflective and collaborative cycles, frequently involving teachers and students to foster change and continuous improvement (Syah et al., 2021; Desfandi et al., 2017). Ethnographic studies were characterized by the researcher's immersion in the field, using participant observation to capture interactions and experiences in their natural context (Persson et al., 2024a; Soulé et al. 2022; Berman, 2021).

Among the instruments chosen by the researchers was the questionnaire, a commonly used method in the literature, some with open-ended questions, others with two or more response options, or using Likert scales. Additionally, standardized tests or custom-designed assessments were used to evaluate knowledge or skills, often inspired by international frameworks. For interviews, a semi-structured approach with question guides was employed to obtain in-depth information from participants (Utomo et al. 2023; Chanapimuk et al., 2018; Häggström and Schmidt, 2020; Berman, 2021; Callahan, Echeverri, Ng, Zhao and SAtterfield, 2019). Regarding observation, it was generally participant-based and complemented with field notes, photographic documentation, or audio and video recordings. In relation with focus group discussions, these allowed for group interaction and the exploration of collective perspectives (Utomo et al. 2023). About document analysis, it included reviewing reports, educational materials, or even song lyrics as literary texts. Finally, regarding specific inventories, researchers worked with forest inventories to record biodiversity data (Soulé et al. 2022).

The studies employed various techniques to ensure the validity and reliability of their data. In inferential statistics, they used tools such as ANOVA, MANOVA, Pearson's correlation, and Kendall's Tau to assess the relevance of the results (Dlimbetova et al., 2023; Soulé et al. 2022; Desfandi et al. 2017). The researchers carried out reliability tests of the instruments, such as Cronbach's alpha or the Kuder–Richardson test for questionnaires. Regarding content validation, they relied on expert judgment or consistency indices. With respect to data triangulation, they compared the information obtained from multiple sources to increase credibility; in addition, they performed independent double coding, where qualitative data were categorized by several researchers coding separately to ensure consensus. Finally, they applied normality and homogeneity tests to confirm the suitability of the data for parametric analyses (Soulé et al. 2022; Sigit et al. 2023).

An analysis of ecoliteracy methodologies shows that one of their main strengths is the diversity of approaches, combining both quantitative and qualitative methods, which allows for a multifaceted understanding of ecoliteracy. In addition, the pursuit of authentic contexts is evident, as several studies were conducted in real-world settings such as schools, schoolyards, or during fieldwork, enhancing the practical relevance of the findings. Regarding the involvement of multiple actors, including students, teachers, school administrators, and parents enriches the perspectives and strengthens the validity of the results (Dlimbetova et al. 2023; Häggström and Schmidt, 2020). In exploring innovative approaches, some studies examine less traditional areas, such as the role of music or encounters with the non-human, opening new lines for research.

There are limitations regarding generalizability. One limitation is that qualitative studies often have small sample sizes, which restricts the ability to extend their findings to larger populations. In relation to behavior measurement, self-report questionnaires may reflect awareness rather than actual behavior, carrying a high risk of bias since participants might respond in a way that seeks approval or to present themselves favorably to the surveyor (Desfandi et al. 2017).

Among research biases, selection bias is notable, as purposive sampling or voluntary participation can result in samples that are not fully representative of the general population, affecting external validity. Additionally, participants may respond in ways they perceive as socially acceptable or expected, rather than reflecting their true opinions or behaviors (Berman, 2021; Utomo et al. 2023). Bias can also arise from the direct involvement of researchers in qualitative data collection, such as participant observation or interviews, where their interactions with communities or interpretation of results may influence the findings.

