v. 5, n. 11, 2025

Scientific Journal of Applied Social and Clinical Science

Acceptance date: 19/08/2025

UNIVERSITY PROFESSIONAL TRAINING IN CHILE: TRANSDISCIPLINARITY LINKED TO TEACHING IN ENVIRONMENTAL SCIENCES

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Abstract: This article addresses the discussion regarding transdisciplinary professional teaching in tertiary education in Chile. It analyzes educational aspects, both for students and faculty, from an epistemological perspective anchored in complex thinking and the science of sustainability. It critically examines university organization and its resistance to the integration of knowledge. It concludes that transdisciplinary training, which articulates scientific and extra-scientific knowledge and is based on an epistemology of complexity, is fundamental for the development of robust competencies in environmental sciences. With regard to university campuses, the persistence of disciplinary structures and organizational systems that are obsolete in the face of the interconnected nature of contemporary socio-ecological challenges is noted.

INTRODUCTION

In recent decades, the Chilean education system has faced constant scrutiny due to unsatisfactory results in standardized measurements, both nationally and internationally. This phenomenon, documented in international tests such as TIMMS and PISA, as well as in national SIMCE and PSU tests, confirms this (ACE, 2022; OECD, 2023), revealing a structural crisis that transcends indicators and points to pedagogical and curricular paradigms that require a thorough review.

This complex scenario was further affected by the consequences of the pandemic. Indeed, according to the World Bank Group (Patrinos et al., 2022), school closures due to the pandemic had a profound impact on learning. The organization estimates that each month of lost classes meant a month of learning loss. Similarly, another analysis using data from the PIRLS test (Kennedy, A. I., & Strietholt, R., 2023) found that learning progress stagnated in most countries in 2021, but even more so where school closures were more prolonged. The study adds that the estimated effect of one year of school closures corresponds to a loss of just over half a school year. According to the OECD, Chile was the country in that organization that had its schools closed for the longest period of time: 259 school days. In addition, according to data from the Analysis of the National Survey of School Monitoring during the Pandemic in 2022 (Canales *et al.,* 2023), the return to face-to-face learning was slow and gradual, and on average, in 2021, students only had access to 25% of the face-to-face hours of a normal year, a situation that was corrected over time to reach 95% in 2023.

In this context, higher education, as the heir to the education provided in high schools and colleges, not only inherits the educational gaps of school education but also faces its own limitations. Traditionally, it has operated under a reductionist approach, focused on training professionals to meet the immediate demands of the labor market, often to the detriment of a comprehensive and critical education. In this regard, factors such as an internal organization fragmented into disciplinary "silos," funding models that encourage competition rather than collaboration, which has no solution in sight with the new Higher Education Financing (FES) initiative (Eyzaguirre, 2024), and the rigidity of curricula based on content transmission have contributed to this scenario.

In response, there has been growing concern in the university sphere about moving towards more flexible and inclusive models that respond to the demands of a globalized and complex society (Motta *et al.,* 2015). This has forced a review of the role of the university in today's society, as well as a rethinking of traditional curriculum designs (Goñi Mazzitelli, Vienni-Batista, and Hidalgo, 2023). A notable example of this effort has been the migration toward competency-based curri-

culum designs, a process that the University of Chile initiated in several of its undergraduate programs.

In this regard, initial analyses of the programs involved (engineering) have shown that curricular transformation has been more complex than anticipated. The focus has remained predominantly disciplinary and interdisciplinary, which is insufficient to address the intrinsically transdisciplinary nature of environmental sciences. As Motta (2002) argues, current educational models are obsolete in the face of the emergence of complex socio-ecological problems that require the integration of multiple forms of knowledge. The environmental crisis is not an ecological crisis *per se,* but a crisis of human thought and perception, which requires an effort to integrate knowledge that the current university structure inhibits (Leff, 2004).

Therefore, it seems necessary to make an effort to integrate knowledge. However, to achieve this goal, an academic body with experience in collaborative dynamics and a transdisciplinary view of the world, anchored in a systemic and complex epistemological model, is required, a profile that is currently scarce in academia.

In this regard, the University of Chile provides a good example. With the aim of addressing the complexity of environmental sciences and the need for spaces for different disciplines to come together, in 2019 the University formed the EneAS Transdisciplinary Network: Energy, Water, and Sustainability, with the support of the Vice-Rector's Office for Research and Development (Acuña et al., 2023). In this regard, it was proposed to coordinate research and teaching efforts from an interdisciplinary and transdisciplinary approach to address the challenges of climate change. To this end, with the aim of establishing bridges of communication and collaboration, the work carried out by academics and researchers at the University of Chile in relation to these issues was systematized, connected, and made visible. However, the initiative has faced several problems. The Network depends solely on individual interest in the interdisciplinary and transdisciplinary activities that are developed, without the possibility of offering incentives that support academic careers, but only collective learning and the possibility of sharing knowledge. This creates a high degree of dependence on the interest, willingness, and time that the academic body can offer with regard to this exercise in methodological and epistemological openness. Although this allows the Network to have highly motivated and committed collaborators, the lack of institutional support is a major barrier within the organization, as it affects the development and projection of activities.

