

Transdisciplinary teacher education: A theoretical framework to address socio-environmental complexity

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Abstract

This essay examines the theoretical underpinning and methodological implication of integrating transdisciplinarity into teacher education to strengthen public policy in education to address the complex socio-environmental challenges of the 21st century. Drawing on complexity theory and transformative learning frameworks, we argue that traditional disciplinary boundaries are increasingly insufficient for tackling multifaceted issues such as climate change, social inequality, and technological advancement. Transdisciplinarity, by integrating diverse knowledge systems including scientific, ancestral, and artistic wisdom, offers a more holistic framework for understanding to these complexities. This approach fosters critical thinking and problem-solving skills in teacher education, enabling them to develop innovative pedagogical strategies that bridge knowledge gaps and promote holistic student learning. The essay concludes by highlighting the crucial role of transdisciplinarity in shaping education policy that empowers teachers as facilitators of knowledge sharing and agents of positive social and environmental change.

Keywords: environmental education; epistemology; knowledge transfer; philosophy education; teacher education.

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1 Introduction

The 21st century, marked by the increasing complexity of socio-environmental issues, necessitates a re-evaluation of the structures of societal knowledge dissemination. The current postmodern era is characterized by the prevalence of multifaceted crisis, including natural disasters, climate change, poverty, hunger, migration, social inequality, unemployment, and terrorism, among other civilizational challenges (Hagan & Wassink, 2020). In this scenario, the educational sciences approach to teacher education aims to create new epistemological horizons that allow theoretical and methodological innovation in the didactic strategies of the social and experimental sciences, as well as in the processes of knowledge exchange.

In many higher education contexts, particularly those shaped by rigid curricular structures and evaluation systems centered on disciplinary specialization, teacher education may prioritize disciplinary content mastery over reflective and integrative learning. While numerous institutions promote critical thinking and civic engagement, other settings continue to reproduce fragmented models of knowledge production that limit the articulation of complex socio-environmental issues. Recognizing this heterogeneity is essential to avoid reductive interpretations and to situate transdisciplinary education as a response to specific institutional and epistemic constraints.

Authors such as Morin (1996) and González and Toledo (2020) concur on the existence of a paradigmatic crisis that precipitates the fragmentation of knowledge, hyper-specializes disciplinary areas (Estrada-García, 2020) and affects how social, political, economic, and educational problems are approached and discussed. In this context, Morin (1996) advanced the concept of complex thinking as an alternative to the paradigmatic crisis. At the end of the 20th century, Morin focused on the idea of integrating diverse methods to address such issues without isolating their elements, i.e., without reducing the inter-systemic complexity that connects them. Likewise, he supported the bidirectional relationship between subject-object involved in the research process.

The primary challenge of education lies in transcending the traditional paradigms that govern the creation and innovation of science, thereby creating spaces to discuss holistic methods that enable the articulation of knowledge. Consequently, the analysis focuses on the diversity of methods, techniques, and strategies that are used for teaching, that is, to create and innovate knowledge in the context of formal education within contemporary societies. Therefore, it is pertinent to ask: How are contemporary societies called to create and innovate knowledge

in the era of Artificial Intelligence (AI)? What methods are considered valid for the creation and innovation of knowledge? Is the traditional method of modern science still valid, or has it become obsolete with the discovery of quantum physics? What are the challenges of the knowledge and information society in the digital era?

For this reason, the integrated understanding of the knowledge that circulates in the academic context, based on the transdisciplinary approach, demands the adoption of methods, models, or approaches that encourage dialogue between the institutions responsible for knowledge creation and innovation. This approach helps establish consensus among institutions to ensure the methodological rigor through which new knowledge is generated.

Transdisciplinarity (TD) is not a science or a scientific discipline; rather, it is a philosophical, methodological, and epistemological approach that enables the organization of ideas from various scientific disciplines, as well as other epistemes emerging outside formal scientific domains. Likewise, in the field of scientific research, TD functions as an epistemological orientation that enables dialogue for systemic intervention in complex problems (POHL, 2011). The TD approach creates conditions for mutual recognition, reflexivity, and co-interpretation when confronting complex social and environmental problems. TD is applied in several areas such as social sciences (Brammar, 2023), engineering (Sharunova, et al., 2022), environmental sciences (RILEY & PROCTOR, 2022), and arts and humanities (Przymus, 2023). These applications aim to elucidate the complex elements that constitute the problems under study in each of these areas.

