

EPISTEMOLOGICAL AND ONTOLOGICAL FOUNDATIONS FOR A TRANSDISCIPLINARY TEACHER TRAINING¹

Fundamentos epistemológicos y ontológicos para una formación transdisciplinar de los docentes

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Abstract

The article aims to reflect on the epistemological and ontological foundations to improve teacher training in a transdisciplinary way. Framed in the field of the philosophy of education, the paper contributes to the social sciences debate on teacher training from an innovative perspective that integrates epistemic and ontological complexity. The research uses a qualitative, analytical, exploratory and descriptive methodology to identify the characteristics of the historical evolution of science. First, this evolution is explored and described with the advances of modern science based on the logical postulates derived from classical or Newtonian physics. Subsequently, the epistemic and ontological postulates of the sciences of complexity, based on the Quantum Revolution, are addressed. Then, the formative dimensions of transdisciplinary education are presented as an opportunity to rethink pedagogical theories from a critical educational philosophy. As a result, the construction and management of knowledge resulting from the dialogue between the pedagogy of complexity and transdisciplinary education is discussed. This philosophical dialogue allows theorizing the practice and practicing the theory about the challenges of teacher training in the 21st Century. Finally, it concludes with humanist and educational philosophical perspectives that promote the development of educators through the exercise of critical, complex, philosophical and creative thinking.

Keywords

Philosophy of education, History of science, Humanism, Social sciences, Complexity, Transdisciplinarity.

Resumen

Este artículo tiene como objetivo reflexionar sobre los fundamentos epistemológicos y ontológicos para mejorar la formación docente de forma transdisciplinar. Enmarcado en el campo de la filosofía de la educación, el trabajo busca contribuir al debate de las ciencias sociales sobre la formación docente desde una perspectiva innovadora que integra la complejidad epistémica y ontológica. La investigación utiliza una metodología cualitativa, analítica, exploratoria y descriptiva, para identificar las características de la evolución histórica de la ciencia. En primer lugar, esta evolución se explora y describe con los avances de la ciencia moderna basados en los postulados lógicos derivados de la física clásica o newtoniana. Posteriormente, se abordan los postulados epistémicos y ontológicos de las ciencias de la complejidad, fundamentadas en la revolución cuántica. Después se presentan las dimensiones formativas de la educación transdisciplinar como una oportunidad para repensar las teorías pedagógicas desde una filosofía educativa crítica. Como resultado, se discute la construcción y gestión del conocimiento resultante del diálogo entre la pedagogía de la complejidad y la educación transdisciplinar. Este diálogo filosófico permite teorizar la práctica y practicar la teoría sobre los retos y desafíos de la formación docente en el siglo XXI. Finalmente, se concluye con perspectivas filosóficas educativas humanistas que promueven el desarrollo de los educadores a través del ejercicio del pensamiento crítico, complejo, filosófico y creativo.

Palabras clave

Filosofía de la educación, historia de la ciencia, humanismo, ciencias sociales, complejidad, transdisciplinariedad.

Introduction

In the context of the contemporary civilizational crisis —characterized by profound socio-environmental, epistemological, and cultural transformations— it is essential to rethink the professional orientation of teacher-training processes through the lens of a transdisciplinary educa-

tional philosophy. The current global landscape demands a critical revision of the teacher profile, aimed at fostering a global citizenry capable of understanding and addressing the complexity of 21st-century socio-environmental challenges (Luong and Nguyen, 2026). As Morin (2015) suggests, an unfolding planetary crisis is exposing the limits of the Western, modern, industrial, and capitalist paradigm, thereby necessitating a radical rethinking of the relationships between humanity, nature, and knowledge. Within this context, disruptions in ecological equilibrium reveal a profound environmental crisis, wherein global systemic shifts trigger complex chain reactions (WWF, 2014). Concurrently, we are witnessing a crisis of thought that demands new ways of understanding reality through integrative approaches in dialogue with emerging currents in humanism and the social sciences. The relevance of this research lies in the urgency of transitioning toward a regenerative culture that enables educational institutions to respond ethically and effectively to the limits of modernity.

According to Norgaard (2006), these alterations in ontological reality² have transformed the continuum of matter, energy, and information that co-evolutionarily interconnects natural and social systems. Consequently, Collado (2017) emphasizes that teacher training must instill the premise that nature possesses an intrinsic right to exist, and that schools must actively restore ecosystems through a regenerative culture. For this reason, Morin (1999) argues that a comprehensive reform of thought, education, and politics is required. Aligning with this perspective, the present study delineates the historical evolution of science and explores the formative dimensions of teacher education from a transdisciplinary philosophical standpoint.

While the history of education encompasses diverse schools of thought and universities have adopted a wide array of theoretical and philosophical frameworks (Danvers, 2020; Nicolas, 2018), this study specifically adopts Morin's philosophical vision of complexity and transdisciplinarity. In *Seven Complex Lessons in Education for the Future*, Morin (2000) asserts that the scientific paradigm directly correlates with the epistemological paradigm, which subsequently shapes schooling practices for children and adolescents. Therefore, this article draws upon Morin's (2000) complex thinking to explore how the professionalization of teacher training requires the integration of theoretical advances in complexity, thereby enriching the pedagogical, epistemological, and scientific dimensions of teacher education (Lagemann, 2000). From this perspective, the study aims to examine the limits of



traditional teacher training through a reorganization of the ecology of knowledge, linking the complexity of thought with an ethic of interdependence that enables educators to co-evolve alongside 21st-century socio-environmental challenges.

