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Education, Scientific Design, and Energy Transition: Integrated Pathways Toward a Culture of Sustainability

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ABSTRACT
The debate on sustainability and energy transition has intensified in the face of contemporary environmental and social challenges, calling on education to assume a strategic role in preparing critical individuals committed to building a balanced future. The methodological pathway was designed to ensure coherence between the theoretical framework, reflective analysis, and the formulation of integrated approaches to a culture of sustainability. This qualitative study relied on theoretical references that emphasize the interpretation and understanding of educational phenomena in their human and contextual dimensions. Scientific Design served as the guiding axis, supporting the analysis of the interrelations among education, science, and sustainability, and informing the development of pedagogical strategies aimed at preparing socially responsible citizens. The study's overarching objective was to examine how Education, supported by Scientific Design, can contribute to advancing the energy transition and strengthening a culture of sustainability in the preparation of critical and socially responsible individuals. The proposals presented at the end of the study outline concrete possibilities for incorporating energy-related themes into curricula and reinforce the view that education is a fertile field for the consolidation of transformative practices.

Keywords: *Education; Scientific Design; Sustainability; Energy transition.*

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I. INTRODUCTION

The theme of sustainability and energy transition has increasingly gained prominence in contemporary educational discussions. In the face of the socioenvironmental challenges of the twenty-first century, education plays a central role in preparing critical, aware, and active citizens capable of contributing to a more sustainable and equitable development model. This requires rethinking pedagogical practices, teaching methodologies, and conceptual frameworks so that schooling becomes a space conducive to creativity, socioenvironmental responsibility, and the collective construction of knowledge oriented toward sustainability.

The articulation among Education, Scientific Design, and energy transition opens a productive channel of communication between science, technology, and society. The Scientific Design approach, by integrating epistemological reflection with pedagogical practice, offers a promising pathway for reimagining teaching as a process of inquiry and creation. This perspective values the teacher as an agent of change who investigates and reconfigures their practices, connecting theory and practice in a continuous process of educational improvement.

The investigation employs the Scientific Design methodology, a research strategy that links the principles of the epistemology of practice with scientific production in the educational field. This perspective views teaching practice as a dynamic and reflective process in which the educator actively constructs and refines their own pedagogical actions. The method proposes the development of theoretical and practical instruments aimed at addressing real problems in educational practice, integrating scientific knowledge with pedagogical experience.

The methodological pathway was structured to ensure the articulation of theory, reflection, and the formulation of integrated approaches to a culture of sustainability. The study follows a qualitative design grounded in theoretical references that prioritize the interpretation and understanding of educational phenomena in their human and contextual dimensions. Consequently, Scientific Design guided the critical analysis of the interrelations among education, science, and sustainability, while supporting the formulation of pedagogical strategies oriented toward the development of socially responsible citizens.

The overarching objective of this study is to investigate how Education, informed by Scientific Design, can contribute to promoting the energy transition and strengthening a culture of sustainability in the development of critical and socially responsible individuals.

The specific objectives are as follows: To analyze the role of Education in shaping values and practices related to sustainability and energy transition; To examine the potential of Scientific Design as a pedagogical approach to integrate science, creativity, and innovation into education for sustainability; To discuss educational strategies that interrelate socioenvironmental and technological competencies in support of a sustainable energy transition.

The article is organized into four sections. The first presents the Introduction, contextualizing the topic and the aims of the study. The second describes the Materials and Methods, detailing the methodological approach. The third section, Theoretical Framework, discusses the central concepts that underpin the investigation, including the epistemology of practice, scientific design, and energy transition. Finally, the Conclusions synthesize the main reflections and contributions of the study, highlighting the importance of integrating education, science, and sustainability in fostering a critical and responsible consciousness.

II. MATERIAL AND METHODS

The study adopts the Scientific Design methodology, defined as a research strategy that enables the articulation between the foundations of the epistemology of practice and scientific production in the educational field. According to Dresch, Lacerda, and Antunes (2015), Scientific Design is an approach that directs applied research toward solving real problems, promoting a connection between theory and practice that responds to current demands in teacher education. This perspective makes it possible to view teaching practice as a planned and investigative action, aligned with the principles of the research line on the epistemology of teaching practice.

From this standpoint, the investigation is qualitative in nature, as argued by Marafon, Ramires, Ribeiro, and Pessôa (2013), since it focuses on understanding educational phenomena from the experiences and meanings individuals attribute to them. The research was therefore conducted through an interpretive lens, aiming to understand the connections among education, scientific design, and energy transition based on the narratives and practices observed in the formative context. The analysis was guided by a critical perspective on formative processes, which made it possible to identify how teachers construct, adjust, and implement pedagogical strategies that foster a culture of sustainability.