The overall objective of this article is to discuss transdisciplinary university professional training in environmental sciences in Chile in light of the epistemological and social demands of the 21st century, arguing that such training is inseparable from the adoption of the complexity paradigm.

ENVIRONMENTAL SCIENCE EDUCATION: BEYOND TRADITIONAL APPROACHES

Environmental education is recognized as an emerging and cross-cutting field that should permeate all levels of the education system. The specialized literature agrees that integrative approaches, which transcend disciplinary boundaries to address real-world problems, are the most appropriate strategy for training in this area (Pedroza and Argüello, 2002).

A transdisciplinary approach, which not only combines disciplines but also integrates academic knowledge with the practical knowledge of non-academic actors, emerges as the desirable horizon.

However, its implementation faces significant obstacles: (a) a profound epistemological ignorance among teachers regarding the dynamics of knowledge co-production and systemic thinking; (b) structural isolation of educational institutions that perpetuates the fragmentation of knowledge; and (c) the persistence of obsolete organizational and perceptual schemes that resist innovation (Motta, 2002).

The way in which teaching and learning processes on environmental issues have historically been carried out has responded to different pedagogical trends:

a. Behaviorist view: Based on the stimulus-response paradigm (Skinner, Pavlov), it promotes passive and mechanistic learning, which is inadequate for fostering critical thinking and complex problem solving that characterize environmental sciences. This theory is applied in both formal and non-formal education, and is even applied in the family environment, where punishments and rewards are given for compliance or disobedience in certain activities.

b. Constructivist view: With its emphasis on the active construction of knowledge by the subject in interaction with their environment (Klein and Ramírez, 1994), it offers a significant advance by recognizing the role of cognitive structures and learning as a scaffolding process.

c. Humanistic view: It contributes the dimension of the integral development of the person (Maslow) and the relevance of meaningful learning (Ausubel), which connects new knowledge with the student's previous experiences and interests, a crucial element for the formation of environmental commitment.

Although these trends have contributed valuable elements, environmental education for sustainability needs to go a step further, toward a **transformative pedagogy**. Authors such as Sterling (2001) argue that it is not enough to learn about sustainability, but that learning that transforms the student's worldview is necessary. This implies "third-order learning," where underlying assumptions and paradigms are questioned and reconfigured, a process aligned with Mezirow's (2000) notion of "transformative learning."

Today, the priority debate must focus on the articulation of knowledge, the transition from multidisciplinarity to authentic transdisciplinarity, and the development of methodologies that allow these notions to be put into pedagogical practice (Motta, 2002; Max-Neef, 2005).

TRANSDISCIPLINARITY, COMPLEXITY, AND THE ENVIRONMENT

It is essential to clarify the distinction between the different levels of knowledge integration. While "pluri" and "multi" denote a mere addition of disciplines, "inter" and "trans" imply a dynamic interaction that transforms the participants and their conceptual frameworks (RAE, 2014). There is often confusion between multidisciplinary work (juxtaposition of analyses from different perspectives) and interdisciplinary work, which requires conceptual synthesis (Motta, 2002).

In this regard, Max-Neef (2005) analyzed the concepts of disciplinarity, multidisciplinarity, pluridisciplinarity, interdisciplinarity, and transdisciplinarity, framed within a discussion on tertiary (university) education, where he states that undergraduate education has been oriented in a unidisciplinary manner.

- Max-Neef (2005) defines the concept of disciplinarity as mono-disciplinary, specialized, and isolated (specialization in isolation), citing as an example the horizontal relationship between biology, physics, sociology, and anthropology. Along the same lines, Morin and Le Moigne (2006) highlight that hyper-specialization produces blindness to the global context and fragments complexity.
- With regard to the concept of multidisciplinarity, the author approaches it from the perspective of studying the object from the individual paradigm of each of the sciences, without any integration in the analyses.
- The concept of pluridisciplinarity implies cooperation between different disciplines, but without coordination at a common hierarchical level. Interdisciplinarity is organized at two hierarchical levels, where there are cooperative relationships within and between the upper and lower levels. Medicine, agriculture, and architecture are examples of interdisciplinary activities (Figure no.1).