In this regard, this study integrates the philosophy of education with humanism and the social sciences to understand how the epistemological and ontological foundations of complexity can enhance teacher education in addressing contemporary socio-environmental challenges. The research begins by recognizing a persistent problem: the prevalence of fragmented educational models that hinder a comprehensive understanding of socio-environmental phenomena and limit teachers' capacity to address the complexity of contemporary reality (Capra, 2010). This issue manifests as a disconnect between traditional teacher training and the demands for interdependence that characterize modern ecosystems.

In response to this situation, it is argued that transdisciplinary teacher education, inspired by complex thinking, enables the integration of knowledge, the overcoming of traditional dichotomies, and the promotion of a more holistic understanding of the world (Wilson, 1998). Thus, the study advocates that transdisciplinary training allows educators to move beyond educational reductionism, fostering a teaching practice capable of navigating global uncertainty. The relevance of this approach lies not only in the urgency of addressing current global socio-environmental challenges, but also in the need to rethink the foundations of educational knowledge during a historical moment defined by uncertainty and interdependence. Consequently, this article is structured around a review of the historical evolution of science, followed by an analysis of the contributions of the complexity sciences, and concludes with a reflection on their implications for teacher education from a transdisciplinary educational philosophy.

Method

From this philosophical perspective on education, a qualitative, analytical, exploratory, and descriptive methodology is used to identify the evolution of the epistemological and ontological foundations that have historically shaped teacher education processes. Through a review of the specialized literature on teacher training, this study demonstrates that enhancing the education of children and adolescents requires training



teachers within a critical paradigm—one that remains open to the complexity of knowledge (Piéron, 1951; Piaget, 1970). To this end, a dialogue is established between the pedagogy of complexity and transdisciplinary education, aiming to delineate the epistemological and ontological foundations that ought to be integrated into teacher education programs, particularly within the social sciences and humanities.

This approach implies the necessity of exploring forms of knowledge that elude evaluation by classical scientific methods centered on reproducibility, measurement, quantification, commensurability, or standardized assessment. To design a holistic education that integrates distinct epistemic and ontological levels, a transdisciplinary dialogue is developed between scientific knowledge and ancestral, spiritual, artistic, and emotional ways of knowing. Far from neglecting the breakthroughs and discoveries of contemporary scientific methods, this perspective seeks the opposite. The transdisciplinary methodology aims to reconcile the subject-object relationship, which has historically been bifurcated by the traditional scientific approach of logical positivism. As illustrated in Figure 1, discoveries in quantum physics demonstrate that the subject and their environment are inseparable realities within an interdependent network structured by multiple ontological levels (Bohm and Hiley, 2009).

Consequently, the methodological process seeks to define the skills, abilities, aptitudes, and training methods required by contemporary educators. From this viewpoint, the orientation of professional teaching profiles is intrinsically linked to the evolution of science, which simultaneously implies the evolution of epistemology itself (Larsen, 2012). According to Essen and Rogers (2003), teachers play a fundamental role in social transformation and technological innovation, as they actively shape the ideas, actions, and attitudes of future professionals, including engineers, architects, entrepreneurs, artists, and politicians. Finally, the history of science is examined alongside the evolution of scientific thought to discuss the design of curricula dedicated to the transdisciplinary pedagogical training of teachers.

History of Science and the Evolution of Thought

The origins of modern science date back to the 17th century, when intellectuals sought to distance themselves from the dogmatic stance of religious authorities, who dictated the nature of ontological reality

without empirical foundation. Naturally, scientific perspectives during this era were far from monolithic. While Galileo and Newton maintained that philosophy and theology remained vital frameworks for understanding reality, other pioneers of the modern scientific method, such as Bacon and Descartes, adopted a different posture. Descartes, in particular, posited that all material phenomena should be studied independently of the spiritual realm, thereby discarding subjectivity in favor of rigorous objectivity. Subsequently, European Enlightenment thinkers and positivists began to structure knowledge in a hyper-specialized manner, isolating the parts from the whole to analyze them in abstraction (Daston, 2017).

By the 19th century, positivism had solidified as an epistemological school rooted strictly in empirical experience, systematically rejecting any form of knowledge that eluded quantification, measurement, or commensurability via the scientific method. Consequently, philosophical, theological, spiritual, artistic, and emotional dimensions were marginalized from scientific discourse for centuries. This paradigm culminated during the first half of the 20th century with the “logical positivism” of the Vienna Circle—an epistemological movement that reacted sharply against idealist and speculative philosophy by asserting that true knowledge derives exclusively from the empirical analysis of facts through scientific verification (Kuhn, 1970).

Over time, modern science became deeply anchored in this reductionist framework of separation and analysis. Although this approach catalyzed unprecedented technological and material breakthroughs, it simultaneously sidelined dimensions incompatible with empirical verification, including the arts, emotions, spirituality, and indigenous ways of knowing (Malo et al., 2024; Staddon, 2018). As Leff (2001) argues, this positivist epistemology objectified nature, reducing it to a mere supplier of raw materials for industrial exploitation in perfect alignment with the *laissez-faire* ideology of speculative markets.

