



Education for sustainable development in teacher education: challenges, gaps, and transformative perspectives

Formação docente em educação para o desenvolvimento sustentável: desafios, lacunas e perspectivas transformadoras

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ABSTRACT

This article critically examines Education for Sustainable Development (ESD) within teacher education, considering its alignment with the Sustainable Development Goals. Adopting a theoretical-critical approach, this study is based on a critical narrative review of national and international publications from 2015 to 2024, combined with thematic analysis. Forty-two works were selected from databases including Scientific Electronic Library Online (SciELO) and the Coordination for the Improvement of Higher Education Personnel (CAPES), and were analyzed using thematic analysis. The findings reveal interrelated gaps across multiple dimensions that hinder the effective implementation of ESD. Conceptually, an anthropocentric and economic bias predominates, accompanied by a lack of epistemological reflection on alternative frameworks such as planetary health. In the pedagogical dimension, behaviorist approaches emphasize individual actions without critically addressing socioeconomic structures, thereby weakening interdisciplinarity. Institutionally, resistance persists toward breaking with rigid disciplinary curricula, alongside insufficient support for transdisciplinary practices. Politically, the study identifies a disconnect between Brazil's National Common Curricular Base (*Base Nacional Comum Curricular* — BNCC) and the effective integration of environmental themes, as well as the hegemony of a competency-based neoliberal logic that depoliticizes education. These gaps are particularly evident in teacher education, which lacks robust curricular components and adequate professional development opportunities. Critical environmental education emerges as a transformative perspective by fostering ecological awareness and socio-environmental justice. The study concludes that overcoming these challenges requires strengthening critical, interdisciplinary, and territorially contextualized training practices that integrate scientific, social, and ethical-political knowledge, thereby preparing educators to transform the structures that perpetuate the socio-environmental crisis.

Keywords: education for sustainable development; teacher training; transversality; interdisciplinarity.

RESUMO

Este artigo analisa criticamente a Educação para o Desenvolvimento Sustentável (EDS) na formação de professores, considerando sua articulação com os Objetivos de Desenvolvimento Sustentável. Adotando uma abordagem teórico-crítica, este estudo baseia-se numa revisão narrativa crítica de publicações nacionais e internacionais de 2015 a 2024, combinada com análise temática. Foram selecionados 42 trabalhos em bases como Scientific Electronic Library Online (SciELO) e Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), analisados por meio de análise temática. Os resultados revelam lacunas inter-relacionadas em diferentes dimensões que dificultam a efetiva implementação da EDS. No plano conceitual, predomina uma visão antropocêntrica e economicista, acompanhada da ausência de reflexão epistemológica sobre abordagens alternativas, como a saúde planetária. Na dimensão pedagógica, abordagens behavioristas enfatizam ações individuais sem problematizar as estruturas socioeconômicas, fragilizando a interdisciplinaridade. No âmbito institucional, observa-se resistência à superação de currículos disciplinares rígidos e insuficiente apoio a práticas transdisciplinares. Na dimensão política, identifica-se um descompasso entre a BNCC e a integração efetiva das temáticas ambientais, além da hegemonia de uma lógica neoliberal baseada em competências, que tende a despolitizar a educação. Essas lacunas se manifestam de forma mais evidente na formação docente, marcada pela fragilidade de componentes curriculares e pela insuficiência de oportunidades de desenvolvimento profissional. Nesse contexto, a educação ambiental crítica emerge como uma perspectiva transformadora, ao promover a consciência ecológica e a justiça socioambiental. Conclui-se que a superação desses desafios exige o fortalecimento de práticas formativas críticas, interdisciplinares e territorialmente contextualizadas, integrando conhecimentos científicos, sociais e ético-políticos para formar educadores capazes de atuar na transformação das estruturas que perpetuam a crise socioambiental.

Palavras-chave: educação para o desenvolvimento sustentável; formação docente; transversalidade; interdisciplinaridade.

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Introduction

As issues such as climate change, environmental degradation, and social inequality become increasingly urgent, the development of critical and conscious individuals becomes essential to promote social justice and environmental responsibility (UNESCO, 2020). In this context, the inclusion of Education for Sustainable Development (ESD) in school curricula is crucial and must involve a holistic transformation capable of influencing both content and learning outcomes. This requires the integration of key themes such as climate change, disaster risk reduction, health and well-being, equity, and sustainable consumption (UNESCO, 2017a; Jorgenson et al., 2019; IPCC, 2021; Parry and Metzger, 2023).

For ESD to be transformative, it must move beyond information transmission and promote reflective, participatory, and action-oriented pedagogical processes grounded in sustainability-related competencies (Rieckmann, 2018a; Husamah et al., 2024). Furthermore, Rieckmann (2018a; 2018b) argues that civic education is essential to the development of sustainable societies, as it equips individuals with the tools needed to understand and address global challenges.