This systematic literature review reveals several contributions. First, the synthesis and organization of existing knowledge allow for the integration of theories, models, and approaches on ecoliteracy (Orr, 1992; Capra, 2006), highlighting areas of convergence and divergence. It also identifies emerging trends and approaches, recognizing recent lines of research such as the use of digital storytelling, experiential learning, and education for sustainability in school and community contexts. Regarding thematic and conceptual delineation, the review clarifies the understanding of ecoliteracy in the literature, distinguishing it from general environmental education. Concerning the critical analysis of methodological approaches, it describes how ecoliteracy has been studied through qualitative, quantitative, and mixed methods, identif-

ying strengths and weaknesses in the studies. Consequently, it highlights research gaps, indicating unde-rexplored areas, such as ecoliteracy in technical and vocational education. Moreover, the review serves as guidance for educational policies and practices, providing evidence and arguments for designing more effective school, community, or institutional programs.

3.3. Exploration of educational strategies for ecoliteracy

In line with the literature on pedagogical strategies for strengthening ecoliteracy, it is evident that there is a clear interdisciplinarity, in which scientific, technological, artistic, and humanistic values are present in the design of pedagogical strategies aimed at environmental education. This also highlights that eco-literacy constitutes a transversal educational practice that brings multiple benefits to students and to the overall educational process. Precisely, Table 3 illustrates the interdisciplinary nature of the pedagogical strategies and the comprehensive development of environmental competencies.

Table 3.
Educational strategies for ecoliteracy

Strategy	Interdisciplinarity	Authors
Virtual Reality (VR) and Augmented Reality (AR)	- Biology - Technology and Informatics - Art Education	Aguayo and Eames, 2017; Callahan et al. 2019.
Nature Research through Student Observation	- Biology - Ethics - Religion - Mathematics - Language - Social Sciences	Daesusi and Asy'ari, 2019; Persson et al. 2024a.
Green School	- Biology - Psychology	Dlimbetova et al. 2023; Soulé et al. 2022; Utomo et al. 2023.
Ecoreading	- Biology - Languages	Rantung et al. 2023.
Science, Technology, Society, and Environment Approach	- Biology	Chanapimuk et al. 2018.
Ecosystem Functioning	- Biology - Art Education -Technology and Informatics	García-Rodeja et al. 2020.

Note: Own elaboration.

When analyzing the diverse pedagogical strategies associated with ecoliteracy, the use of virtual and aug-mented reality technologies can be traced across multiple fields of knowledge, such as biology, computer science, and art education (Aguayo and Eames, 2017; Estrada-Perea and Pinto-Blanco, 2021). Maybe, the incorporation of these digital and cyber tools likely responds to their ability to provide immersive expe-riences and interactive activities that significantly impact students' learning and environmental awareness. This is because the training involves sensory experimentation and goes beyond mere theory or repeated rhetoric about environmental awareness, making it more meaningful for students. The study by Aguayo and Eames (2017) is notable for its innovative approach in proposing the use of AR and VR in mobile learning for ecoliteracy, especially in freely chosen environments such as non-formal education. Their work empha-sizes the need to move beyond simply substituting technology toward its transformative use. Continuing with the analysis of pedagogical strategies associated with ecoliteracy, many of them rely on observation as the basis for learning and scientific inquiry (Daesusi and Asy'ari, 2019; Persson et al., 2024a), as they promote direct contact with the living environment and the comparison between academic knowledge, rea-lity, and the cultural or axiological values held by members of a given educational community. In this area, researchers Persson, Andrée and Caiman (2024b) are highlighted for applying a posthumanist perspective and actor-network theory to analyze human and non-human encounters in fieldwork. They underscore the

importance of materiality and tactile, sensory experiences in the development of ecoliteracy, arguing that these experiences cannot be replicated in a classroom. This addresses a gap as it goes beyond cognition to include the social dimension of environmental learning.