Furthermore, it is important to consider McGregor's (2023) analysis, which identifies three epistemological currents that drive research processes and provide theoretical and methodological assumptions for this application across different areas of study. The Nicolescuian school began in 1985 with the founding of the International Center for Transdisciplinary Research (CIRET) in France. This current is distinguished by its foundation on three axioms: ontology, epistemology, and logic (Nicolescu, 2002). Meanwhile, the Zurich current focuses on addressing problems in a collaborative, grounded in the science-society relationship, and is characterized by a practical approach (Klein et al., 2001). The goal of this approach is to propose innovative solutions to real-world problems, maintaining that knowledge is created or innovated in the context of its application (Nowonty et al., 2001). The third approach, the Brazilian school, views TD as enabling the holistic understanding of reality, a process

called *holopraxis*. This process consists of two aspects: (a) synthetic methods (subjective: emotions and intuition) and (b) analytical methods (objective: sensation and thinking) (Mcgregor, 2023, p.3). It relates to the other approaches by seeking to create or innovate knowledge applied to the understanding of complex problems (Da Costa, 2022).

In this essay, epistemological elements of the three approaches are utilized to explain the fundamental reasons that support the implementation of the TD approach in teacher education. These three approaches can also be conceived as three generations, where a fourth generation is likely to emerge, integrating technological advances and AI into new phenomenological interpretations. Initially, the focus is on promoting transdisciplinary education through the implementation of innovative didactics for knowledge dissemination, accompanied by the transdisciplinary philosophy in the understanding of environmental issues: from sustainability to the regenerative paradigm. In this context, this essay argues that TD is a critical approach within teacher education, as it enables the complex understanding of the everyday problems faced by humans.

2 What is transdisciplinary education?

The proposal for an education based on the TD approach aims to transcend disciplinary confinement, which has caused the fragmentation of knowledge and led to a “disciplinary big bang” (Nicolescu, 2002). While some institutions promote the development of problematizing capacities and ethical-political engagement oriented toward social participation, other academic contexts exhibit disciplinary rigidity, particularly through inflexible curricular structures, evaluation systems centered on rote content mastery, and accreditation logics that narrow the educational horizon. These dynamics are sustained by an educational rationality that often adheres to a mechanistic model characterized by hyper-specialized content within a single area of knowledge. From this perspective, the critical thinking promoted in universities is marginalized, as the educational process focuses on transmitting information functional to specific labor market roles. In the workplace, professionals execute actions under a linear cause-effect paradigm, lacking the critical reasoning that should have been cultivated during the learning process. This occurs because it is an educational system “founded on the values of another century, increasingly out of sync with contemporary changes” (Nicolescu, 2002, p.102).

In this context, traditional education is often characterized by a pedagogy of ‘truth’. This instills a societal belief that new knowledge is absolute and unquestionable,

a notions that permeates different fields and disciplines (chemistry, biology, physics, mathematics). Consequently, students often passively accept this reality, believing they are being educated on the basis of immutable truths, which implies less intellectual effort from them.

A clear example in the experimental sciences is the teaching of the Big Bang Theory, which is often presented without sufficient discussion of its historical development, theoretical debates, or epistemological limits. In some cases, educators reiteratively explain the origin and evolution of the universe, without discussing its argumentative or theoretical gaps. Critically, they fail to explain how this theory came to dominate the international debate over other theoretical proposals, effectively becoming dogma. However, a philosophical examination reveals that this theory is not an absolute truth. A TD approach does not seek to discredit scientific knowledge, but to contextualize it, inviting future teachers to engage with scientific theories as evolving interpretations rather than as immutable truths.

This mechanistic conception of teaching fosters the formation of passive teachers, who do not question received instruction and merely repeat textbook content. This complacency impedes the resolution of everyday problems, as the educational process fails to address the actual needs of the students' own contexts. This highlights a critical deficiency in universities: educating professionals who lack the necessary knowledge to address specific societal problems.