Kopnina (2020b) offers a sharp critique of the conceptual and practical limitations of ESD by highlighting its systematic neglect of ecological justice in favor of narratives centered on economic growth. Although the Sustainable Development Goals (SDGs) and ESD aim to foster educational transformation in favor of sustainability, she denounces their anthropocentric and technocratic foundations, which often reinforce oppressive structures and contradict the very ideals of sustainability they claim to uphold. According to Kopnina (2020b), by prioritizing economic growth and human well-being, policies associated with the SDGs sometimes perpetuate a hierarchy of values that overlooks ecological integrity as a foundation for lasting sustainability.

This critique invites a deeper epistemological discussion that is often overlooked in the literature on educational policies. The very term “sustainable development” carries a historical and political weight rooted in capitalist logic, frequently associated with the notion of “green growth”—an approach that seeks to reconcile economic expansion with environmental preservation without challenging the structural underpinnings of the socio-ecological crisis.

From this perspective, “sustainable development” differs substantially from the concept of “sustainability,” which, in its stronger interpretations (such as strong sustainability or ecological sustainability), prioritizes the integrity of ecosystems and non-human life over economic interests. This distinction is not merely semantic; it reflects divergent worldviews and carries profound implications for teacher education. Adopting an uncritical stance toward ESD risks reproducing the same productivism logic that education claims to overcome.

Considering this tension, ESD represents but one of several possible frameworks for rethinking the role of education in times of so-

cio-ecological collapse. Contemporary discussions have proposed alternative or complementary approaches, such as Planetary Health, which emphasizes the interdependence between human health and natural systems; Ecological Intelligence, which focuses on developing the cognitive and affective capacities necessary to perceive and respond to ecological interdependencies; and Ecosystem Literacy, which grounds education in the understanding of ecological principles and the relationships between living systems. Each of these frameworks offers distinct epistemological and pedagogical pathways, some of which place greater emphasis on decolonial perspectives, post-anthropocentrism, or the critique of capitalist extractivism—dimensions that are frequently diluted in mainstream ESD policy documents. Choosing to focus on ESD, therefore, is not a neutral or self-evident decision. It requires a deliberate justification: we engage with ESD in this study not as a unified or uncontested field, but precisely because its internal contradictions and dominant interpretations offer a productive starting point for interrogating how teacher education has responded—or failed to respond—to the socio-ecological crisis. Rather than taking ESD as a given framework, we approach it as a contested terrain whose limits and possibilities must be examined critically.

Additionally, it is essential to recognize the challenges faced in the educational context, influenced by factors related to teacher training, school structures, and the broader education system. In this context, several challenges emerge in teacher education, school practices, and systemic organization, particularly when attempting to align teaching with sustainability principles and local territories’ valorization (Jacobi et al., 2016).

Othman et al. (2024) analyzed the obstacles that hinder the integration of SDGs into school curricula through Information and Communication Technologies (ICTs), considering barriers at the levels of teachers, schools, and the education system. Their findings indicate that teacher-related barriers, such as lack of adequate training, insecurity in using ICTs, or unfamiliarity with the SDGs have the greatest negative impact on motivation. Similarly, systemic barriers, such as the absence of clear policies or insufficient institutional support, also play a significant role.

Santos et al. (2017) emphasize that the traditional model of education, characterized by excessive specialization and compartmentalization of knowledge, limits the critical and integrated understanding of socio-environmental issues, which are inherently complex and multifaceted. Their work presents a critical reflection on interdisciplinarity, revealing its importance not only as a method for integrating different disciplines, but also as a vital strategy for cultivating critical and conscious citizens capable of acting as agents of social transformation. In this context, interdisciplinarity transcends technical concerns and emerges as an epistemological and political perspective essential to confronting the crisis of modern rationality and promoting change in social, environmental, and educational realities.

Like interdisciplinarity, transdisciplinarity is also frequently promoted as an ideal approach to integrating sustainability into education. However, its practical application still faces numerous challenges. From a theoretical standpoint, this perspective is a substantial improvement, as it endeavors to break down rigid disciplinary boundaries by engaging external actors, including organizations, communities, and citizens, in a collaborative knowledge production process. Figueró and Raufflet (2015), however, emphasize that numerous calls for transdisciplinarity are merely rhetorical and lack specific strategies to challenge established disciplinary structures.

In this sense, this study seeks to understand how ESD has been discussed in the context of teacher training. Rather than presupposing a single pathway or endorsing a particular model, we aim to identify the main theoretical approaches, proposed pedagogical practices, and—above all—the persistent gaps in the literature and the implementation of educational policies.