Almeida (2017) notes that between the 17th and 19th centuries, modern science consolidated the schism between the individual and nature—the subject-object dichotomy—by establishing three foundational postulates:

- The existence of universal laws expressed through mathematics.
- The elucidation of these laws via controlled experimentation.
- The absolute reproducibility of experimental data.

Consequently, mathematics emerged as the definitive language of this empirical-rational ideology, rapidly becoming dominant within

academic circles tasked with formulating objective theories of knowledge (Bachelard, 1977).

In broader terms, Capra (2010) underscores that the birth of modern science was inextricably linked to a philosophical evolution that culminated in an extreme formulation of mind-matter dualism. A quintessential manifestation of this positivist ethos is the analytical method articulated by René Descartes in his *Discourse on the Method* (1637). His foundational principle—*cogito ergo sum* (“I think, therefore I am”)—laid the groundwork for a substantial dualism separating body (*res extensa*) from soul (*res cogitans*), subject from object, spirit from matter, feeling from reason, and freedom from determinism (Firode, 2008).

Within the historiography of science, Lakatos (1971) explains that classical physics provided the epistemological bedrock for organizing modern scientific knowledge, conceiving the universe as a mechanistic, predictable clockwork governed by the principles of continuity³, local causality⁴, and determinism.⁴ In his critique of scientific orthodoxy, Feyerabend (1975) points out that the apparent simplicity of these three axioms captivated generations of Western rationalist intellectuals. This widespread enthusiasm drove a reconfiguration of knowledge that Morin (1990) terms the “mechanistic paradigm” or “simplification paradigm,” characterized by the fracturing of knowledge into increasingly specialized disciplines that address progressively smaller fragments of reality.

Paradoxically, Nicolescu (1996) observes that the hyper-specialization of modern science has ended up challenging the conceptual boundaries of its own reductionism. After decades under this rigid framework, disciplinary knowledge has reached its intrinsic limitations—which have reverberated into cultural and educational spheres. As Morin et al. (2003) highlight, this reductionist mindset became the axis for paradigm formulation, giving rise to the cognitive fallacy of unlimited progress fueled by the “science-industry-economy-technology” quadrimotor. These shortcomings underscore the urgency of restructuring teacher education through transdisciplinary approaches capable of overcoming knowledge fragmentation, particularly in the humanities and social sciences.

While Western epistemological reductionism undeniably facilitated significant material development, Shiva (2020) contends that the globalization of this epistemic paradigm has engendered unprecedented levels of exclusion. According to an Oxfam report (2022) published during COVID-19 pandemic, “the 10 richest men in the world possess more wealth than the 3,100 million poorest people” (p. 10)—a socioeconomic disparity that Riechmann (2014) describes as a form of “planetary apart-

heid.” Concurrently, the exponential escalation of environmental crises makes it imperative to rethink the training of 21st-century teachers, who must act as vital agents of socio-environmental transformation (UNESCO, 2015).

To address this crisis, De Sousa Santos (2010) proposes decolonizing Western thought to pave the way for “other possible worlds” that integrate a plurality of epistemes—such as ancestral practices, indigenous wisdom, arts, spirituality, and emotional dimensions—which are inherently unverifiable by standard scientific metrics. Likewise, Latour (1996) introduced the concept of “interobjectivity” to redistribute and reassemble the interaction between subject and object, correcting the artificial separation imposed by traditional methodology.

Furthermore, Cahour and Lancry (2011) note that replicating this reductionist scientific framework within educational settings has marginalized everyday human activities that cannot be experimentally tested. A stark manifestation of this systemic exclusion is the history of indigenous resistance against racist practices in Latin American and Caribbean schooling (Marker, 2009). Consequently, 21st-century educators face the challenge of revaluing and reintegrating those holistic dimensions previously relegated to the periphery of school curricula (Moignard, 2018)—a reorientation that is foundational to a transdisciplinary philosophy of education.

From a critical sociological perspective, Bourdieu and Passeron (1970) challenge the historical rigidity separating scientific knowledge from academic knowledge, viewing both as socially and psychologically constructed phenomena. Similarly, Cardon and D’Enfert (2017) argue that the history of school disciplines demonstrates they are not merely passive modes of knowledge transmission or cognitive formation, but active structures of power. According to Martin (1993), the reductionist paradigm birthed an epistemic illusion that led Western societies to revere scientific knowledge as the sole path to truth, institutionalizing its supremacy within the academic world.

Nevertheless, rather than merely devaluing positivism for its reductionist constraints, it is necessary to transition toward a complex paradigm that offers a holistic, systemic approach. Galeffi (2017) suggests that a plurality of epistemological conceptions demands a “polylogical” vision where diverse representational models coexist. While positivism isolates and fragments knowledge, transdisciplinarity builds bridges to integrate diverse dimensions (Pasquier and Nicolescu, 2019), allowing for a theo-



retical and methodological coexistence where the whole and its constituent parts are analyzed simultaneously in their reciprocal relationships.