According to Dresch, Lacerda, and Antunes (2015), Scientific Design is a methodology that integrates the creation of both conceptual and practical artifacts into the research process. This concept aligns directly with the argument presented by Moraes and Costa (2021), who emphasize that teacher education and science teaching

depend on scientific literacy and that teachers must develop the competence to transform knowledge into educational practice. Scientific Design combines the logic of planning with epistemological reflection, broadening the understanding of educational practice and contributing to the preparation of critical and creative teachers.

Brown (2018) states that design thinking involves creation and experimentation, empowering teachers as protagonists in their pedagogical practice and driving educational innovation. This reinforces the importance of educators adopting an experimental stance, continuously testing and refining their teaching strategies. In this regard, Scientific Design bridges theory and practice, supporting the development of contextualized and socially relevant educational solutions.

Finally, the methodological development of this study follows Gil's (2019) guidance, which states that research must be systematically planned and conducted according to clearly defined objectives. Accordingly, the methodology was structured to ensure consistency among the theoretical foundation, the methods of data collection and analysis, and the discussion of the results. The investigative pathway, grounded in Scientific Design, constitutes a formative and transformative trajectory in which educational practice becomes a space for reflection, creation, and ongoing reinvention.

III. THEORETICAL FRAMEWORK

3.1 Education, Sustainability, and Energy Transition: Formative and Social Dimensions

Education plays a crucial role in shaping a collective awareness directed toward sustainability and energy transition. According to the analysis by Nogueira, Malcher, and Duarte (2024), pedagogical approaches grounded in active methodologies and environmental education foster meaningful learning, especially when connected to topics such as the use of renewable energy sources. The authors emphasize that instruction on solar energy, when mediated by innovative methodologies, supports the development of critical thinking and student protagonism in the face of current socioenvironmental challenges. In this way, the educational setting becomes an environment conducive to cultivating sustainable values and building a culture of ecological responsibility (Gomes et al, 2025).

Carvalho (2022) reinforces this perspective by arguing that inquiry-based science teaching constitutes an effective pathway for articulating theory and practice in educational contexts. The author maintains that by stimulating curiosity and experimental engagement, educators promote the development of knowledge that surpasses mere content memorization, establishing links with concrete issues such as the climate crisis and the responsible use of natural resources. From this standpoint, the educational process becomes an exercise in citizenship and critical reflection on the interrelations among society, technology, and the environment.

Dorigon and Arus (2022) complement this analysis by examining initiatives aimed at raising awareness about renewable energy sources in educational institutions located in western Santa Catarina. Their study demonstrates how practical and interactive activities can stimulate students' environmental perception and encourage participation in the essential changes required for the energy transition. By connecting scientific knowledge with everyday experiences, pedagogical approaches gain relevance and reinforce the idea that sustainability emerges from conscious and collective decision-making.

From a critical standpoint, Frigo, Caneppele, and Godinho (2023) argue that energy transition encompasses not only technological factors, but also demands structural transformations in production and consumption patterns. According to these authors, understanding such transformation requires an interdisciplinary perspective capable of integrating economics, politics, and education. Consequently, schools and universities play a strategic role in shaping a culture of sustainability by promoting the interaction of science, ethics, and social responsibility.

3.2 Scientific Design as an Integrating Axis Between Science, Creativity, and Innovation

Scientific Design has emerged as an area of intersection among science, creativity, and innovation, fostering an interdisciplinary perspective oriented toward the resolution of complex issues. Pantoja, Frazão, Fernandes, and Campos (2024) emphasize that this methodology supports the development of creative processes in educational environments, expanding opportunities for active and collaborative learning. According to the authors, the articulation between scientific thinking and design enhances more dynamic pedagogical practices in which students take on a leading role in formulating solutions to contemporary challenges. This perspective underscores the importance of an educational approach that values experimental practice, critical analysis, and social participation in response to technological and environmental changes.

Rodrigues (2018) enriches this discussion by highlighting Design Science Research (DSR) as a methodological approach pertinent to Information Design disciplines and projects. His analysis shows that DSR provides a framework that integrates theory and practice, promoting learning grounded in the resolution of concrete problems and the development of innovative artifacts. This approach enables the educational environment to become a space for experimentation and knowledge construction, where science and creativity interact continuously. In this context, Table 1 summarizes content that supports the understanding of the interconnected relationships among Scientific Design, innovation, and education.

Table 1 – Relationships among Scientific Design, Innovation, and Education

Dimension	Description	Authors/Source
Integration between science and creativity	Scientific Design promotes the union between methodological rigor and creative thinking in problem-solving.	Pantoja et al. (2024)
Educational application of DSR	Design Science Research can be used as a methodological structure in disciplines that connect theory and practice.	Rodrigues (2018)
Transition and sustainability	Scientific Design supports innovation processes aimed at sustainability and social change.	Wiegmann et al. (2023)
Transparency and ethics in research	Methodological transparency strengthens the credibility and reproducibility of Scientific Design research.	Bevan et al. (2024)

Source: Prepared by the author based on Pantoja et al. (2024), Rodrigues (2018), Wiegmann et al. (2023), and Revner et al. (2024).