By bringing together different perspectives and challenges, we seek to examine the extent to which integrating ESD into teacher education implies not only curricular changes but also the possibility of revising school structures, pedagogical models, and the relationships between school, territory, and society. This exploration is guided by the question of whether such revisions, as suggested in the literature, genuinely contribute to an education committed to sustainability, social justice, and the formation of critical individuals engaged in transforming the world, or whether they risk reproducing the very contradictions that define the current socio-ecological crisis.

Despite the growing body of academic literature on ESD, a gap remains regarding the integrated analysis of its conceptual, pedagogical, institutional, and political contradictions in the field of teacher education. Much of the literature addresses specific dimensions, such as competencies, pedagogical practices, curriculum, or educational policies, but fewer studies critically articulate these elements to understand how ESD has been incorporated, or limited, in teacher education.

This article seeks to address this gap by systematizing, through a critical narrative review with thematic analysis, the main challenges and tensions that shape the relationship between ESD, teacher education, interdisciplinarity, transdisciplinarity, and critical environmental education.

Methodological Approach

This study is characterized as qualitative, theoretical-critical research, based on a critical narrative review with thematic analysis. This methodological design was adopted because it allows the inclusion, comparison, and critical interpretation of different types of academic and institutional sources, enabling a broader understanding of how Education for Sustainable Development has been discussed in relation to teacher education (Chart 1). The review was not designed to be systematic in the strict sense, nor did it aim to provide an exhaustive mapping of all publications on the topic. Rather, it sought to identify, organize, and critically interpret recurring conceptual, pedagogical, institutional, political, and teacher education gaps in the literature.

The bibliographic data collection was carried out between 2015 and 2024, using major academic databases such as SciELO and the CAPES portal. The search strategy combined the main descriptor “Education for Sustainable Development”, applied to the title field, with complementary descriptors applied to any field of the record: “interdisciplinarity”, “transdisciplinarity”, and “teacher training” using the “contains” criterion. This combination aimed to retrieve studies directly focused on Education for Sustainable Development and related to interdisciplinary and transdisciplinary approaches in teacher education.

The selection of literature was guided by its relevance to the research objectives, rather than aiming at exhaustiveness. Inclusion criteria comprised publications that address ESD critically or reflectively; studies discussing interdisciplinarity and transdisciplinarity in the educational context; research on initial and continuing teacher training

Chart 1 – Methodological procedures adopted in the study.

Item	Description
Methodological design	Critical narrative review with thematic analysis
Research approach	Qualitative and theoretical-critical
Analytical technique	Thematic analysis
Databases and sources	SciELO and CAPES Portal
Period covered	2015–2024
Search descriptors	“Education for Sustainable Development”; “teacher training” “interdisciplinarity”; “transdisciplinarity”;
Inclusion criteria	Studies addressing ESD, teacher education, sustainability, environmental education, interdisciplinarity, transdisciplinarity, SDG.
Exclusion criteria	Duplicated texts; texts outside the selected period; publications unrelated to teacher education or sustainability education; studies with exclusively descriptive treatment and no relevant theoretical or analytical contribution
Final corpus	42 works
Analytical dimensions	Conceptual, pedagogical, institutional, political and teacher education dimensions

in the environmental field; and official documents such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) guidelines and reports from international organizations related to the SDGs. Articles with a solely descriptive nature or lacking significant theoretical grounding were excluded from the analysis.

For transparency, Figure 1 presents the procedures used to delimit the analytical corpus. Although this review was not designed as a systematic review in the strict sense, the flowchart enhances methodological clarity by showing the stages of identification, screening, eligibility assessment, and final selection. The final corpus comprised 42 works.

The selected texts were analyzed using the thematic content analysis approach, aiming to identify and categorize the main contradictions, challenges, and proposals related to ESD. The process involved the following: the identification of central ideas and theoretical-conceptual reflections that emerged from each document; the systematization of thematic categories, such as teacher training, interdisciplinarity, and ethical-political aspects of ESD; and the confrontation of these categories with existing theories to facilitate critical reflection on the limitations and potential of ESD.

It is important to emphasize that this study does not aim to provide an exhaustive or systematic mapping of the literature, but rather to develop a theoretically grounded and critically oriented interpretation of key debates in the field. As such, the focus lies on analytical depth rather than quantitative coverage. This research is theoretical in nature and does not rely on empirical data collected in the field, which limits the generalizability of its conclusions to specific contexts. However, this approach enables a deeper conceptual and critical understanding of the topic, contributing to the advancement of academic debate and providing a foundation for future empirical investigations that may further explore the practical dimensions of ESD.