The notion of a school that prioritizes the environment and has firmly established its environmental values, or what is sometimes referred to as a "green school", offers an innovative contribution by emphasizing the infusion of psychological methodologies into environmental pedagogy as a way to overcome the limitation of environmental education, which often remains theoretical and fails to influence students' behavior. This is a crucial contribution for bridging the gap between awareness and behavior (Dlimbetova et al. 2023; Soulé et al. 2022; Utomo et al. 2023), In such schools, various areas of knowledge are directed toward environmental education, attributing a central role to environmental care across all disciplinary fields, rather than assuming that environmental awareness pertains only to specific areas. For example, ecoreading (Rantung et al., 2023) emerges as a pedagogical strategy that promotes reading comprehension through texts addressing environmental topics, thereby enhancing learning objectives in areas such as biology and language, framed within what contemporary studies have termed ecoliterature. This approach presents a creative and inter-artistic perspective since it incorporates song lyrics to improve both ecoliteracy and language competence. Therefore, this approach is highly original as it breaks with traditional methodologies and addresses ecoliteracy from an artistic and cultural dimension. Additionally, it examines Indonesian bands, filling a gap in the study of non-Western song lyrics.

On the other hand, there is an approach called CTSA, framed within science, technology, society, and the environment (Chanapimuk et al., 2018), which provides an understanding of the relationships between contemporary societal environmental issues and scientific knowledge, thus leading to strategies that aim to comprehend the social and ethical implications of scientific understanding. In this context, some strategies that investigate students' specific difficulties in applying ideas about ecosystem functioning (decomposers, energy flow, chemical energy) and the causal thinking patterns these concepts activate emerge in research. A valuable contribution to comprehensive education is proposed by García-Rodeja et al. (2020), who highlight the need to make explicit the connection between Biology, Chemistry, and Physics, addressing a fundamental gap in interdisciplinary understanding that is often overlooked in more general approaches to environmental awareness.

Ecoliteracy as an educational approach has been implemented in different educational scenarios crossing traditional boundaries of environmental content learning; the teachers have created proposals that create a new way of engaging with nature inside the classroom. This allows ecoliteracy to contribute to the holistic education of students (Desfandi et al., 2017). Researchers have carried out projects in which they evidence the great benefits that different fields of knowledge bring to ecological education, that is the case of mathematics which enrich pedagogical approaches developing abstract thinking applied to solving current environmental problem (Fernández-Torres, Hildebrandt and Sempuga, 2020). Additionally, didactic proposals that promote students' reflective processes regarding environmental issues through direct observation of the natural educational environment are highlighted (Okyay et al., 2022).

Proposal such as green school evidence the positive impact of integrating pyschology in the teaching processes with students, since they effectively foster ecological awaranees in people (Dlimbetova et al., 2023). However, the findings of this review evidence how when implementing the ecoliteracy approach, there are difficulties due to the precarious economic conditions of the educational centers that limit access to materials, resources and equipment (Suwandi, Drajati, Handayani and Tyarakanita, 2024). Furthermore, addressing emotions within ecoliteracy approaches is fundamental, as it allows students to establish a deep connection with nature (Persson et al., 2024b). This, in turn, enables the creation of innovative school spaces, such as biodiverse playgrounds and forest gardens, which stand out as strategies to promote ecological literacy. Therefore, it is essential that the development of these educational spaces involves the participation of the entire school community (Almers, Askerlund, Samuelsson and Waite, 2021; Hammarsten, Askerlund, Almers, Avery and Samuelsson, 2019).

Each of the strategies presented in the table serves as evidence of how ecoliteracy is being effectively implemented through various models that place interdisciplinarity at their core. They clearly demonstrate that ecological education cannot be seen as a collection of isolated contents or restricted to a few areas of knowledge; rather, it must be approached as a broad, integrated matter that demands changes in the curriculum and careful consideration of the specific educational contexts in which ecoliteracy is to be implemented. Furthermore, it is important to note that each of these pedagogical strategies responds to the diverse dimensions of learning experienced by educational actors, thus providing a wide range of actions to explore meaningful pathways for ecological education that influence both students' perceptions and their actions toward environmental care and sustainability.