Ultimately, Wilson (1998) suggests that the ontological complexity of human thought evolves through diverse models of knowledge management, noting that addressing reality's complexity *with* reductionist tools constitutes science, whereas doing so *without* them constitutes art. Remarkably, just as abstract art emerged concurrently with quantum mechanics, transdisciplinarity has crystallized within the historical epoch of the Anthropocene (Crutzen, 2006). Within this contemporary context, transdisciplinarity assumes critical relevance by enabling us to confront multifaceted global crises that elude isolated disciplinary fields. Consequently, the development of a transdisciplinary educational model becomes paramount for equipping future educators to navigate the complex socio-environmental challenges of the 21st century.



Epistemological and Ontological Foundations in Teacher Education

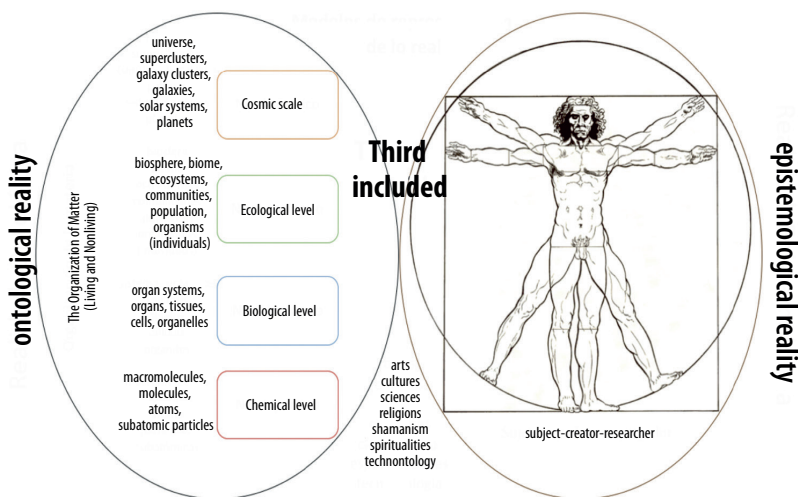
Amidst the coexistence of diverse epistemological frameworks, the complexity sciences emerge with a systemic and holistic methodological vision that complements the reductionist and specialized paradigms of modern science (Rury and Tamura, 2019). This coexistence becomes imperative in light of the structural limitations underscored by numerous contemporary intellectuals. Dussel (2006), for instance, criticizes modern science for its Eurocentric tendency to trace the origins of knowledge exclusively back to Ancient Greece, thereby marginalizing the rich intellectual heritage of other ancient civilizations, such as the Chinese, Indian, Egyptian, Babylonian, Mesopotamian, Mayan, and Incan cultures. Similarly, Popper (2005) dismantled the linear assumptions of logical positivism and the inductive method, demonstrating the inherent fallibilism of deriving universal laws from the observation of isolated fragments of reality. Concurrently, the absolute validity of the deductive method was destabilized by the incompleteness demonstrated in Kurt Gödel's mathematical theorems and Alfred Tarski's semantic logic (Morin and Le Moigne, 1999).

Consequently, no scientific theory can be regarded as definitive or complete; rather, each constitutes a phenomenological approximation of an ontological reality that is inherently transdimensional and dynamic. In this vein, the transdisciplinary theorist McGregor (2015) notes that the reductionist view of modern science historically validated only a single

level of phenomenological reality—that governed by classical physics. As illustrated in Figure 1, a comprehensive, multilevel approach bridges this dualistic divide, which traditionally conceptualized the subject's spirit and the concrete dimension of matter as independent components of reality (Jahn and Dunne, 2009). For Morin (2000), this “scientific blindness” (*aveuglement scientifique*) fails to recognize the distinct ontological and epistemological strata mediating the relationship between subject and object, thereby obstructing the appreciation of their diverse spaces of interaction (Lotrecchiano, 2012; Nicolescu, 1996).

Furthermore, Moraes (2017) argues that the evolution of scientific knowledge experienced a profound paradigm shift during the quantum revolution, which demonstrated that this specific stratum of ontological reality is actively perturbed by the observer. Indeed, the double-slit experiment illustrates that the act of conscious observation modifies wave-particle behavior and collapses the wave function, thereby materializing the particle⁶. For this reason, the complexity sciences must be understood through a non-linear epistemological lens that demands the ontological unification of subject and object. These epistemological and ontological pillars are foundational for 21st-century teacher education, as they instill a nuanced understanding of a dynamic, multidimensional reality.

Figure 1
Models representing ontological and epistemological reality



As illustrated in Figure 1, the traditional tools, postulates, and mechanisms of modern science are insufficient to grasp the full complex-

ity of coexisting ontological strata. To account for this complexity, they must be complemented by frameworks from the complexity sciences that encompass the totality of both epistemological and ontological levels of reality. Vedral (2018) explains that reality is structured across distinct tiers of organization in living and non-living matter, conceptually designated as levels of reality.

At the microscopic scale, microphysical and quantum realities operate. Microphysics is characterized by the non-separability of spacetime, simultaneity, instantaneity, indeterminacy, and overdetermination. At the quantum level, subatomic particles exhibit spatial and temporal indeterminacy, the uncertainty principle, the wave-particle dichotomy, and the instantaneous unity of the whole. Conversely, on the macrocosmic scale, the cosmic level of reality is defined by entropy, homogeneity, and continuous spacetime. Intermediary levels —specifically the biological and ecological spheres— are characterized by negentropy and the evolution of a spacetime that remains sensitive to the positioning of the subject-observer-creator (Lima and Gómez, 2024).