Theoretical Framework

Education for Sustainable Development

Before examining the conceptual and pedagogical dimensions of ESD, it is necessary to clarify why this framework occupies a central place in the present analysis. ESD is the dominant discourse in international educational policy, particularly within the context of the SDGs. As such, it shapes curricula, teacher education guidelines, and institutional practices worldwide, including in Brazil. However, ESD is not a monolithic or uncontested field; it embodies deep epistemological and political contradictions. While some approaches reduce sustainability to behaviorist and economic formulas, others open space for critical reflections on structural inequalities, ecological justice, and the very meaning of development. Engaging with ESD critically allows us to interrogate how teacher education has responded—or failed to respond—to the socio-ecological crisis. Alternative frameworks such as Planetary Health, Ecological Intelligence, or Ecosystem Literacy offer important insights, but they have not yet achieved the same policy penetration. Thus, focusing on ESD provides a strategic entry point to examine the tensions, gaps, and transformative possibilities within teacher education, without endorsing its hegemonic interpretations.

ESD is frequently defined as “learning to live sustainably” (UNESCO, 2021) and is the most used term in international debates on education, learning, and sustainability, as well as being a central element of the SDGs. ESD promotes an inter- and multidisciplinary approach, integrating curricular content such as ethics, institutional management, and collaborative community actions (Rieckmann, 2018a). However, it presents concerning trends and contradictions, since, while addressing issues such as poverty eradication and health improvement, it often neglects fundamental aspects such as controlling population growth and consumption (Gupta and Pouw, 2017). As such, education based on these principles is considered problematic due to its anthropocentric and economy-centered bias, which fails adequately to prioritize the ecological integrity necessary for safeguarding the future of both human and non-human species (Kopnina, 2020a).

To address the complex and multifaceted challenges of sustainability, innovative thinking about the nature and purpose of education and learning is required. The so-called “traditional education,” criticized for preparing students primarily for consumer-oriented lives and national economies, is deemed insufficient for this task (Shephard et al., 2019; Parry and Metzger, 2023). ESD, by contrast, transcends mere knowledge transfer and calls for a deeper and more practical approach (Figueiró and Raufflet, 2015; Kopnina, 2020c; Probst, 2022).

One of the core challenges is an excessive focus on the environmental dimension without integrating the development of critical thinking and problem-solving skills, which opposes the superficial inclusion of sustainability in curricula. This often results in ad hoc or fragmented approaches, rather than comprehensive integration (Figueiró and

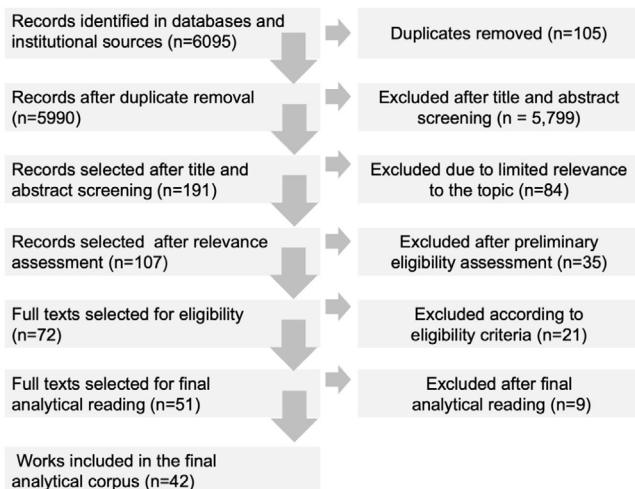


Figure 1 – Flowchart of the selection process of the analytical corpus.

Raufflet, 2015; Grosbeck et al., 2019). Historically, education has prepared students for participation in the global economy; however, the discourse on sustainability now incorporates values, ethics, and geopolitical concerns. Teachers, therefore, must develop an understanding of their educational practice considering these interconnected dimensions (O'Grady, 2023).

Incorporating sustainability issues into school curricula faces complex challenges that require a more structured and integrated approach. Among these, knowledge fragmentation and subject compartmentalization hinder the development of a holistic and interconnected understanding among students (Parry and Metzger, 2023; Othman et al., 2024). It is commonly observed that many environmental education projects in schools are implemented in isolation, often tied to commemorative dates, thereby limiting their pedagogical potential. Such fragmentation not only disrupts continuity but also impedes critical and transformative reflection on socio-environmental issues, restricting the development of educational practices that could lead to meaningful changes in students' relationships with their environment (Figueiró and Raufflet, 2015; Sass et al., 2020).

Lima and Pato (2021) point out that the most common approaches in environmental education projects tend to follow naturalistic or conservationist practices, including activities such as gardening, waste sorting, and reducing water and energy consumption. Studies on environmental education programs show that outdoor activities and conservation-oriented practices may positively affect pro-environmental attitudes and behaviors. However, when centered mainly on individual actions, such initiatives often remain insufficient to develop critical ecological awareness or address the structural causes of socio-environmental problems (Baierl et al., 2021; Cincera et al., 2023).

Implementing more integrated and reflective educational strategies can provide environmental education that moves beyond individual behaviors and fosters structural change with positive community impacts (Cebrián and Junyent, 2015; Cincera et al., 2023). Conradt and Bogner (2022) highlight the prevailing focus on acquiring scientific knowledge and skills, often harming crucial ESD elements such as the promotion of ethical values, positive sustainability attitudes, and emotional awareness.