Addressing the urgent need for new educational pathway driven by complex thinking requires adopting the theoretical, epistemic, and methodological approach of transdisciplinarity is addressed. This concept gained global prominence with UNESCO (2002), through the Management of Social Transformations (MOST) program. Within this program, Discussion Paper No. 70, titled *Transdisciplinarity and Complexity in Social Analysis* (Carrizo et al., 2004), was produced to stimulate reflection on new forms of knowledge production, based on the historical context of social thought, transdisciplinarity perspectives, and research.

In the field of anthropology, Paul (2003) published *Formation du Sujet et transdisciplinarité*, arguing that TD is an epistemology that integrates the object with the scientific subjects, transcending isolated disciplines. Other prominent scholars, including Moraes (2020), Pohl (2011), and Darbellay (2015), contribute to raising societal awareness of transdisciplinarity. They demonstrate that a new understanding of coexisting phenomena is possible across diverse

fields such as medicine, politics, economics, engineering, education, and the environmental sciences.

Given the challenges faced by the educational system and the obsolescence of traditional didactic and pedagogical models, an education that embraces complexity and generates new knowledge is imperative. This is possible through the promotion of a transdisciplinary education, which transcends disciplinary approaches and recognizes the multidimensionality and intrinsic dynamism of the phenomena interacting in the formation of human beings (Daneshpour & Kwegyir-Afful, 2022).

Generating interest in transdisciplinary education requires cultivating the philosophy of transdisciplinary research in teacher education. This involves managing knowledge through diversity and overcoming disciplinary barriers via a dialogue of knowledges. This perspective posits that education aims for societal transformation, focusing on the understanding of the human being from the biological, psychological, philosophical, and social perspectives.

Transdisciplinary education is inherently “practiced not only in educational institutions, from preschool to university, but also throughout life and in all places of life” (Nicolescu, 2002, p.111). Its epistemology is based on an ecology of knowledge, where scientific inquiry interacts with the knowledge of different cultures. This vision helps to rethink the pedagogical and didactic act. It is important to emphasize that TD is not considered a new discipline; therefore, transdisciplinary thinkers are not ‘new’ specialists.

Educating through transdisciplinarity entails transforming the teaching and learning process into a dialogic and dynamic stage. Consequently, a formative process is promoted in which teaching and learning are experienced in a constant and evolutionary way, at every moment and in any circumstance (Tubay-Zambrano & Estrada-García, 2024). To manage knowledge from a TD perspective within educational institutions, it is essential to establish research networks composed of both faculty and students. Within these networks, the educator guides the student by implementing diverse transdisciplinary methodological constructions that empower learners to navigate the uncertainties of the unpredictable world we inhabit. Furthermore, educating transdisciplinary educators necessitates an intercultural, decolonial and biocentric approach, as these are understood to be constitutive principles.

Within transdisciplinary teacher education, interculturality is understood as the coexistence of heterogeneous elements, identities, and forms of knowledge that neither merge nor cancel one another; instead, they remain in a productive, conflictive, and creative tension that preserves difference. This stance involves inhabiting the epistemological conflict emerging from incommensurability, without resolving it through totalizing or homogenizing syntheses (Rivera, 2010). A decolonial perspective further problematizes the historical power relations that have shaped the hierarchization of knowledge, emphasizing the need to challenge the epistemic exclusions reproduced in educational institutions, particularly those that hierarchize bodies and dictate the production of meaning (Segato, 2015). Biocentrism, in turn, challenges anthropocentric assumptions by affirming the intrinsic value of all life forms, thereby expanding the ethical horizon of teacher education toward ecological responsibility (Gudynas, 2015). Collectively, these orientations foster the development of inner spiritual self-awareness, alongside other perceptive, affective, rhetorical, poetic, epistemic, and cognitive dimensions.

3 Innovative Didactics on Environmental Education to Knowledge Transfer

The transdisciplinary philosophical approach has gained paramount relevance in education due to unprecedented global challenges, such as climate change, biodiversity loss, and the urgent need to regenerate the planet to avoid irreversible ecological points of no return (Unesco, 1997). To address these civilizational challenges, it is imperative to develop innovative didactic approaches that integrate knowledge from the social and experimental sciences through a transdisciplinary lens. While the social sciences provide an understanding of contemporary social dynamics, the experimental sciences address nature's co-evolution processes. The integration of social and natural dimensions enables the generation of multiple epistemic connections and didactic innovations in the classroom, ranging from the use of recyclable materials to AI, and the critical study of food consumption patterns.