3.4. Ecoliteracy and sustainability

Table 4 summarizes the pedagogical approaches and teaching methods associated with ecoliteracy and sustainability identified in this systematic literature review. The content of this table illustrates the multiple dimensions from which ecological education is approached in educational settings. For example, the first approach, referred to as the community-based approach and represented by the ideas and concepts of Desfandi et al. (2017), proposes an interdisciplinary learning process in which teamwork, dialogic interaction, and recognition of the local context can strengthen environmental awareness and foster significant changes for harmonious coexistence between humans and their environment.

Table 4.
Ecoliteracy and sustainability.

Pedagogical Approaches	Teaching methods	Authors
Community-based.	Interdisciplinary learning.	Desfandi et al. 2017.
Post-sustainable thinking.	Critical pedagogy.	Häggström and Schmidt, 2020.
Curricular.	Knowledge, norms, and ethics.	Persson et al. 2024.
Tourism.	Environmental education.	Berman, 2021.
Environmental problem-focused.	Creative thinking.	Sigit et al. 2023.

Note: Own elaboration.

On the other hand, the post-sustainability thinking approach proposed by Häggström and Schmidt (2020), is a clear invitation to critically reflect on the discourses and narratives that have traditionally or archaically shaped sustainability. The aim of this reflection is to pursue emancipation and change in both discourse and action, seeking to generate a genuinely significant impact on environmental education. They contribute to the field by applying place-based critical pedagogy to primary education (children aged 7 to 10), an age group less frequently studied in this context. Their work demonstrates how direct engagement with authentic locations fosters student interaction and meaning-making, linking general literacy with ecoliteracy in a holistic manner. Continuing with the explanation of the approaches presented in Table 3, the curricular approach proposed by Persson et al., (2024a), focuses on teaching environmental knowledge, norms, and ethics. This approach reflects a perspective more aligned with institutional structures, where curricular content predominates, and ecoliteracy is framed in a formalistic and normative sense, strongly influenced by external regulatory institutions within the territory.

In early childhood education, significant strategies were identified, such as rainwater harvesting and school gardens, which help foster environmental awareness from the early stages of children's development (Soulé et al., 2022; Hipkiss, Windsor and Sanders, 2020). The authors fill a gap when they investigate the diversity of woody species and their benefits in urban schoolyards in the African Sahel. Their findings about the low capacity of students to name these species despite the high biodiversity in the surroundings highlight the clear disconnect and a gap in local botanical education.

The educational proposals in ecoliteracy present a development in critical and creative thinking that allow students to reflect on climate change and resource scarcity (Curwen, Ardell and Lambert, 2018). On the other hand, children's literature contributes to the development of ecoliteracy, facilitating students' links with nature through fantastic narratives narratives (Ramos and Ramos, 2014). Furthermore, ecofictions in the school curriculum contribute as an efficient mechanism for students to analyze customs related to overconsumption, which creates better environmental conditions. One of the most distinctive perspectives advocating for the integration of literary education and tangible and intangible cultural heritage is presented by García-Rodeja et al. (2020). It is important to highlight that with environmental education, especially regarding water culture which critiques the division between the humanities and sciences and propose that narratives, imagination, and fiction can challenge stereotypes and promote a holistic and critical view of the environment that goes beyond purely technological or utilitarian approaches. This approach is crucial for recovering cultural memory associated with nature and contrasts with the more strictly scientific or behavioral perspective of many other studies.