Although initiatives linked to environmental programs are important, they must be accompanied by a critical perspective that considers power relations, social dynamics, and the political dimension of human-environment interactions (Jacobi et al., 2016; Kopnina, 2020a; 2020b; 2020c; Berg and Verster, 2023; Hamwy et al., 2023). Sass et al. (2020) argue that isolated knowledge seldom results in actual behavior change or effective environmental action.

According to the authors, it is essential to develop action competence, where individuals are not only informed but also prepared and motivated to act consciously and intentionally in addressing the root causes of environmental problems rather than merely their con-

sequences. "Competence," in this context, implies the ability to participate actively and meaningfully in solving environmental challenges, going beyond automatic or repetitive behaviors. Meaningful environmental action must be based on informed, deliberate decisions aimed at transforming the structural roots of environmental crises. Sustainability competence thus involves not just basic habits like saving energy or recycling but active engagement in initiatives that reshape broader production and consumption systems at local, regional, and global levels (Olsson et al., 2022).

Competency-based education has become a dominant paradigm in educational reforms, including in Brazil. Although often presented as innovative and student-centered, it tends to emphasize skills associated with employability, productivity, and adaptability to labor market demands (Perrenoud, 1999). From the perspective of critical pedagogy and critical environmental education, this orientation may reinforce an instrumental rationality that reduces education to technocratic training and weakens its ethical, political, historical, and ecological dimensions (Arrais and Bizerril, 2020; Kopnina, 2020a). In this sense, Giroux (1986) and Freire (1996) help frame competency-based education as part of a broader process of educational depoliticization, in which critique, dialogue, and collective knowledge construction are displaced by standardized and measurable practices. Critical environmental education, in contrast, advocates an educational praxis committed to socio-environmental justice, cultural diversity, participatory democracy, and ecological responsibility (Sauvé, 2005).

Therefore, it is necessary to critically examine the conceptual foundations of competency-based education and its implications for human development. Education must not be reduced to a process of functional adjustment to the market but should instead be understood as a space to produce meaning, the strengthening of autonomy, the collective construction of knowledge, and ethical and political engagement with the world. Critical environmental education urges us to rethink the role of schools, curricula, and the pedagogical act itself, reaffirming the centrality of life, community, and care for the commons in an era marked by environmental degradation and social exclusion.

Teacher training for Education for Sustainable Development

Sass et al. (2024) address the implications of ESD and teacher training, emphasizing the need for adequate preparation of educators, both during initial training and throughout their careers. Their research highlights that high school students do not clearly perceive the implementation of ESD, and that teachers often feel unprepared to address this task.

A study conducted by Hamwy et al. (2023) in Qatar investigated curricular, cultural, and environmental challenges associated with teaching sustainability, based on the responses of 981 public and private school teachers. The study presents a dual perspective on teaching ESD and the SDGs. First, it highlights the various challenges that

arise when addressing these topics, underscoring the necessity of tailoring pedagogical approaches to the specific needs of countries and schools. Second, the findings reveal disparities between teachers in public and private schools, serving as a reminder not to generalize the challenges educators face without considering differing educational contexts. A notable issue identified was the scarcity of professional development opportunities tailored to the specific needs of educators teaching these topics.

Brandt et al. (2019) discuss what it means to become a teacher in the field of ESD, identifying several key aspects of pedagogical content knowledge that go beyond technical skills and traditional subjects. They argue for a holistic approach that fosters attitudinal change. Although the literature on ESD has yet to reach consensus on the specific components of professional competencies, various perspectives emphasize crucial elements. Among them, pedagogical content knowledge is essential in teacher education, as it enables educators to adapt sustainability content to diverse educational contexts and to design learning units that encourage active student participation. According to the authors, teachers must have a profound understanding of the complexity and interconnectedness of sustainability issues and be able to present them in a way that students can apply in real-world situations.

The capacity of teachers to promote attitudinal and behavioral change, fostering critical reflection and a more sustainable worldview, can be contextualized through the ideas of Paulo Freire (1970), particularly concerning teacher training and critical consciousness, as teachers bear the responsibility of reflecting critically on what, why, and how they teach.

Another important element identified in studies on teacher education is the expanded understanding of the concept of sustainability, reinforcing the need for ongoing opportunities throughout training programs (Olsson et al., 2022). Learning must be a continuous process, with multiple opportunities to develop competencies at different stages of academic training, allowing teachers to feel confident in implementing ESD in their pedagogical practices (Conradty and Bogner, 2022; Othman et al., 2024).

Early childhood educators in public schools in Curitiba, Brazil, report that they often rely on the internet to plan environmental education activities, despite uncertainties regarding the reliability of the sources. The teachers expressed a strong desire for trustworthy materials, continued education courses, and opportunities to exchange experiences with peers to enhance their pedagogical practices (Rodrigues and Saheb, 2019).

