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Environment, Scientific Education, and Work: Integrated Approaches and Reflective Educators in Sustainable Professional Training

Alberto Monteiro Chaves[1] https://orcid.org/0000-0002-9225-7924; Ana Karen Silveira Pereira Caracas[2] https://orcid.org/0009-0003-2262-1043; Antonio Werbiton Marinho Almeida[3] https://orcid.org/0009-0002-1904-7522; Danielle Taumaturgo Dias Soares[4] https://orcid.org/0000-0001-6816-6857; Ernandes Farias da Costa[5] https://orcid.org/0000-0002-9855-9667; Fabiola Fernandes de Menezes[6] https://orcid.org/0009-0007-6190-8820; Francisco José Lopes Cajado[7] https://orcid.org/0000-0002-8824-9251; Irene Mendes Fontes[8] https://orcid.org/0009-0002-3152-6649; Joilson Pedrosa de Sousa[9] https://orcid.org/0009-0006-2891-0841 Julyanne Lages de Carvalho Castro[10] https://orcid.org/0000-0001-9865-3736; Marcos Antonio Ferreira Soares[11] https://orcid.org/0000-0003-1470-2890; Nailton Rodrigues Maciel[12] https://Orcid.Org/0009-0001-7544-4795; Onete Raulino da Costa[13] https://orcid.org/0000-0002-1975-7009; Paula Raquel Barbosa Sousa[14] https://orcid.org/0009-0005-3491-8017; Paulo Henrique Barbosa Sousa[15] https://orcid.org/0009-0007-1269-7860; Rickardo Léo Ramos Gomes[16] https://orcid.org/0000-0001-6101-9571; Roberto Augusto Caracas Neto[17] https://orcid.org/0000-0001-8484-411X;

[1]*Master's Degree in Intellectual Property and Technology Transfer for Innovation – PROFNIT / IFCE / FORTEC*
[2] *Director of Innovation at the Science, Technology, and Innovation Club of the Fortaleza Military School.*
[3] *Master's student in Administration and Controllership at UFC*
[4]*Master's Degree In Teaching, Specializing In The Teaching Of Human And Social Sciences, From The Graduate Program In Teaching - POSENSINO – UERN/UFERSA/IFRN*
[5] *Postgraduate Degree in Mathematics Education – FAK*
[6]*Master in Educational Sciences from Universidad Del Sol - UNADES*
[7] *Prof. Dr. in Agricultural Biotechnology (RENORBIO – UFC)*
[8] *Postgraduate Degree In Criminal Law From Uniateneu University Center*
[9] *Master's Degree in Science and Mathematics Teaching from the Federal University of Ceará (UFC)*
[10] *Master's Degree In General Accounting From FUNCAP*
[11]*Professional Master's Degree in Intellectual Property and Innovation Technology from the Federal Institute of Ceará (IFCE)*
[12]*Specialist in Brazilian History – Faculdade Única*
[13]*Currently pursuing a Doctorate in Education Sciences from Del Sol University (UNADES)*
[14]*Specialist in Public Management – Dom Bosco Catholic University*
[15] *Ph.D. in Educational Sciences, FCSA (DINTER Program*
[16] *Doctorate in Biological Sciences - FICL; Master's in Phytotechnics - Federal University of Ceará*
[17] *Doctoral Student at the Academy of the National Institute of Industrial Property*
Corresponding Author: Rickardo Léo Ramos Gomes

ABSTRACT: *In light of current environmental, social, and educational challenges, the interrelationship between the environment, scientific education, and the labor market has become increasingly significant. Such integration represents a promising foundation for rethinking professional education from a sustainability perspective. The research was conducted through a qualitative approach, which is particularly suitable for analyzing the complexity of educational, sociocultural, and environmental phenomena. The method employed consisted of a*

bibliographic review, defined as the systematic analysis of published scientific works, aimed at establishing conceptual connections, identifying theoretical convergences, and critically examining the scope and limitations of the available frameworks. The main objective of this study was to analyze how integrated approaches involving the environment, scientific education, and the world of work can promote sustainable professional development, considering the role of reflective educators in this process. Based on the elements examined, it is concluded that integrated strategies encompassing environment, science, and labor, mediated by reflective teachers, represent a promising educational proposal for training professionals equipped to act critically, responsibly, and innovatively.