Another approach observed is tourism proposed by Berman (2021), which emphasizes environmental education as a means or tool to raise awareness among those who, for academic or personal reasons, visit certain locations where ecosystems could be negatively impacted if respectful behaviors toward the environment are not observed. For this approach, it is crucial to foster environmental awareness processes to ensure tourism is practiced sustainably. The researcher highlights the role of tourism as a catalyst for environmental education in schools in Kenya, a very specific and under-researched context. Berman also critiques the lack of integration of scientific knowledge about ecological disasters into educational curricula, suggesting a broader systemic gap. Finally, Sigit et al. (2023) propose the concept of creative thinking as a methodological alternative within the so-called environmental problem-focused approach. This approach emphasizes the urgency of generating innovative solutions to incorporate a pluralistic perspective into ecological education, moving beyond a one-size-fits-all approach that attempts to address everything without considering particularities. This is precisely the aspect on which ecoliteracy is based: it does not aim to constitute a homogeneous path but rather starts from the context, realities, and specific needs of each community-educational in this case--allowing for meaningful, relevant ecoliteracy that inclusively engages the environment and the interests of community members. This study is one of the few that quantifies the contribution of ecoliteracy to creative thinking skills, identifying originality as a particularly low dimension. This represents a significant contribution, as other studies on ecoliteracy do not always explore these high-level cognitive connection.

3.5. Ecoliteracy and culture

The information presented in Table 5 provides a summary of the methods linking ecoliteracy with the cultural dimension, in which interdisciplinarity is fostered through specific competencies. For example, the first method highlighted is the ecoliteracy and competencies approach proposed by Daesusi and Asy'ari (2019), which aims to establish the coexistence of multiple competencies such as verbal, numerical, scientific, moral, social, and motor, within ecological education that integrates and respects linguistic diversity and multiple cultures.

Table 5.
Ecoliteracy and culture

Method	Competencies	Authors
Ecoliteracy and competencies	- Verbal (Indonesian, English, and Arabic) - Numerical - Beliefs and moral - Scientific - Social and motor	Daesusi and Asy'ari, 2019; Soulé et al., 2022.
Ecoreading	- Critical thinking - Historical and cultural knowledge	Berman, 2021; García-Rodeja et al., 2020; Häggström and Schmidt, 2020.
Emotional ecoliteracy	- Systemic thinking	Persson et al. 2024b; Syah et al. 2021.

Note: Own elaboration.

On the other hand, a second method, called ecoreadings, theoretically proposed by Martos (2021) can be appreciated. This method emphasizes critical thinking and the need to understand historical and cultural knowledge associated with ecological issues. Furthermore, this method encourages students to read texts and narratives that influence the perception each individual or community holds regarding the environment. This approach aligns with decolonial pedagogy and seeks to identify local knowledge that emerges within the territories themselves, as opposed to knowledge imposed by external institutions, which often dominates educational narratives. Finally, the approach called emotional ecoliteracy, presented by Persson et al. (2024b), explores the emotional connections that are woven between living beings and the environment they inhabit, aiming to project that the care of the environment and the actions carried out are linked, to some extent, to an emotional plane, a reason that should lead to exploring this affective connection between students and the environment they inhabit in ecological education.

Each of the methods presented are the evidence that ecoliteracy is directly related to the cultural dimension, and that, in turn, environmental education is linked to language, the axiological plane, beliefs, and the historical narratives and traditional knowledge of communities (Abbas et al., 2024); that is, under this approach, ecoliteracy is not only made more contextually relevant, but it also paves the way for fostering environmental education in which critical thinking becomes a transversal competency (Kumpulainen, Byman, Renlund and Wong, 2020), and at the same time, serves as the driving force behind positive transformations in response to the environmental challenges faced by contemporary society.

The studies also reveal common limitations and point to directions for future research. Regarding generalizability, several qualitative studies, by their very nature involving small samples and specific contexts, explicitly acknowledge the limitation in applying their findings more broadly. In the case of García-Rodeja et al. (2020), the researchers suggest expanding the sample and including interviews to gain deeper insights into the gap between awareness and actual behavior. The difficulty of measuring real environmental behavior as opposed to mere awareness or intention is a recognized limitation. Surveys often measure awareness and self-assessment rather than actual practices, which can introduce social desirability bias (Berman, 2021). Additionally, it is emphasized that theoretical environmental education often fails to influence behavior (Dlimbetova et al., 2023). This highlights a persistent gap in research on how to effectively translate knowledge and intention into sustainable actions. Another limitation is the focus on specific educational levels, with several studies concentrating on a particular stage, for example, secondary education in García-Rodeja et al. (2020) and Sigit et al. (2023), primary in Häggström and Schmidt (2020), indicating the need to extend research to other contexts, such as university students, as recommended by Sigit et al. (2023).