In fact, innovative teaching and learning strategies were previously promoted in Ecuador through the Environmental Education Program (2017). This program is configured as a transdisciplinary initiative both in its design and pedagogical orientation, insofar as it enables the situated articulation of multiple ways of knowing, including indigenous wisdom, linked to values, worldviews, and relational ways of being with nature. The reference to Ecuador is introduced as an illustrative case that demonstrates how transdisciplinary principles can be operationalized within public educational policy. Its relevance lies in

the explicit articulation of environmental education with cultural diversity and situated pedagogical practices. Although its implementation was heterogeneous, the program established an institutional framework for public policies that emphasized the integration of diverse scientific disciplines with non-academic knowledge. By incorporating indigenous wisdom, the program fostered effective environmental educational practices in more than 10,000 schools (Falconí et al. 2019).

TD in environmental education involves the integration of knowledge and methodologies from various disciplines to address complex problems holistically. In line with Nicolescu (2002), transdisciplinarity functions “in, between and beyond” disciplinary boundaries to create a new framework for understanding and action. This perspective is crucial in environmental education, where problems transcend the scope of any single discipline, instead, they require a broad understanding that synthesizes the social and natural sciences.

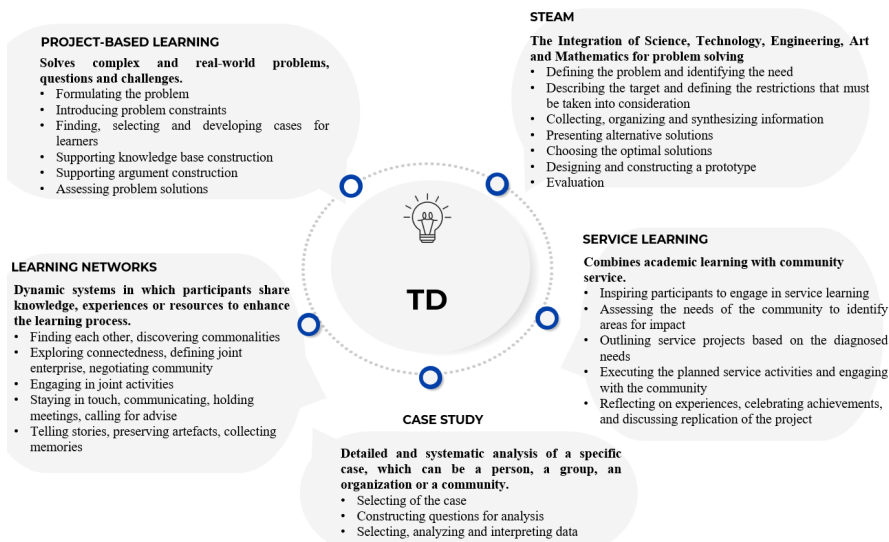
The transdisciplinary philosophical integration of social and experimental sciences facilitates the development of case studies and research projects from multiple perspectives, promoting a holistic and systemic understanding. Yin (2018) highlights that case studies are especially effective in environmental education, as they facilitate the exploration of complex problems that exceed the explanatory capacity of isolated disciplines. Such problems require the articulation of scientific knowledge with territorial and experiential perspectives, addressing phenomena such as natural disasters, pollution, biodiversity conservation, natural heritage management, ecosystem regeneration, and climate change.

Thus, the use of innovative teaching methods enhances knowledge transfer within the transdisciplinary field of environmental education, where social and experimental sciences converge. Learning networks, including communities of practice and professional consortia, enable collaboration and collaborative inquiry among educators, students, and professionals. Wenger (2010) highlights the importance of these networks for continuous professional development and the iterative improvement of educational practice. In environmental education, these networks connect students with experts and authentic projects, enriching their educational experience while fostering a deeper understanding, and commitment to environmental issues.

Finally, Science, Technology, Engineering, Art, and Mathematics (Steam) represents an educational approach that integrates these disciplines to promote practical exercises within the transversal axis of environmental education through holistic

and creative learning. Santillán et al. (2019) argue that this approach promotes collaboration among students, teachers, and professionals from diverse disciplines who co-create with the community (see Figure 1).

Figure 1 – Didactic Innovation Methodologies.