The discontinuous transition from one level of reality to another is governed by the logic of the “included third” formulated by Lupasco (1960). This logical principle reconciles the distinct levels of reality bifurcated by the mechanistic logic of modern science, which artificially separates waves from particles. By conceptualizing the quantum state as a simultaneous superposition of wave and particle, new logical, epistemic, and philosophical formulations of ontological reality emerge. In this sense, Nicolescu (2014) explains that the “included third” operates precisely within the intermediary space bridging ontological and epistemological reality. In other words, the logic of the included third enables the emergence of historical, representational models through which humanity constructs meaning about its environment, integrating artistic, cultural, spiritual, religious, shamanic, and scientific frameworks, alongside virtual environments and other expressive modalities.

Furthermore, it is essential to introduce a fourth decisive element in this conceptualization of reality: the observing subject. Far from being an external or neutral entity, the subject actively participates in the configuration of phenomena. As developments in quantum physics demonstrate, the relationship between energy and matter cannot be decoupled from the act of observation, given that the very process of observing alters the manifestation of that reality. This breakthrough of the quantum revolution catalyzed the emergence of the complexity sciences, prompting a radical reconsideration of the classical subject-object dichotomy



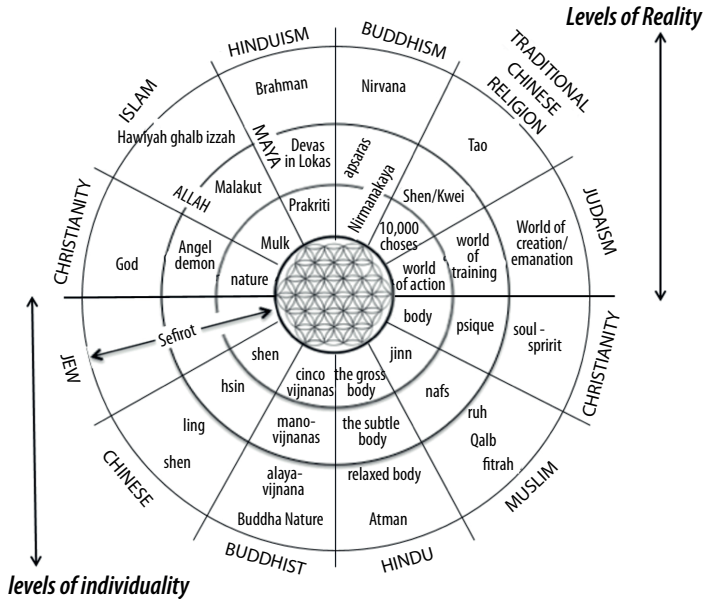
championed by positivist schools and anchored in classical mechanics. Nevertheless, the complexity sciences do not supplant the modern scientific method; rather, both paradigms operate within a shared process of co-constitution (Capra, 2010; Nicolescu, 2014).

From this philosophical perspective, knowledge ceases to be a passive representation and transforms into a situated, contextual, relational, and open experience. In the educational sphere, this shift assumes paramount relevance, compelling us to rethink teacher training beyond the fragmented frameworks inherited from modernity. Consequently, a transdisciplinary education inspired by complexity becomes indispensable within the teaching-learning processes of the social sciences and humanities. This approach equips educators with the capacity to interpret, problematize, and inhabit a multiparadigmatic, multifaceted, dynamic, and deeply interdependent reality (Collado, 2017).

Accordingly, the right-hand image in Figure 1 —derived from Leonardo da Vinci's *Vitruvian Man*— depicts human perception and agency through the distinct epistemological strata that structure and give form to ontological complexity (Sartre and Elkaïm-Sartre, 2012). Other philosophers of education, such as Krishnamurti (2012) and Montessori (2004), similarly addressed the ontological dimensions of teacher training, aiming to foster a critical awareness of a dynamic, multilevel, and multireferential reality. In a similar vein, Smith (2003) conducted an in-depth comparative study of the world's major religions, synthesized in Figure 2. This diagram features four concentric circles that illustrate the dynamics of spiritual transformation, progressing from the material substrate to the most subtle dimensions—encompassing both the levels of reality and the inner individuality of the religious practitioner.

Figure 2 takes the form of a diagrammatic mandala, featuring the Flower of Life at its center to symbolize the ancient wisdom of ancestral cultures. This conceptual framework has been expanded to encompass both epistemic (individuality) and ontological (reality) strata, revealing the interdependent and symmetrical relationships between these distinct dimensions. This configuration demonstrates that numerous cultural and religious traditions delineate analogous structures to conceptualize the spirit-matter relationship within the fabric of reality. Consequently, ontological reality manifests simultaneously within and outside the individual, given that the subject transforms their environment and vice versa (Nicolescu, 1996). This interreligious dialogue provides further theoretical support for integrating these foundational epistemological and ontological pillars into the professional development of 21st-century educators.

Figure 2
The World's Major Religions Complemented
by Levels of Reality and Individuality



Source: adapted from Smith (2003).