At the same time, the importance of continuous investment in curriculum policies, teacher training, and interdisciplinary pedagogical practices is underscored, with the aim of consolidating sustainability as a transversal educational principle in vocational education.

Keywords: *scientific education; labor market; educational phenomena; sustainability.*

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I. INTRODUCTION

In recent decades, discussions on sustainability have become central to the fields of education, science, and labor, driven by global challenges related to environmental crises, social inequalities, and technological changes. In this context, there is a growing demand for educational processes that integrate technical-scientific knowledge with ethical values, environmental awareness, and social commitment, particularly within the scope of vocational education.

The training of individuals capable of acting critically and responsibly in response to contemporary demands requires integrated pedagogical methodologies that transcend disciplinary fragmentation and foster meaningful connections between theory and practice. In this scenario, the role of the reflective teacher assumes strategic importance, acting as a mediator of knowledge and a builder of educational practices aimed at developing professional training committed to both sustainability and social transformation.

The research was conducted through a qualitative approach, which is particularly suitable for analyzing the complexity of educational, sociocultural, and environmental phenomena. The method employed consisted of a bibliographic review, defined as the systematic analysis of published scientific literature, with the aim of establishing conceptual connections, identifying theoretical convergences, and critically examining the scope and limitations of existing frameworks.

The general objective of this study was to analyze how integrated approaches involving the environment, scientific education, and the world of work can contribute to sustainable professional education, considering the role of reflective teachers in this process. The specific objectives are as follows: (1) to investigate interdisciplinary pedagogical practices that promote the integration of scientific education, sustainability, and vocational training; (2) to examine the role of the reflective teacher in mediating technical-scientific knowledge aimed at critical and sustainable professional education; and (3) to evaluate how the inclusion of environmental themes in vocational education can contribute to the development of students' socio-environmental competencies.

This article is structured into four main sections to ensure clarity of presentation and coherence of the methodological approach. The initial section presents the introduction, which contextualizes the research topic, outlines the study's objectives, and highlights the relevance of the proposed discussion. The following section, dedicated to materials and methods, describes the chosen qualitative approach and details the bibliographic procedures used in the analysis.

The third section consists of the theoretical framework, which is divided into three subsections addressing, respectively: the connection between scientific education and interdisciplinarity in sustainable professional training; the role of the reflective teacher in bridging science and pedagogical practice; and the development of scientific and socio-environmental competencies within the context of critical environmental education. Lastly, the final section presents the concluding remarks, which summarize the main contributions of the research and outline directions for future investigations.

II. MATERIAL AND METHODS

The research was conducted using a qualitative approach, which is particularly appropriate for analyzing the complexity of educational, sociocultural, and environmental phenomena. Qualitative research enables the interpretation of meanings, the formulation of theoretical categories, and the understanding of relationships that are not limited to numerical measurements, but that require a sensitive analysis and argumentative rigor. As argued by Guerra et al. (2024), qualitative inquiry is essential for analyses that encompass multiple dimensions of human experience, such as educational processes, pedagogical practices, and the interconnections among science, the environment, and labor. The choice of this approach is thus closely aligned with the aim of this article, which

seeks to critically interpret the articulation between scientific knowledge, pedagogical practices, and sustainable professional education.

The method employed consisted of a bibliographic review, defined as the systematic analysis of published scientific literature, with the objective of establishing conceptual connections, identifying theoretical convergences, and problematizing the limitations and scope of the available frameworks. According to Severino (2016), bibliographic research constitutes a valid approach for the development of scientific knowledge, provided it is conducted with rigor in the selection and analysis of sources. In this study, such a procedure was essential to understand how the categories of scientific education, reflective teaching, sustainability, and vocational training have been addressed by different authors across various contexts. Bibliographic research, by enabling the development of a critical and evidence-based analysis, supports the advancement of academic debates and the proposal of innovative educational approaches within the field of professional education.