The lack of institutional support and insufficient resources are significant factors that hinder teachers' participation in ESD initiatives. The absence of adequate support, such as continued training programs, appropriate teaching materials, and incentives to integrate ESD into teaching practices, leads many educators to feel demotivated or ill-

equipped to implement meaningful changes in their classrooms (Qablan, 2018; Parry and Metzger, 2023).

In the Brazilian context, teacher education for sustainability has been the subject of numerous studies that reveal structural and epistemological tensions. Authors such as Tozoni-Reis (2002) and Layrargues (2020) emphasize that teacher education in Environmental Education often oscillates between conservationist approaches and a critical perspective, the latter being essential for addressing socio-environmental crises. Studies such as those by Jacobi et al. (2016) indicate that, despite advances in curricular guidelines, a gap persists between the discourse of sustainability and effective pedagogical practices in schools, reinforcing the need for continuing education policies that articulate theory with school reality. Furthermore, research conducted by Tozoni-Reis and Campos (2014) shows that the integration of the environmental dimension into teacher education is still treated in a fragmented manner and is often limited to isolated projects, aligning with the structural challenges identified by Qablan (2018) and Parry and Metzger (2023) in the international context.

A critical document that shapes teacher education and curriculum in Brazil is the National Common Curricular Base (BNCC). Although the BNCC includes environmental themes under the "Environment" macro-area, its approach has been strongly criticized for promoting a superficial and fragmented insertion of sustainability. Nepomuceno et al. (2021) argue that by treating environmental education as a transversal theme without mandatory integration into core subjects, the BNCC reduces its transformative potential and reinforces a conservative, behaviorist view. Lima and Pato (2021) further note that the obligatory inclusion of environmental topics often results in tokenistic practices, disconnected from the school community's real needs and lacking critical depth. Moreover, the BNCC's underlying logic is deeply aligned with competency-based education, emphasizing measurable outcomes and individual skills rather than collective, political, and ethical dimensions of socio-environmental issues. This orientation directly conflicts with the principles of critical environmental education, which demands that teacher training foster autonomy, participation, and a systemic understanding of ecological and social interdependencies.

Consequently, despite the official recognition of environmental education in Brazilian policy, the BNCC's framework creates institutional barriers that hinder the meaningful integration of ESD into teacher education. Teachers are left without clear guidance, adequate preparation, or institutional support to develop critical, context-sensitive pedagogical practices. This gap is further exacerbated by precarious working conditions, lack of time for collaborative planning, and the absence of continuing education policies that coordinate theory with school reality. Addressing these structural obstacles is essential if teacher education is to move beyond the rhetoric of sustainability toward a genuinely transformative praxis.

Interdisciplinarity and transversality in Education for Sustainable Development

Rieckmann (2018b) emphasizes that teachers should develop disciplinary, interdisciplinary, and transdisciplinary perspectives on ESD. In this context, interdisciplinarity involves collaboration among different disciplines, integrating their perspectives, theories, and methods to develop a more comprehensive and holistic understanding of problems. Transdisciplinarity, on the other hand, goes beyond academic boundaries, involving stakeholders with practical knowledge outside the academic sphere, such as professionals, policymakers, and community members. For instance, in a sustainable development project, alongside teachers and researchers, local farmers or community leaders may contribute practical knowledge to understand and address the issue (UNESCO, 2017a).

According to the National Education Council, transversality and interdisciplinarity are complementary but distinct concepts (Brasil, 2019). Interdisciplinarity refers to a knowledge production approach that organizes didactic-pedagogical work by integrating themes and thematic axes into conventional school subjects. Transversality, in turn, is a pedagogical orientation that links systematic knowledge to real-life issues, fostering learning that connects theoretical knowledge to practical reality. Thus, while transversality provides a framework for applying knowledge to students' daily lives, interdisciplinarity concerns the structural interconnection among disciplines.

Godemann (2006) proposes a theoretical classification of interdisciplinarity and transdisciplinarity according to different levels of integration among disciplines, leading to distinct forms of scientific cooperation, each with specific demands regarding communication, challenges (Chart 2).

In practice, interdisciplinarity often remains limited to isolated projects, such as cultural weeks or semester-end exhibitions, without sustained integration among disciplines. This limitation is reinforced by rigid schedules, standardized assessments, and insufficient teacher preparation for collaborative planning. Transdisciplinarity, in contrast, represents a shift beyond the boundaries of science and society (Moraes, 2015). It challenges academia to leave its comfort zone and recognize other ways of producing knowledge. Yet, it requires a higher degree of ethical and methodological commitment, valuing often marginalized or discredited knowledge systems. Both approaches offer critical responses to contemporary challenges but differ in scope and implications: interdisciplinarity refines science, while transdisciplinarity seeks to transform reality alongside science.