This integrative educational philosophy stands in stark contrast to the hegemonic positivist paradigm that currently prevails in scientific, academic, and educational institutions. It is within this restrictive context that Foucault (1975) conceptualizes schools as spaces of social and psychological confinement. Herein lies the significance of training teachers upon diverse epistemological and ontological foundations, thereby transforming schools, colleges, and universities into complex, co-evolving eco-systems (Salgado, 2021). As Heylighen (2011) explains, the recursive interactions among order, disorder, and organization generate increasingly complex systems, prompting the emergence of more sophisticated epistemic frameworks to represent ontological complexity. Hence, it becomes essential to integrate the logical, epistemic, and philosophical postulates derived from quantum physics to examine representational models of reality through a transdisciplinary lens.

In this vein, Pineau (2004) and Paul (2009) propose transdisciplinary models of human formation aimed at unifying ontological and

epistemological levels. On the one hand, Pineau (2004) explores the methodology of life histories, establishing three interconnected dimensions of human formation: *self-formation* (in relation to oneself), *hetero-formation* (in relation to others), and *eco-formation* (in relation to the natural world). On the other hand, Paul (2009) introduces *ontoformation*, arguing that human formation constitutes “the global and general process (at once particular and singular, yet also social and collective)” (p. 28). These models of transdisciplinary formation offer a multilevel framework that clarifies the epistemological and ontological foundations required to confront the planetary unsustainability facing 21st-century humanity. In this sense, a transdisciplinary approach to education facilitates a nuanced comprehension of the continuous material, energetic, and informational co-evolution that defines ontological reality.



To operationalize these constituent principles of complexity, Galvani (2002) examined popular education from an emancipatory perspective, proposing that transdisciplinary teacher training account for the history of human interactions and structural couplings within physical, social, and ecological environments. Within this framework, three distinct modalities of formative interaction between the individual and their environment are identified: a *practical* dimension linked to gesture, a *symbolic* dimension associated with the imaginary, and an *epistemic* dimension related to conceptual construction. Consequently, these three axes of interaction correspond to three levels of representational meaning: *gesture* as a sense of orientation, *image* as a sense of perception, and *concept* as a sense of meaning. Synthesized, these structural couplings shape human agency, generating representations of the world, of others, and of the self.

Ultimately, these epistemological and ontological foundations indicate that the professional profile of 21st-century educators must evolve toward a transdisciplinary educational philosophy. Within this context, a transdisciplinary model for teacher training is proposed, anchored upon:

- The integration of epistemological and ontological strata.
- A rigorous dialogue between scientific knowledge and alternative ways of knowing.
- The integration of complex thinking within educational practice.

Accordingly, research within the epistemological domain of teacher training should embrace this holistic vision, which elucidates the multidimensionality and interconnectivity of structural couplings and real-world phenomena. In this regard, universities bear a profound ethical responsibility; given their pivotal role in the production and dissemina-

tion of knowledge, they serve as vital catalysts for transforming contemporary educational models through transdisciplinary approaches.

Discussion on Transdisciplinary Teacher Education

Strengthening the philosophical foundations of education through a transdisciplinary teacher-training approach requires integrating the aforementioned epistemological and ontological pillars to comprehend the diverse levels of interaction between individuals and their environment (Galvani, 2016). According to Holzkamp (1981), it is imperative to reconceptualize teacher training and critical thinking in light of the complexity sciences. From the perspective of ergonomic psychology, Leplat and Terssac (1990) similarly assert that knowledge of complex systems plays a pivotal role in transforming educational structures and enhancing critical thinking across childhood, youth, and adulthood. Within this framework, the present proposal advocates the gradual incorporation of transdisciplinary methodologies from the complexity sciences into teacher-training curricula. By integrating knowledge from the social sciences and humanities, this approach aims to overcome disciplinary fragmentation and foster a situated understanding of educational phenomena.

Grounded in this vision of educator training, Walsh (2013) argues that postcolonial and decolonial pedagogies provide critical frameworks to rethink global governance through intercultural educational practices that facilitate both material and intellectual unlearning and relearning. This professional orientation operates concurrently as a “political-social-epistemic-ethical project and a pedagogical tool, both of which eagerly seek an educational praxis oriented toward decolonization” (p. 156). Such a decolonial pedagogical praxis draws upon the inter-epistemological dialogue emerging from the multifaceted representational models that human beings employ in relation to their reality. Consequently, teacher education must cultivate complex thinking capable of recognizing multilevel phenomena in constant interaction across local, regional, national, and global strata (Pasquier, 2019). From this perspective, it is proposed that teacher education programs systematically incorporate training opportunities focused on the critical analysis of socio-environmental issues, intercultural dialogue, and the development of reflective competencies, thereby enabling educators to position themselves as mediators between distinct levels of reality and diverse systems of knowledge.



According to Godemann (2008), integrating these diverse models of knowledge representation requires transdisciplinary cooperation. Consequently, transforming the school and academic becomes a matter of urgency, given that disciplinary hyper-specialization and fragmentation are rooted in a dichotomous understanding, a compartmentalized epistemology, and a reductionist strategy. In this regard, Guimaraes and Funtowicz (2015) underscore that a purely reductionist, positivist framework is structurally incapable of addressing either the current socio-environmental crisis or burgeoning socioeconomic inequalities. These pedagogical practices demand an intercultural political-educational commitment aimed at transforming social structures, institutional frameworks, and the objectified relationships between humanity and nature (Pasquier, 2019). Hence, the transdisciplinary approach must not be reduced to a mere integration of curricular content; rather, it entails a profound transformation of educational practices wherein knowledge is constructed relationally, structurally incorporating ethical, social, cultural, and humanistic dimensions.