The analyses and articulations presented throughout the text were grounded in the reading and systematization of twenty-eight scientific articles published in both national and international academic journals. These articles were selected based on criteria related to thematic relevance, timeliness, and methodological rigor. This body of work represents a significant volume of scientific production capable of providing a robust theoretical foundation and ensuring the coherence of the discussions. The diversity of authors and perspectives addressed in the reviewed literature allowed for the construction of a multifaceted reflection, one that considers the particularities of teacher education, the demands of the labor market, and the current challenges associated with critical environmental education. The evaluation of the texts followed a thematic categorization procedure, which contributed to the construction of the analytical frameworks that structure the main sections of this article.

The methodological approach adopted in this study not only ensures consistency with the research objectives, but also aligns with an established tradition in science that values critical dialogue with pre-existing academic production. The interrelation between the qualitative approach and bibliographic research offers analytical tools that allow for a deeper understanding of complex educational processes, fostering informed and socially contextualized reflections.

III. THEORETICAL FRAMEWORK

The theoretical foundation of this article was organized around three interconnected thematic axes that guided the analysis of the interactions among science, labor, and sustainability. The first axis explores the relationship between scientific education and interdisciplinarity in professional training oriented toward sustainability. The second focuses on the role of the reflective educator in bridging scientific knowledge and educational practice. Lastly, the third topic addresses the perspective of critical environmental education, as well as the development of scientific and socio-environmental competencies within the realm of vocational education.

3.1 Scientific Education and Interdisciplinarity in Sustainable Professional Training

In the current landscape of socio-environmental challenges and transformations in the labor market, scientific education holds a central role as a critical and formative social practice. This perspective dismantles the traditional conception of science as a neutral, decontextualized body of knowledge detached from the historical, cultural, and political dimensions of reality (Lima et al., 2019; Moura, Jager, & Guerra, 2020). Professional education guided by the principles of sustainability, therefore, requires the integration of scientific knowledge, environmental concerns, and skills for ethical and transformative action in the workplace. According to Almeida and Nardi (2020), research on science education in Latin America has advanced in recognizing scientific education as a tool for emancipation—especially when associated with other fields of knowledge through interdisciplinary and contextualized approaches.

Within this context, reflective educators play a fundamental role: they act as critical mediators who foster educational processes oriented toward understanding science in its multifaceted nature, prioritizing dialogue, critical reflection, and the collective construction of knowledge.

Interdisciplinarity, understood as a pedagogical approach that goes beyond the mere juxtaposition of content, is essential for integrating science, environment, and labor in professional education (Fonsêca & Borba, 2024; Massuga, Soares, & Doliveira, 2020). This approach helps overcome fragmented education, thereby enabling the comprehension of complex phenomena that require multiple theoretical and methodological perspectives. As noted by Catarino and Reis (2021), pedagogical experiences during the pandemic highlighted the effectiveness of interdisciplinarity in promoting critical scientific education, especially when associated with themes of sustainability and citizenship. Practices that integrate different disciplines—as represented by the interactions outlined in Table 1—based on the analysis of real-life situations, can foster the training of individuals committed to social and environmental change, while also broadening the meaning of scientific knowledge in students' daily lives.

Table 1 – Interactions among Scientific Education, Interdisciplinarity, and Sustainable Professional Training

Articulating Axis	Pedagogical Principles	Developed Competencies
Critical Scientific Education	Science as a social construct; nature of science	Critical thinking; scientific literacy
Contextual Interdisciplinarity	Problematization; integration of knowledge	Intellectual autonomy; systemic vision
Training for the World of Work	Sustainability; ethics; real-world problem solving	Socio-environmental responsibility; social innovation

Source: Based on Almeida and Nardi (2020); Catarino and Reis (2021); Fonsêca and Borba (2024); Massuga, Soares, and Doliveira (2020).