Source: Wenge (2010) and Bertrand & Namukas (2022).

As can be seen in the specialized literature, transdisciplinary education unifies the social and experimental sciences by integrating diverse perspectives and methods, resulting in a comprehensive understanding of environmental education. This approach allows researches and educators to address socio-environmental problems from multiple angles, considering both scientific data and socioeconomic or cultural factors. The use of innovative teaching methods, such as those mentioned above, facilitates the transfer of knowledge to society by making learning more interactive and accessible, thereby motivating students to apply theoretical insights within their local communities. In addition, the transdisciplinary education of teachers is crucial, as it provides them with the necessary pedagogical devices and knowledge to design and implement integrated educational programs. This prepares students to face current and future challenges in an informed and proactive manner through a transformative praxis aimed at the regeneration of nature.

4 Transdisciplinary philosophy in environmental issues: from sustainability to regenerative paradigm

Scientific consensus posits that the origins of life on Earth date back approximately 3.8 billion years, with the emergence of modern humans occurring only about 200,000-100,000 years ago. During this period, as Alliez and Lazzarato (2019) notes, life evolved strategies to survive and endure. However, human activities have degraded the natural heritage, frequently mischaracterized as a ‘natural resource’ from the Western economic perspective. The widespread pollution generated over the last centuries precipitated the Anthropocene era, characterized by substantial geological changes and divided into three phases that gradually undermined biological diversity.

According to Alliez and Lazzarato (2019), the first stage of the Anthropocene commenced in 1492 with the genocide of the indigenous peoples of the Americas, marking the onset of a subperiod termed the Necrocene. The second stage began during the late 18th and early 19th centuries with the Industrial Revolution, the advent of the steam engine, and the introduction of the dominant discourse regarding the ideal of development, solidifying the start of the Thermocene and the Anglocene. The “Great Acceleration” occurred in 1945, heralding the Thanatocene, following the atomic bombings of Japan and subsequent nuclear testing. Alliez and Lazzarato (2019) explain that these “three stages in the development of capitalism express the profound nature of the Anthropocene: the Anthropocene is a Capitalocene” (p. 308).

Neoliberal ideology promoted the hegemonic idea that poverty could be eradicated solely through economic growth, measured by Gross Domestic Product (GDP) and defined by market liberalization, privatization, and “personal freedom”. To increase GDP, an alliance with the educational sector became necessary. “Human capital” would play a crucial role in competitiveness and productivity, where schools, by focusing on strictly instrumentalist teacher training, would contribute to wealth generation.

This narrative regarding poverty soon proved flawed, especially during the late 1960s and early 1970s. In this context, Unceta (2009) identifies four critical areas: 1) unemployment, underemployment, and inequality did not decrease despite the growth in GDP per capita; 2) the environment and natural heritage deteriorated due to the technologies employed in the growth model; 3) labor productivity gaps between men and women widened in the 1970, a trend attributed to the development strategies of that time; and 4) the curtailment of freedoms and the violation of rights increased in parallel with the rise in GDP per capita.

In response to growing environmental concern, in 1977, UNESCO and the United Nations Environment Programme (UNEP) convened the First International Conference on Environmental Education in Tbilisi (USSR). For the first time, a call was issued to integrate environmental education into the curricula of all nations. Consequently, education had to be grounded on two principles: 1) a new ethic that challenges modernist ethics based on Kant's (1999) individualism and Descartes' (1987) reductionism, which legitimizes the exploitation of nature; and 2) the conception of the world as a complex, interactive and interconnected system. Nevertheless, many education initiatives continued to operate within an anthropocentric framework that prioritized human needs or assigned humans the role of protector, observer, and controller of nature, instead of considering themselves an integral part of it (Van Weelie & Wals, 2010).

Concurrently, policies (Banco Mundial, 1990; CEPAL, 1996) and development and cooperation strategies (World Food Summit, 1996) emerged, proposing greater attention to dimensions such as equity, social justice, and human well-being. This fostered the recognition that economic activity alone was insufficient for effective poverty reduction.