In summary, the studies reveal a deep and multidimensional field of research in ecoliteracy. While some focus on the effectiveness of pedagogical interventions (Dlimbetova et al., 2023), others explore students' conceptual understanding (García-Rodeja et al., 2020) or institutional dynamics (Utomo et al., 2023; Desfandi et al., 2017). An emerging set of studies explores innovative approaches, such as Rantung et al. (2023) with music, Aguayo and Eames (2017) with technology, Persson et al. (2024a) with fieldwork, and humanistic and cultural perspectives (Martos, 2021). The persistent gap between awareness and behavior, as well as the need to integrate diverse dimensions of knowledge, remains a common challenge and an opportunity for future research.

4. Conclusions

Ecoliteracy has become a key educational approach for addressing today's environmental challenges. The educational field is leading the way with creative, inclusive, and context-based teaching strategies that enable communities to develop critical and creative thinking, giving them the tools needed to take responsible actions for the protection of ecosystems. Hence, ecoliteracy is seen as a bridge connecting sustainability, citizenship, environmental education, the green curriculum, and ecological justice. This perspective highlights a field that is actively evolving and reflects a discourse that goes beyond purely ecological concerns to include ethical, social, and pedagogical dimensions.

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Regarding educational practices, innovative strategies have been identified that foster meaningful and context-based learning, such as project-based learning, problem-based learning, outdoor education, and the integration of interdisciplinary knowledge. These approaches align with a holistic perspective that positions students as active agents in their relationship with the environment. In terms of ecological approaches, the literature highlights initiatives focused on sustainable development, education for action, environmental ethics, and community participation, which help expand the understanding of ecoliteracy beyond the classroom and situate it within broader socio-environmental transformation processes.

Likewise, the importance of cultural context in the development of environmental competencies is recognized. Several studies emphasize how local values, worldviews, languages, and practices influence the way students understand and interact with their environment. This cultural dimension constitutes a key element for designing relevant, inclusive, and context-sensitive ecoliteracy programs. Taken together, the findings reaffirm the need to conceive ecoliteracy as a comprehensive educational process that is contextually aware and aimed at fostering critical, ethical, and sustainability-oriented citizenship.

The limitations of the present study lie in constraints that may affect its scope, such as coverage in access to research; the review may be limited to publications from certain regions that have the means to publish their studies, leaving out relevant research from other contexts that lack sufficient administrative or financial support to be disseminated in academic journals. Additionally, limitations arise from the availability and access to sources, due to restrictions on subscription-based databases that may contain relevant evidence.

Based on the foregoing, a future line of work is proposed that involves developing studies integrating ecoliteracy with various areas of knowledge in primary and secondary education, through the implementation of active methodologies and educational innovation that promote students' direct interaction with their environment. This approach aims to strengthen the understanding of the role humans play within the ecosystem, as well as to foster the development of environmental skills, attitudes, and values.

It is suggested to explore the potential of digital storytelling as a pedagogical tool to articulate meaningful ecological experiences, allowing students to critically reflect on their relationship with the environment and creatively communicate it through digital media. Likewise, the implementation of the STEAM educational approach, which promotes the acquisition of knowledge, the development of skills, and attitudes to solve real-life problems while fostering 21st-century competencies, is recommended. This involves carrying out interdisciplinary projects that recognize the application of knowledge from different fields to proposed situations, enhancing understanding from conceptual, social, environmental, scientific, cultural, economic, and technological perspectives.

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