In light of the considerations presented, it becomes evident that the connection among science, the environment, and labor should not be confined to compartmentalized school content or to technical training aimed solely at the job market. What is required is the adoption of educational practices that promote the formation of individuals capable of acting critically and ethically in the world. Girão et al. (2017) emphasize that sustainable development, beyond being a normative concept, must be understood as a central axis of educational initiatives aimed at social transformation. In this context, the role of the reflective educator becomes even more significant—as one who, aware of their ethical and political commitment, fosters collaborative and investigative learning experiences that are connected to both local and global realities. Thus, interdisciplinary scientific education becomes not merely a tool for the acquisition of knowledge, but a fertile ground for shaping professional subjects capable of contributing to sustainable practices across diverse fields of activity.

Finally, it is important to highlight that the most impactful teaching and learning experiences emerge from active listening, the interaction between different types of knowledge, and the collaborative construction of meaning about the world. Such a pedagogical stance requires receptiveness to complexity and preparedness to confront the challenges posed by curricular fragmentation and the technicist logic that still prevails in many educational institutions. As noted by Candau (2020) and Lima et al. (2019), the training of reflective educators demands formative environments that are intercultural, critical, and committed to the promotion of social justice. In this context, pedagogical approaches must be understood as inherently political actions, capable of reconfiguring the interaction between scientific knowledge, sustainable development, and the world of work—thus fostering an education that is truly integral and transformative.

3.2 The Reflective Teacher in the Articulation of Scientific and Professional Education

The concept of the reflective teacher has been extensively discussed as fundamental to the promotion of critical and contextualized pedagogical practices, especially in the field of scientific education oriented toward sustainable professional training. Drawing on the contributions of Donald Schön, it can be stated that the reflective educator is one who is capable of thinking critically about their own actions as they carry them out, thereby transforming the educational act into a continuous process of inquiry. This approach requires specific skills, including the ability to articulate technical, scientific, and pedagogical knowledge in order to enable meaningful learning that bridges theory and practice in real training contexts.

According to Perrenoud, the professionalization of teaching is intrinsically linked to the development of intellectual autonomy and the ability to make pedagogical decisions based on both situational and epistemological diagnoses (Perrenoud, 2000). The connection among scientific education, labor, and sustainability thus requires that the educator fulfill the role of a critical mediator, aware of the social, ethical, and environmental implications of the knowledge applied within the school environment.

In this context, the role of the educator goes beyond the mere transmission of knowledge and becomes an active process of shaping individuals capable of critically reflecting on reality and engaging in transformative action. Castejon et al. (2023) argue that reflective pedagogical practice takes place in school environments when active listening, problematization, and the appreciation of diversity in students' experiences are effectively promoted. Oliveira, Amaral, and Amaral (2023), in a recent case study, demonstrate that pedagogical practices grounded in critical reflection can successfully articulate scientific knowledge with local experiences, fostering student engagement in solving concrete problems related to their communities and contexts of action.

In this sense, sustainable professional development depends on the engagement of educators who understand teaching as a social, historical, and contextualized practice, guided by a commitment to socio-environmental justice and the emancipation of individuals. The competencies associated with such educator profiles are presented in Table 2 below:

Table 2 – Competencies of the Reflective Teacher for Sustainable Scientific and Professional Education

Competency Domain	Description	Impact on Professional Training
Epistemological	Understanding science as a social and historical construct	Development of critical thinking and autonomy
Pedagogical	Planning of interdisciplinary and contextualized methodologies	Meaningful learning and real-world problem solving
Ethical-political	Practice committed to equity, diversity, and sustainability	Formation of conscious and socially engaged citizens
Reflective-investigative	Capacity for self-assessment and continuous improvement of teaching practice	Improvement of pedagogical practice and adaptation to real-world contexts

Source: Based on Perrenoud (2004), Schön (2000), Oliveira, Amaral, and Amaral (2023), and Calefi and Fortunato (2018).