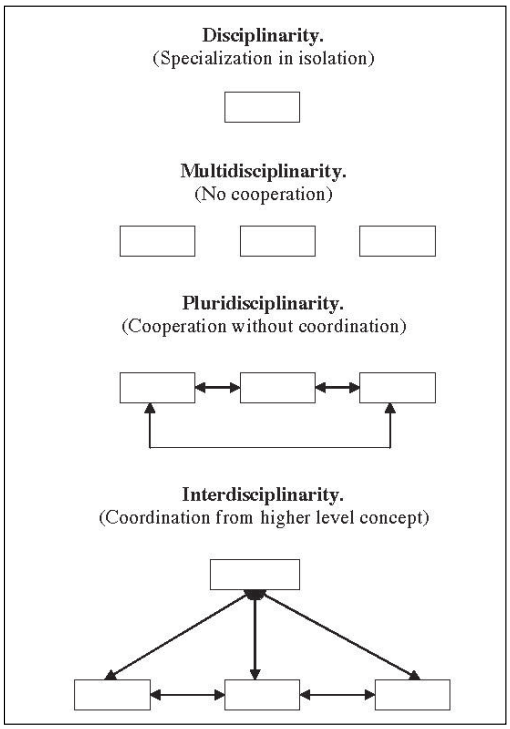

Figure no.1 . Relationships of cooperation and coordination with respect to the concepts of disciplinarity, multidisciplinarity, pluridisciplinarity, and interdisciplinarity.

Source: Max-Neef, 2005.

In this regard, Saldivia Maldonado (2011) defines interdisciplinarity as the systematic integration of theories, methods, instruments, and actions of members of scientific communities from various disciplines, with the aim of achieving a unified vision of an area of knowledge. In other words, it is the coordination of disciplines at the same hierarchical level under a higher-level purpose or concept. Agriculture and public health are classic examples.

Finally, Max-Neef (2005) argues that transdisciplinarity represents the highest level of integration and is therefore the result of coordination between different epistemic levels. In this regard, disciplines form the base of the pyramid (Figure No.2), describe the world and human behavior, and answer the question, "*What exists*?" The organization of language at this level is logical.

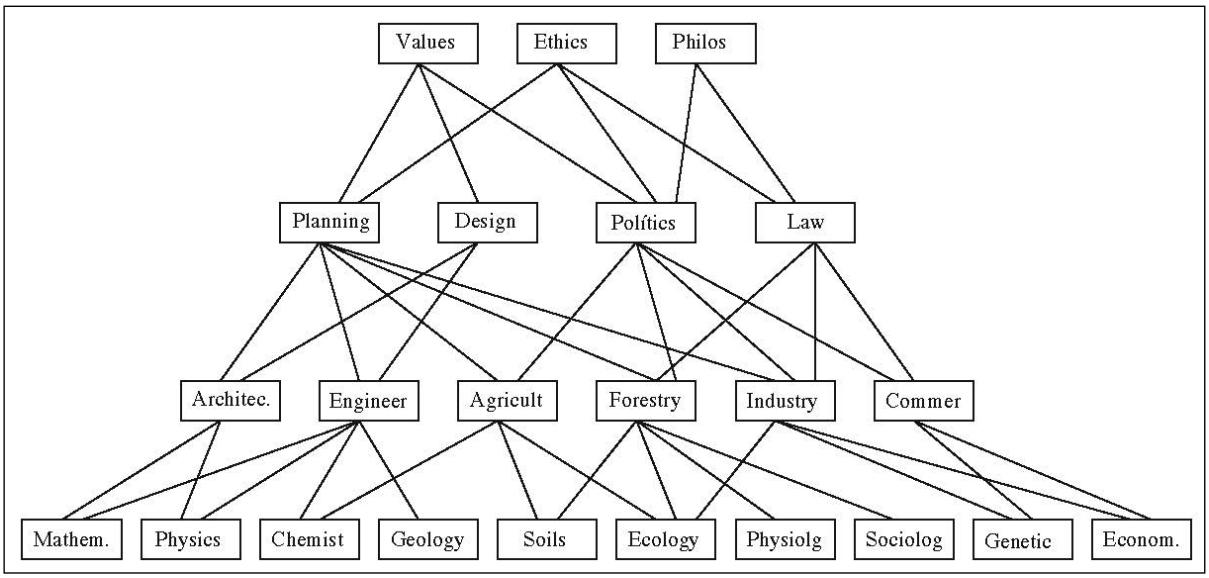

Figure no.2 . Diagram of transdisciplinarity. It should be read from the bottom up. The first level refers to "what exists." The second level refers to "what we are capable of doing." The third refers to "what we want to do." Finally, the fourth level refers to "what we must do." In other words, it moves from an empirical level to a pragmatic level, then to a normative level, and finally to a value-based level.

Source: Max-Neef, 2005.