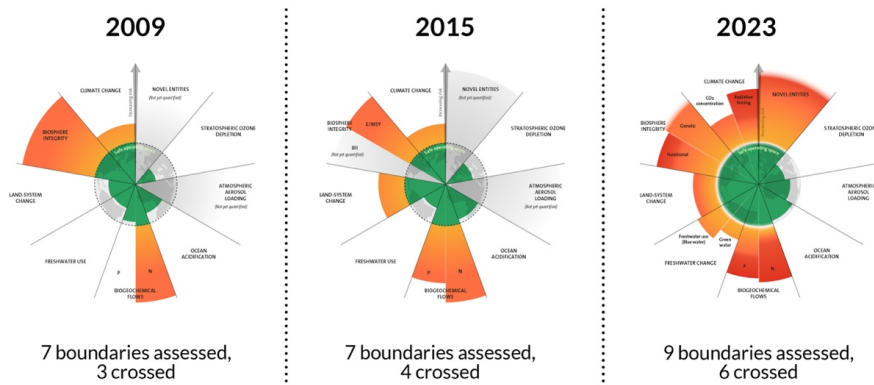
The *Shaping the 21st Century* Report (OECD/DAC, 1996) outlined seven development goals based on agreements and resolutions from various United Nations conferences, inspiring the Millennium Declaration, and the eight Millennium Development Goals (UN, 2010) proposed in 2000 and signed by 189 countries. Specifically, Goal 7 aimed to ensure environmental sustainability, defined as meeting current human needs without compromising the environment's ability to meet those needs in the future.

The main failure of the MDGs lay, paradoxically, in reiterating a problem detected in the 1960s: the exclusive focus on poverty and human deprivation. At the same time, highly relevant factors such as security and vulnerability were neglected. A sign of this imbalance was that by 2008, the "ecological overshoot" had escalated to a deficit of 50 percent; meaning the Earth required 1.5 years to regenerate renewable resources and absorb the CO₂ generated in that same year (WWF, 2012).

Following the Rio+20 Conference on Sustainable Development (2012), a major paradigm shift occurred in response to the imminent danger to the "biological support of the planet and the very survival of many societies" (Unicef, 2018, p. 67). This shift is reflected in the Sustainable Development Goals (UN, 2019),

consisting of 17 goals linked to 169 targets. The SDGs were developed with a developmental and monocultural perspective that prioritizes a single colonial matrix as universal, rooted in a Western vision imposed on the collective imagination of all countries in the world. Therefore, Collado et al. (2021) advocate for alternative epistemological, cultural, and political ways of being, living, and acting to achieve the SDGs. These alternatives aim to decolonize the foundational logic of capitalism, characterized by infinite accumulation and profit maximization, and instead foster a relational understanding of the interdependence among socioecological systems. However, critical voices have identified three major problems with the SDGs.

The first problem was the lack of binding commitments and, consequently, the absence of enforceable responsibilities, including those within the educational system. Everything was reduced to a “free voluntary commitment, beyond any legal obligation” (Vallaes, 2014). The second problem lay in the formulation of the objectives. For example, Goal 7 on Affordable and Clean Energy and Goal 11 on Sustainable Cities and Communities failed to address the structural inequity between nations and people. Goal 2, Zero Hunger, which promotes international cooperation to ensure investment in the infrastructure and technology needed to improve agricultural productivity, overlooked the fact that the agro-industrial modernization of agriculture has caused irreversible damage to ecosystems. It also failed to highlight the importance of sustainable, diversified, and small-scale agricultural practices (Müller, 2016). Additionally, the proposal to increase food production to alleviate hunger did not consider the root of the problem: inequitable food distribution and waste, effects of the concentration of power influencing the global economy (Müller, 2016). Goal 12 on Responsible Production and Consumption was restricted to the idea of prevention, reduction, recycling, and reuse, which proved insufficient because people still needed access to “cheap” water and energy to produce and recycle what they had already consumed, thus perpetuating the degenerative economic model. Thirdly, and most significantly, is the perpetuation of lifestyles that have fostered the idea of unlimited access to everything (communication, goods, etc.) at all times, the extraction of materials from the earth, their transformation according to human desires, their transient use, and subsequent disposal (Raworth, 2017).

Figure 2 – Ecosystem Points of No Return.

Source: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. (2023), Steffen et al. (2015) and Rockström et al. (2009).