The work of the reflective teacher in educational practices that interconnect science, sustainability, and labor is essential for developing a critical and integrated form of training. According to Luzzi and Coutinho (2019), this professional must operate based on a research-oriented pedagogical approach, in which the teaching and learning process is understood as a two-way path—one in which both the educator and the student act as active agents in the construction of knowledge. This process requires openness to dialogue, attentive listening, and a willingness to revise practices based on experiences within the educational context. The articulation of technical and scientific knowledge should not occur in a decontextualized or purely technicist manner, but rather through the construction of shared meanings, establishing a dialogue with the demands of the labor market and emerging environmental issues.

In this process, scientific education becomes a key space for linking school knowledge, local culture, and sociotechnical needs. As Moraes and Costa (2021) affirm, the training of educators must, from its foundations, incorporate an understanding of science as a contextualized social practice, rather than treating it as absolute and universal knowledge. This perspective expands the educator's ability to connect school content with students' sociocultural backgrounds, thereby promoting the reduction of inequalities and fostering a more inclusive and sustainable education. Thus, the practice of the reflective teacher is not confined to the school environment but extends to institutional and political spheres, insofar as this educator assumes the role of a transformative agent committed to holistic education and the construction of viable futures.

3.3 Critical Environmental Education and Scientific-Socioenvironmental Competencies in Vocational Education

The introduction of critical environmental education within vocational education goes beyond mere ecological awareness or the implementation of environmentally responsible practices. It primarily constitutes an educational proposal that integrates the ethical, political, and epistemological dimensions of environmental knowledge with the goal of promoting social transformation. This approach seeks to develop scientific and socioenvironmental competencies that enable students to understand the complexity of today's environmental challenges and to act critically and constructively within their realities. Costa and Loureiro (2024) argue that critical environmental education should be understood as a mediating force between socioenvironmental conflicts and educational processes, capable of challenging the paradigm of peripheral capitalism and its impacts on territories and ways of life. In this regard, vocational training environments should incorporate both scientific and popular knowledge, fostering educational practices grounded in research, problem-solving, and sustainable projects contextualized to students' lived experiences.

The development of such competencies requires approaches that integrate scientific knowledge with the practical challenges of the labor market and sustainability. Moura, Azevedo, Freitas, and Azêvedo (2023) propose a polytechnic and socioenvironmental model of education that encourages students to critically interpret environmental phenomena and to propose integrated, collaborative, and context-based solutions. This educational model requires overcoming fragmented and instrumentalist paradigms, prioritizing interdisciplinarity and critical analysis of reality as essential pedagogical foundations. Lopes, Abílio, and Moura (2023) emphasize that initial training—particularly in teacher education and vocational programs—holds potential as a space for developing investigative and emancipatory competencies, especially when science education is infused with the political and cultural dimensions of environmental issues.

The role of work as an educational principle, in this context, goes beyond the generation of employment. It extends to the formation of ethically and politically conscious individuals, capable of intervening in productive processes grounded in the values of socioenvironmental justice. These values align with a pedagogical rationale rooted in the development of scientific-socioenvironmental competencies, as proposed in Table 3 below:

Table 3 – Scientific-Socioenvironmental Competencies in Vocational Education: Dimensions and Formative Strategies

Formative Dimension	Description	Pedagogical Strategies
Cognitive	Critical understanding of scientific and socio-environmental concepts	Case studies, analysis of local problems
Ethical-political	Recognition of environmental conflicts and emancipatory positioning	Interdisciplinary projects, debates, and simulations
Technical-practical	Application of scientific knowledge in work and sustainability contexts	Workshops, experiments, sustainable technological projects
Collaborative and territorial	Articulation with community knowledge and local grassroots actions	Partnerships with communities, interpretative and ethnographic trails

Source: Based on Costa and Loureiro (2024), Moura et al. (2023), Lopes, Abílio, and Moura (2023), Dias (2021)

A critical analysis of environmental education directly fosters the enhancement of skills that transcend the mere technical aspects of professional training, as it encompasses the individual in their entirety, situated within a specific historical and ecological context. Keim (2019) emphasizes that critical environmental education should be understood as learning about the environment and life, guided by eco-vital principles that recognize the interdependence between human beings and ecosystems. From this perspective, preparing individuals for work involves equipping them for the sustainability of life by integrating technical and sensitive rationalities, as well as cognitive and affective dimensions. Educational approaches grounded in this paradigm challenge both educators and students to reconsider their interactions with knowledge, geographic space, and a shared future.