In BNCC, six thematic macro-areas relate to ESD and are reflected in 15 transversal contemporary themes, including Environmental Education and Consumer Education under the "Environment" macro-area (Brasil, 2019). Although the legislation presents transversality as a pedagogical guideline, critics argue that the BNCC promotes a political and epistemological weakening of Environmental Education. Nepomuceno et al. (2021) argue that, when Environmental Education is incorporated in a peripheral and non-mandatory manner within core subjects, it loses its transformative potential and is reduced to behavioral and conservationist practices.

For example, Lima and Pato (2021) observe that requiring schools to incorporate environmental themes may result in a superficial and obligatory approach that truly fails to engage the school community. Finally, the research indicates that, despite the official endorsement of critical education, the school system frequently maintains conservative and oppressive components that restrict the roles of teachers and impede participation in environmental education.

Chart 2 – Comparison between Interdisciplinarity and Transdisciplinarity.

Element	Interdisciplinarity	Transdisciplinarity
Definition	Integration of different scientific disciplines around a common problem	Integration of scientific and non-academic knowledge to address complex and socially relevant issues
Nature of the problem	Nature of the problem	Nature of the problem
Participants	Scholars from various scientific fields	Scholars from various scientific fields
Main goal	To produce more robust and critical knowledge within science	To generate practical, socially relevant solutions to complex issues
Knowledge integration	Integration of methods, theories, and approaches across disciplines	Co-construction of knowledge between science and practice: situated knowledge
Expected outcomes	Theoretical innovation, scientific advancement, and new perspectives on academic problems	Social transformation, community empowerment, and applied solutions with social legitimacy
Challenges	Superficial integration risks juxtaposition without synthesis	Difficulty reconciling distinct logics (scientific vs. practical); risk of diluting scientific rigor
Transformative potential	Internal science strengthens disciplinary evolution and critical exchange	External to science: fosters knowledge democratization and collective decision-making

Source: Adapted from Godemann (2006).

While ESD promotes a profound transformation in thinking, learning, and acting, it values both interdisciplinarity and transdisciplinarity. Nevertheless, there are important critiques of both concepts regarding their real-world applicability, ethical depth, and commitment to social transformation.

Interdisciplinarity is often criticized for being superficial. While it may be promoted as an innovative approach, it often results in the mere juxtaposition of content from different disciplines without true integration. This undermines the systemic perspective that ESD advocates by perpetuating the compartmentalization of knowledge. Furthermore, even in interdisciplinary projects, there is often a dominance of traditionally prestigious disciplines such as natural and exact sciences, marginalizing human and social sciences, fields critical to understanding the ethical, political, and cultural dimensions of sustainability (Sousa and Pinho, 2021). Institutional resistance also plays a role, as curricula and evaluation systems remain heavily discipline-based, impeding meaningful interdisciplinary practice.

Transdisciplinarity, although more aligned with ESD's transformative principles, also faces criticism. A recurring concern is the romanticization or instrumentalization of traditional or practical knowledge, often incorporated without genuine ethical dialogue and horizontal collaboration. Additionally, transdisciplinary approaches frequently encounter institutional and methodological obstacles.

Effective university-society collaboration requires time, political will, and openness to conflict, elements not always present in educational contexts. ESD warns against excessive relativism: in attempting to integrate diverse knowledge systems, there is a risk of weakening the scientific rigor necessary for responsible and sustainable solutions. Moreover, transdisciplinary processes may mask inherent socio-environmental conflicts by promoting artificial consensus, ignoring power disparities, accessing inequalities, and representation gaps.

In basic education, interdisciplinarity and transdisciplinarity are often promoted rhetorically as desirable, innovative paths to make learning more meaningful, contextualized, and connected to students' lives. However, their implementation faces numerous structural, pedagogical, and cultural barriers that deserve critical examination.

Although curriculum guidelines and pedagogical projects encourage interdisciplinarity, it often remains limited to isolated projects such as cultural weeks or semester-end exhibitions. These efforts, while well-intentioned, frequently lack deep integration due to rigid disciplinary schedules and standardized assessments.

Many educators have not received initial or ongoing training in interdisciplinary work (Silva et al., 2018). This lack of preparation creates insecurity and hampers teacher collaboration, especially in precarious working conditions. Still, interdisciplinary teaching is both important and feasible when grounded in real, contextualized problems that mobilize diverse areas of knowledge toward a common, meaningful goal.

Transdisciplinarity, with its more radical intent to break disciplinary boundaries and integrate academic and popular knowledge, faces even greater obstacles in basic education. Historically, schools have been designed to deliver disciplinary content and prepare students for standardized assessments. School culture often devalues community knowledge and students' lived experiences, maintaining a gap between schooling and social reality.