Although positivist science dismantled the conception of nature as a sacred entity—a worldview central to many indigenous traditions—Kauffman (2010) argues that the quantum revolution paved the way for the complexity sciences, wherein science and spirituality can be reconciled to reinvent the sacred. As Morin and Le Moigne (1999) elucidate, the intelligence of complexity thrives on a dialogue among order, disorder, and organization. This perspective does not advocate replacing order with chaos, substituting separation for uncritical interconnection, or abandoning classical logic in favor of frameworks devoid of rationality. Instead, it involves complementing the intelligible principles of classical thought—traditionally anchored in a paradigm of simplification, univocity, and exclusion—with the generative principles of complexity, integration, and transversality (Barroso, 2018). In this sense, transdisciplinary teacher education necessitates a paradigm shift in how knowledge is conceived, moving from a logic of content accumulation to an epistemology of articulated meanings, where educators recognize themselves as active agents in the co-construction of socio-educational reality.

While reductionist thinking interprets reality by fracturing it into its most basic elements through hyper-specialized approaches, complex thinking integrates scientific knowledge with alternative ways of knowing from a transdisciplinary perspective to comprehend systemic phenomena. Similarly, transdisciplinarity draws upon specific disciplines without opposing them, choosing instead to expand and transcend their

boundaries; in like manner, complex thinking situates phenomena within a global framework without obscuring the particular, the concrete, and the individual. For Harvey and Lemire (2001), this paradigm coexistence is foundational to establishing a new model of transdisciplinary education that weaves together the intelligible principles of classical reductionism with the systemic principles of complexity. This articulation anchors teaching practice within a broader horizon, ensuring that education transcends the passive transmission of knowledge and is oriented toward the holistic development of individuals capable of critically interpreting their social, cultural, and ecological contexts.

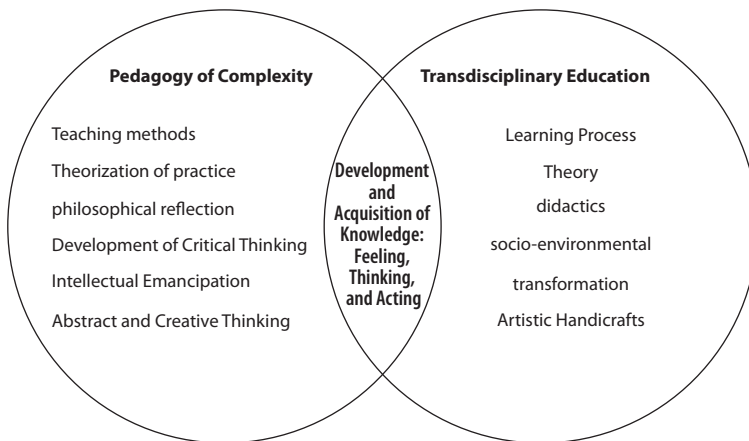
It is precisely within this integrative matrix of epistemological paradigms that transdisciplinary education emerges as an ontological phenomenon for educator training through the pedagogy of complexity (Gibbs, 2017). Transdisciplinary education functions as a principle of human formation that unifies diverse strata of ontological reality. This implies a pedagogy of complexity that harmonizes scientific reason with inner spiritual self-knowledge, indigenous worldviews, and other cognitive, perceptual, affective, rhetorical, poetic, and philosophical dimensions of the human condition (Collado, 2017). From this perspective, the educational proposal assumes a profoundly humanistic character, recognizing the multidimensional nature of human existence and the necessity of integrating ways of knowing historically marginalized by the positivist paradigm, particularly within the social and experimental sciences.

As illustrated in Figure 3, the pedagogy of complexity constitutes the theoretical-epistemological matrix for operationalizing transdisciplinary education, wherein the individual interacts interdependently with ontological reality. This interaction positions the teacher as an active agent in the co-construction of meaning, capable of articulating distinct levels of reality within their pedagogical practice. Consequently, the present proposal transcends a merely theoretical framework, highlighting the imperative to reconfigure teacher-training models through a transdisciplinary lens—incorporating a complex approach that synthesizes diverse epistemologies and ontologies to respond effectively to contemporary global challenges.

According to Dravet et al. (2019), education constitutes the pragmatic act of teaching, whereas pedagogy theorizes educational practice. Although conceptualized as distinct dimensions, they are inherently complementary; educational actions operationalize pedagogical frameworks, while pedagogy recursively theorizes upon that very practice. Ex-

tending this reasoning, the pedagogy of complexity can be defined as the systemic study and theorization of educational practice through a multi-dimensional lens, integrating the diverse elements and phenomena that constitute coexisting ontological strata. While pedagogy must leverage specialized techniques and teaching methods to facilitate specific processes—such as literacy development, reading comprehension, or mathematical logic—this complex vision enables a comprehensive education that synthesizes the ontological and epistemological dimensions of the subject-reality framework (Moraes, 2017).