Finally, in light of the contributions of Loureiro (2019) and Malta and Schmidt (2021), it becomes evident that professional education programs incorporating principles of environmental rationality are better prepared to train individuals capable of confronting the contradictions of development and fostering productive practices that are less predatory and more inclusive. The convergence of scientific, environmental, and professional education thus stands out as a strategic axis for strengthening comprehensive training dedicated to sustainability. By prioritizing investigative methodologies, collaboration, and territorial anchoring, educational environments transform into dynamic spaces for constructing meaning and engaging with contemporary challenges.

IV. DISCUSSION AND CONCLUSION

The investigation conducted during the development of this article demonstrated that the interconnection between scientific education, workforce training, and a critical approach to the environment represents a promising pathway for promoting professional education grounded in principles of sustainability, social justice, and emancipation. In the analysis of interdisciplinary pedagogical practices, it was found that the articulation of scientific, contextual, and ethical-social knowledge contributes to the enhancement of various competencies, such as critical thinking, systemic perspective, intellectual autonomy, and socio-environmental responsibility. These competencies are highlighted in Table 1, which illustrates how the articulating axes—critical scientific education, contextual interdisciplinarity, and preparation for the labor market—directly contribute to shaping a professional profile aligned with current demands, without separating science, ethics, and the socio-technical reality.

Regarding the role of the reflective teacher, the data systematized in Table 2 allowed identification that their performance goes beyond the technical mediation of content. By adopting epistemological, pedagogical, ethical-political, and investigative stances, the teacher decisively participates in the formation of autonomous and socially engaged individuals. This approach emphasizes the urgency of educational policies that promote self-reflection, knowledge contextualization, and exchange with diversity. Thus, the teacher is not limited to being a mere transmitter of knowledge but positions themselves as a strategic agent in implementing an education that recognizes the complexity of formative processes and the various knowledge domains present in students' realities.

The inclusion of environmental issues in professional training, in turn, proved to be an effective path for the development of scientific-socioenvironmental competencies encompassing cognitive, ethical-political, technical-practical, and collaborative dimensions. As organized in Table 3, these dimensions are closely linked to critical understanding of concepts, positioning regarding environmental conflicts, practical application of knowledge, and appreciation of community experiences. Pedagogical activities related to these dimensions—such as case studies, interdisciplinary projects, workshops, and regional collaborations—play a significant role in solidifying the formative process in real contexts, promoting learning connected to daily life and the challenges of ecological transition.

In light of the examined elements, it is concluded that integrated strategies encompassing environment, science, and work, mediated by reflective teachers, constitute a promising educational proposal for training professionals capable of acting critically, responsibly, and innovatively. Simultaneously, the relevance of

continuous investments in curricular policies, teacher training, and interdisciplinary pedagogical practices is highlighted, aiming to consolidate sustainability as a transversal educational principle in professional education.

Along this path, significant opportunities arise for future research that more deeply explores the connection between interdisciplinary pedagogical practices and the enhancement of socio-technical and environmental competencies within professional education. Studies examining educational experiences across diverse curricular structures, especially those including collaborations between educational institutions, communities, and productive sectors, can offer valuable contributions to the field. Furthermore, it is pertinent to analyze how public policies aimed at teacher training have (or have not) contributed to the formation of reflective educators, capable of incorporating ethical, scientific, and territorial dimensions into their professional activities. Empirical investigations directed at assessing the effects of active methodologies and socio-environmental intervention initiatives within school communities emerge as promising areas, particularly when integrated with a critical approach to environmental justice and social inclusion.

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