The next level is mainly composed of technological disciplines. This level answers the question: *what are we capable of doing*? What this level does not say is whether what we know how to do should actually be implemented. The language at this level is articulated in a cybernetic way, emphasizing only the mechanical properties of nature and society.

The next level is the normative level, which answers the question: *What do we want to do*? In modern democratic societies, the answers are determined by the votes of citizens. An example in the area of the environment is the environmental impact assessments promoted by environmental movements. The organization of language is planning.

The value level answers the questions: *What should we do*? Or *should we do everything we want*? It goes beyond the immediate and points to future generations, making explicit the concern for the human species and its environment. Language is organized around a kind of deep ecology.

This vision complements that of Nicolescu (1996) , who argues that transdisciplinarity aims to understand the present world from the imperative of the unity of knowledge. In this regard, dialogue between disciplines and between science and other forms of knowledge (art, spirituality, local experience) is fundamental. His interest is in the dynamics of action inscribed at different levels of reality, in the emergence of new logics and in the emergence of complexity. For this reason, transdisciplinarity arises in relation to the development of quantum physics and the questions raised by Niels Bohr about the unity of knowledge, especially Bohr's work related to concepts such as "indivisibility," "correspondence," and "complementarity," where there is a possible way to understand the relationships between contradictory aspects and where the problem of articulation between different levels of reality plays an important role.

For Nicolescu, as in the proposal by Max-Neef (2005) , the transdisciplinary vision is a

perspective that proposes considering a multidimensional reality structured on multiple levels, replacing the vision of a one-dimensional reality in classical thinking. The author is aware that this proposal requires a rigorous explanation and that it also raises numerous questions, ranging from which theory is capable of describing the passage from one level of reality to another, to the coherence and structural unity of the levels of reality, the privileged level of reality for understanding all other levels, the role of the observing subject in the existence of a possible unity of all levels of reality, and the objective or subjective nature of the unity of knowledge.

Finally, according to Nicolescu, the different levels of understanding result from the harmonious interpretation of knowledge of different levels of reality and different levels of perception, even though reality and its levels of perception are multiple and complex.

Similarly, Gibbons et al. (1994) describe the emergence of a "Mode 2" of knowledge production, characterized by being transdisciplinary, generated in contexts of application, heterogeneous in its organizational forms, and socially responsible. This Mode 2 contrasts with "Mode 1," which is traditionally disciplinary and generated within academia. The sustainability sciences are a paradigmatic example of this new way of doing science (Clark & Dickson, 2003).

TRANSDISCIPLINARITY AND TERTIARY ENVIRONMENTAL EDUCATION

Although UNESCO (Atreya, Lahiry, Gill, Jangira, and Guru, 1989) , already in the 1980s differentiated between multidisciplinary and interdisciplinary models for environmental education, transdisciplinarity continues to be conspicuously absent in Chilean universities. There are valuable efforts, but they are isolated and predominantly interdisciplinary, failing to permeate the institutional structure. The experience of curriculum redesign at the University of Chile, although internationally recognized, highlights the difficulty of institutionalizing these practices.

The training of teachers qualified in the area of transdisciplinarity is currently the most important challenge to be addressed. This challenge requires training efforts that encompass aspects of perception, attitude, and skills, as well as greater communication between the social and natural sciences.

The main obstacle is the training of the teaching staff. As Julie Thompson Klein (2010) argues, transdisciplinary collaboration is not an innate skill; it requires the development of "collaborative competencies," such as the ability to integrate perspectives, reflective thinking, and inter-epistemic communication. Current teacher training, which is often erratic, decontextualized, and lacking a solid epistemological foundation, is not preparing academics for this challenge. Comprehensive and continuous training is needed that incorporates philosophical reflection, a non-mechanistic view of science, and openness to the diversity of knowledge.

As Morin (2001) states, there can be no reform of education without a reform of thinking. This implies "teaching how to navigate an ocean of uncertainties through archipelagos of certainty." The first steps toward this reform require an ecology of collective intelligence that values cognitive diversity and promotes dialogue between different types of knowledge.

CONCLUSION

The transition to transdisciplinary education in environmental sciences in Chile faces profound structural barriers. It is concluded that the main difficulties lie in:

- **Inadequate teacher training**, characterized by a lack of epistemological and methodological preparation to address complexity and facilitate processes of knowledge co-production.
- **Obsolete university structures**, which, with their departmental organization, incentive systems based on disciplinary production, and culture of specialization, inhibit collaboration and the integration of knowledge.

True educational reform is not possible without a reform of thinking. This implies a radical transformation in the training of educators, equipping them with the conceptual and pedagogical tools to guide students in understanding and addressing the complex socio-ecological problems of our time. The university must rethink itself, not as a collection of faculties, but as an open and porous ecosystem of knowledge, capable of dialoguing with society to co-create a more sustainable future.

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