Figure 3
Integration of the Pedagogy of Complexity
and Transdisciplinary Education



These philosophical reflections on education carry profound implications for teacher training, given that transdisciplinary education can be defined as an educational process that synthesizes scientific knowledge with diverse communal, artistic, and contemplative practices (Hagège, 2014). However, it is critical to avoid treating transdisciplinary educator training as a passing academic trend or reducing it to a mere superficial curricular innovation. On the contrary, the present proposal demands a paradigm shift in how knowledge is conceptualized, recognizing that teaching entails engaging with the inherent complexity of reality rather than reducing it. In this sense, preparing teachers from a transdisciplinary perspective ultimately means fostering individuals capable of thinking, feeling, and acting within a world that can no longer be explained through the fragmentation of knowledge. Consequently, this framework embraces complexity in

teacher education by conceptualizing knowledge not as a closed, static system, but as an open, relational, and continuously evolving process.

Conclusion

In conclusion, an exploration of Morin's (2000) complex thinking facilitates the integration of the epistemological and ontological foundations of the complexity sciences into professional teacher training and the humanities. Consequently, educator training must be reconceptualized through a transdisciplinary educational philosophy centered on the recognition of ontological and epistemological strata. This approach enables a comprehensive understanding of reality, a specific comprehension of localized phenomena and relationships, and the articulation of analytical-reductionist thought within a complex, holistic vision, thereby clarifying the recursive dynamics between the parts and the whole. These foundations illuminate the inseparability of subject and object—a realization carrying direct implications for teacher training by weaving ontological and epistemological tiers into pedagogical processes. For this reason, educator preparation must transcend epistemically fragmented models, orienting itself instead toward a relational, dynamic, and situated ontology of knowledge, particularly within the social sciences and humanities.

Accordingly, the pedagogy of complexity complements the reductionist epistemology of classical science by integrating the diverse strata that constitute the ontological phenomena of all living beings. In turn, transdisciplinary education—grounded in an inter-epistemological dialogue where opposing yet complementary realities coexist—enables individuals to feel, think, and act in harmony with nature and the cosmos, unifying scientific knowledge of the external universe with the wisdom of the inner spiritual realm (Collado, 2017). Within this framework, the present proposal serves as an essential pathway for reconfiguring educational models, recognizing that the complexity of reality demands equally sophisticated forms of knowledge. This epistemic posture acknowledges that fragmentation is a cognitive illusion, and that the indivisible totality of a holographic universe can be interpreted by the brain of the subject-observer, which functions as a hologram. Thus, the educator ceases to be a passive transmitter of content and becomes an active subject who interprets, mediates, and co-constructs meaning across multiple, interdependent contexts.

According to Gobat and Berger (2018), teacher training and pedagogical experience shape a professional identity that directly governs the



quality of student learning. By anchoring teacher education within this philosophical framework, the objective is to guide the evolution of critical thinking toward complex, transdisciplinary scientific horizons that actively explore learning processes, intelligence, creativity, and personality (Fürst, 2016). In this sense, transdisciplinary training represents a necessary condition for strengthening an educational model that is critical, ethical, and committed to contemporary systemic crises. Looking ahead, the educational sciences must prepare teachers who can equip citizens to confront climate change and the unfolding sixth mass extinction (Leakey and Lewin, 1996). This task demands an epistemological perspective open to breakthroughs in neuroscience (Damasio, 2018), psychosomatic intelligence (Núñez, 2011), transpersonal psychology (Weil, 2003), shamanic perspectivism (Viveiros de Castro, 1998), and the trans-knowledge of dream ontology (Job, 2013). Far from constituting a scattered eclecticism, this openness responds to the vital necessity of articulating distinct levels of understanding within a coherent framework of human formation.

Ultimately, the 21st century imposes multifaceted challenges upon the educational domain, making it imperative to sustain the philosophical debate surrounding teacher education, pedagogical innovation, and social transformation. How will contemporary educational institutions confront the socio-environmental crises of our time? How will teacher-training programs operationalize the epistemological and ontological advances of the complexity sciences? These questions must remain at the forefront of the philosophy of education to facilitate a transition toward an authentic culture of peace. Consequently, revisiting educator training through the lens of complexity is not a mere theoretical option; it is a historical imperative for constructing more just, democratic, and regenerative societies.

Notes

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2. This article adopts the Anglo-Saxon meaning of the term "ontology," understood as the branch of philosophy that deals with the nature of being and its place within the cosmophysical and bioenergetic dimensions. It is understood as a discipline that studies being, centered on understanding material and energetic phenomena in their inseparable interrelation.

3. From the perspective of human sensory perception, it is impossible to conceive of a movement from point A to point B without passing through the intermediate points that separate them.
4. Physical phenomena are interpreted as the result of a continuous sequence of causal relationships.
5. If the position and velocity of an object are known, it is possible to determine its behavior in spacetime.
6. See the explanation of the double-slit experiment in quantum physics by García Orduña (2012).

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Authors	Contributions
Javier Collado Ruano	Conceptualization, research, project management, fund-raising, writing, review, and editing.
Florent Pasquier	Research, methodology, writing, review and editing, validation, formal analysis, and conceptualization.

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