Genuinely transdisciplinary projects require community dialogue, active listening, democratic management, and time for collective reflection, conditions not easily found in schools burdened by work overload, performance pressures, and limited curricular autonomy. Additionally, there is a tendency for some initiatives to adopt transdisciplinarity as a pedagogical trend without implementing real transformative practices.

Based on the thematic analysis of the selected corpus and on the discussions developed in the theoretical framework, five interrelated analytical dimensions were identified: conceptual, pedagogical, institutional, political, and teacher education related. These dimensions synthesize the main gaps in the literature and indicate their implications for teacher education (Chart 3).

Conclusion

Considering the reflections presented, it is possible to affirm that ESD, although widely disseminated in international and educational discourse, reveals significant limitations when critically analyzed. Its implementation has often been restricted to isolated and behavioral practices, disconnected from a more profound understanding of the

Chart 3 – Thematic synthesis of the main gaps identified in the literature and their implications for teacher education.

Dimension	Main gaps identified	Implications for teacher education
Conceptual	Predominance of anthropocentric and economic approaches	Need to discuss strong sustainability, ecological justice, and planetary health
Pedagogical	Emphasis on behaviorist practices and individual actions	Teacher education should move beyond isolated practices and promote critical analysis of social structures
Institutional	Rigid and fragmented curricula	Need for institutional support for interdisciplinarity and transdisciplinarity
Political	Hegemony of neoliberal and competency-based logic	Teacher education should recover the ethical, political, and emancipatory dimensions of education
Teacher education	Curricular fragility and insufficient continuing professional development	Need to systematically integrate ESD and critical environmental education into teacher education programs

structural causes of the socio-environmental crisis. By privileging individual actions, such as recycling or resource conservation, without fostering a critical analysis of social inequalities, the dominant economic model, and power relations, ESD runs the risk of reinforcing an adaptive and superficial view of sustainability.

The centrality of the competency-based logic in the organization of school curricula also contributes to this critical void, as it transforms education into a functionalist instrument aimed at producing “efficient” individuals for the labor market, at the expense of ethical, political, and ecological formation. This rationale, aligned with the neoliberal project, depoliticizes education and diminishes its transformative potential, reducing knowledge to an instrumental resource and the school to a space for reproducing hegemonic norms.

As demonstrated in the analysis of the Brazilian context, this tendency is exacerbated by the BNCC, which, despite incorporating environmental themes, does so in a fragmented and non-mandatory manner, reinforcing a behaviorist approach and failing to provide teachers with the necessary support for critical, interdisciplinary work.

In this context, teacher education emerges as a point of both tension and potential. Many educators report feeling unprepared to incorporate ESD in a critical and meaningful way, which underscores the urgent need to rethink teacher training processes. Both initial and continuing education must promote the development of ethical-political competencies, pedagogical sensitivity, and a systemic vision so that educators may act in a contextualized and transformative manner.

However, this requires overcoming institutional barriers that are often overlooked in policy discourse: precarious working conditions, the absence of consistent continuing education policies, and a school culture that resists interdisciplinarity and community engagement. Without structural changes that address these dimensions, even well-intentioned training initiatives risk being neutralized.

The proposal for transdisciplinarity arises as a necessary path to overcome the fragmentation of knowledge and the disciplinary rigidity

that still marks most educational institutions. However, its effective implementation requires time, autonomy, active listening, and institutional support, conditions often absent in the daily life of schools. Thus, affirming the value of transdisciplinarity and critical environmental education is not sufficient; it is essential to confront the material and political conditions that enable—or block—their realization. The study’s findings indicate that, without a simultaneous effort to transform curricula, assessment systems, and school management structures, these approaches tend to remain at the level of rhetorical innovation.

In contrast to the limits of hegemonic ESD, critical environmental education offers a perspective that is more committed to social transformation. By valuing situated knowledge, engagement with local territories, environmental justice, and democratic participation, this approach broadens the horizon of educational practice. It calls upon teachers and students to recognize their ecological interdependencies, their collective responsibilities, and the need to act politically in the face of the multiple crises we face. Nevertheless, as this study has shown, a critical perspective cannot be reduced to a set of pedagogical techniques; it requires an explicit political positioning in teacher education, one that challenges the productivist logic embedded in current curricular policies and reclaims education as a space for questioning the socio-environmental order.

Thus, education aimed at sustainability cannot be reduced to proper behavior or curriculum targets. It must be a practice committed to the construction of meaning, the defense of life in all its forms, and the promotion of a more just, solidaristic, and environmentally responsible society. It is within this horizon that ESD must be reconfigured, not as an adaptive discourse, but as part of an emancipatory educational project. Future research should further investigate how teacher education programs can, in practice, articulate critical environmental education with transdisciplinary approaches while navigating the institutional constraints identified here, and what policy changes at the national and local levels would be necessary to sustain such transformations.

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