The implications of these issues are profound. As illustrates in Figure 3, Rockström et al. (2009) posit that six of the nine planetary boundaries –critical thresholds– have been transgressed, making it nearly impossible to sustain life as we know it in the coming centuries. Consequently, humans currently live at the expense of the future environmental budget shared with other species (Steffen, et al., 2015). Rockström et al. (2009) highlight that the most significant anthropogenic impacts are biodiversity loss, nitrogen pollution associated with the Green Revolution, and climate change. These problems are complexly interconnected, collectively driving the global change we face. This complexity calls for moving beyond reductionist perspectives in institutions and academia, opening space for a regenerative paradigm. Yet, in certain institutional and curricular contexts, fragmented disciplinary models still persist, often at odds with critical, participatory, and socially engaged pedagogical practices.

In this regard, Collado and Malo (2019) argue that while sustainability focuses on minimizing anthropogenic harm to nature, the regenerative approach aims to maximize positive impacts through socioeconomic activities centered on restoration and revitalization. Thus, the regenerative paradigm is an epistemological approach that transcends sustainability by seeking to restore, renew, and revitalize natural and social systems. Rather than rejecting sustainability frameworks outright, the regenerative paradigm extends them by emphasizing restoration, relationality, and the co-evolution of social and ecological systems. In teacher education, this shift encourages pedagogical practices that move beyond minimizing harm

toward fostering care, reciprocity, and collective responsibility. This approach is grounded in biomimetic design principles that promote biodiversity, social equity, and collaborative innovation.

Within teacher education, the regenerative paradigm involves creating learning environments that not only impart knowledge, but also foster creativity, connection with nature, and the capacity of students to become agents of positive change. TD teacher education is crucial to advancing the regenerative paradigm. This training must integrate knowledge and methods from diverse disciplines in the natural, social, and human sciences, as well as non-scientific epistemes, enabling educators to address socio-environmental issues holistically. TD teacher education allows them to be better design curricula that incorporate regenerative principles, using innovative pedagogies that connect students with their environment and inspire them to devise solutions to the challenges they face.

Furthermore, transdisciplinary education fosters collaborative and systems thinking skills, which are crucial for addressing the complex and multifaceted challenges of the 21st century. By enhancing educators' capacity to think and teach regeneratively, it promotes an education that not only informs but transforms: empowering students to create a healthier and more equitable future. This requires an institutional commitment to educational innovation and knowledge transfer, integrating the regenerative paradigm at all levels of education. Consequently, the regenerative paradigm is considered a philosophical imperative to catalyze urgent and profound transformations in the ways individuals feel, think, and act.

Similarly, Wahl (2020) posits that the creation of regenerative systems is not limited to technical, economic, ecological, or social changes. Consequently, education for regeneration requires a profound shift in self-perception and in interpersonal and ecological relationships. Regenerative cultures seek to protect and enhance biocultural abundance for future generations and life as a whole. Merely avoiding harm is insufficient; we must heal ecosystems and, in the process, strengthen social cohesion, community resilience, and mutual support in local and regional economies. These economies depend on the functionality of the territory and reflect the unique potential of each place and its people (Wahl, 2020).

Reflecting on the field of educational philosophy, how can schools contribute to dismantling the paradigm of linear, unbounded growth? Drawing on Vallaeys (2014), achieving this requires restructuring the educational system to incorporate management practices aimed at regenerating life, considering the impact of

educational actions across diverse scenarios. In this context, it is essential to foster an ethics of responsibility to instill values aligned with a broader institutional culture committed to societal well-being.

5 Conclusions

Transdisciplinary teacher education contributes to socio-environmental transformation by fostering integrative thinking, ethical awareness, and pedagogical reflexivity. By engaging future teachers with complexity and uncertainty, it supports the development of educational practices capable of responding to contemporary challenges without reducing them to linear or purely technical solutions. The complexity emerging within current contexts, characterized by multifaceted crises such as natural disasters, climate change, poverty, hunger, migration, social inequality, unemployment, and terrorism, among other civilizational challenges, demands a transdisciplinary understanding of the processes aimed at resolving these events. Here, complexity is understood as the chaotic convergence of phenomena that induces a certain degree of disorder within each context. In this sense, a transdisciplinary approach to teacher education enhances teaching and learning processes by fostering an understanding of the elements that comprise them and by facilitating dialogue between scientific culture and others epistemologies, such as the arts. In this way, transdisciplinary intervention proposals are co-constructed to address the pressing issues facing humanity and its natural environment.

From the educational philosophical perspective of this essay, transdisciplinary teacher education is fundamental for socio-environmental transformation and ecosystem regeneration, as it facilitates the integration of knowledge and approaches from various disciplines within a holistic framework that recognizes the interconnectedness between human and natural systems. This approach not only fosters a deeper understanding of the complex relationships that sustain life on Earth but also empowers teachers to act as agents of change, promoting educational practices that prioritize environmental health, biodiversity conservation, and ecosystem regeneration. In a context of global environmental crisis, transdisciplinary education is an indispensable tool for developing critical awareness and an active commitment to the protection of the planet, fostering citizenship capable of co-creating more just and equitable societies in harmony with nature.

Furthermore, transdisciplinary education enables teachers to cultivate students' capacities to address multifaceted challenges and solve complex problems, while generating critical thinking and environmental awareness. It also encourages the

adaptation and integration of diverse curricular content to promote teamwork among teachers through initiatives aimed at combating the socio-ecological crises of the Anthropocene. The viability of transdisciplinary education depends on the pedagogical strategies implemented in praxis. The implementation of these strategies must transcend rigid disciplinary logic and ensure curricular flexibility across all levels of curricular specification. These strategies constitute fundamental elements to cultivate transdisciplinary education and foster the construction of an ethos among future teachers, aligned with civilizational challenges and guided by an ethical responsibility towards society and the environment.

Formação transdisciplinar de professores: uma base teórica para abordar a complexidade socioambiental

Resumo

Este ensaio examina os fundamentos teóricos e as implicações metodológicas da integração da transdisciplinaridade na formação de professores, a fim de fortalecer as políticas públicas em educação para enfrentar os complexos desafios socioambientais do século XXI. Com base na teoria da complexidade e nas estruturas de aprendizagem transformadora, argumentamos que as fronteiras disciplinares tradicionais são cada vez mais insuficientes para tratar de questões multifacetadas, como as mudanças climáticas, a desigualdade social e o avanço tecnológico. A transdisciplinaridade, ao integrar diversos sistemas de conhecimento, como a sabedoria científica, ancestral e artística, oferece uma estrutura mais holística para a compreensão dessas complexidades. A abordagem transdisciplinar estimula o pensamento crítico e as habilidades de resolução de problemas dos professores em processo de formação, permitindo que eles desenvolvam estratégias pedagógicas inovadoras que abordem as lacunas de conhecimento e promovam o aprendizado holístico dos alunos. O ensaio conclui destacando o papel crucial da transdisciplinaridade na formação de políticas educacionais que capacitem os professores como facilitadores do compartilhamento de conhecimento e agentes de mudanças sociais e ambientais positivas.

Palavras-chave: educação ambiental; epistemologia; gestão do conhecimento; filosofia da educação; formação de professores.

Formación transdisciplinar del profesorado: un marco teórico para abordar la complejidad socioambiental

Resumen

Este ensayo examina los fundamentos teóricos y las implicaciones metodológicas de la integración de la transdisciplinariedad en la formación del profesorado con el fin de reforzar las políticas públicas en materia de educación para abordar los complejos retos socioambientales del siglo XXI. Basándonos en la teoría de la complejidad y en marcos de aprendizaje transformativo, argumentamos que los límites disciplinarios tradicionales son cada vez más insuficientes para abordar cuestiones polifacéticas como el cambio climático, la desigualdad social y el avance tecnológico. La transdisciplinariedad, al integrar diversos sistemas de conocimiento como la sabiduría científica, ancestral y artística, ofrece un marco más holístico para comprender estas complejidades. El enfoque transdisciplinar fomenta el pensamiento crítico y la capacidad de resolución de problemas de los docentes en proceso de formación, permitiéndoles desarrollar estrategias pedagógicas innovadoras que aborden las lagunas de conocimiento y promuevan el aprendizaje holístico de los estudiantes. El ensayo concluye destacando el papel crucial de la transdisciplinariedad

en la configuración de una política educativa que capacite a los profesores como facilitadores del intercambio de conocimientos y agentes de un cambio social y medioambiental positivo.

Palabras clave: *educación ambiental; epistemología; transferencia de conocimiento; filosofía de la educación; formación del profesorado.*

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