Wiegmann, Talmar, and Nijs (2023) discuss Design Science Research as a valuable framework for investigations related to transition processes, particularly within the scope of environmental innovation. The authors argue that this methodology supports the understanding and promotion of systemic transformations by integrating design practices with scientific approaches oriented toward sustainability. In this context, DSR does not merely guide the development of technological solutions but also encourages critical reflection on the social and environmental dimensions of changes in the energy sector. This perspective reinforces the connection between scientific research and the concrete needs of society, positioning DSR as a pedagogical and transformative resource.

The importance of transparency in research processes is emphasized by Revner, Parsons, Brendel, Lukyanenko, Tiefenbeck, Tremblay, and Brocke (2024), who highlight the need for methodological clarity in Scientific Design investigations. According to these authors, clarifying the methods and criteria employed strengthens the validity of research and increases confidence in the results obtained. In the educational context, this approach encourages the adoption of pedagogical practices that are ethical and collaborative, grounded in reflective and participatory processes. Therefore, Scientific Design is established as an approach that integrates academic rigor, innovation, and social commitment in the education of citizens prepared to face the challenges of the energy transition.

3.3 Educational Strategies and Competency Development for a Sustainable Energy Transition

The energy transition requires new educational approaches, especially regarding the preparation of citizens capable of understanding and critically engaging with socioenvironmental challenges. In this sense, the articulation between education and sustainability emerges as a central axis in the development of competencies aligned with the Sustainable Development Goals (UNESCO, 2017). As a space for integrative learning, schools must foster processes that connect technical, ethical, and social dimensions, helping students understand the interconnections among energy, environment, and society.

According to recent literature, pedagogical practices rooted in context and combined with contemporary themes strengthen the link between scientific knowledge and everyday life (Silva & Ribeiro, 2024). This connection helps students grasp the importance of science and technology in pursuing sustainable alternatives while cultivating a responsible attitude toward the use of natural resources. Educational mediation grounded in Scientific Design supports experimentation, dialogue among different areas of knowledge, and the creation of shared meanings—all essential elements for developing a culture of sustainability.

Table 2 – Suggested Educational Strategies for Developing Competencies Oriented Toward a Sustainable Energy Transition

Educational Strategy	Synthetic Description	Competencies Developed	Possible Applications
Interdisciplinary projects on renewable energy	Integrates activities from Science, Mathematics, and Geography to explore the use and impact of clean energy sources.	Technical, cognitive, and socioenvironmental competencies.	Elementary and secondary education; school units with laboratories and local partnerships.
Scientific design workshops applied to sustainability	Promotes the use of Scientific Design methodologies to	Creativity, critical thinking, cooperation, and environmental ethics.	Technical courses, integrated secondary

Educational Strategy	Synthetic Description	Competencies Developed	Possible Applications
	propose solutions to real environmental problems.		education, and teacher training programs.
Environmental studies in local communities	Encourages observation and analysis of energy and environmental practices in the school surroundings.	Ecological awareness, empathy, and social responsibility.	Basic education and university extension projects.
Sustainable innovation fairs and exhibitions	Encourages the production and dissemination of experiments and low-impact prototypes.	Scientific communication, innovation, and student leadership.	School settings and institutional events.
Learning pathways on energy transition	Provides educational routes that combine scientific foundations with socioeconomic debates on energy.	Systemic reasoning, critical analysis, and responsible decision-making.	Teacher training programs and continuing education.

Source: Adapted from UNESCO (2017); Cardoso, Novaes, and Sabonaro (2025); Prates, Vergara, and Marques (2024).

Beyond cognition, it is essential to develop socioemotional competencies that foster empathy, cooperation, and shared responsibility toward the environment. According to Cardoso, Novaes, and Sabonaro (2025), the intersection between technical and behavioral skills in the areas of Science, Technology, Engineering, and Mathematics makes students more likely to engage in initiatives focused on the energy transition. Education grounded in a solidarity-based ethic can shape critical individuals capable of acting reflectively and constructively within the socioeconomic dynamics of sustainability.

School environments that integrate projects on renewable energy and energy efficiency show, through innovative learning experiences, that this knowledge extends beyond conceptual understanding and becomes sustainable behavior (Prates, Vergara, & Marques, 2024). These initiatives demonstrate that building human capital for the energy transition is not an isolated action but the outcome of public policies that support inclusive educational practices that connect science, technology, and human values. In this sense, education becomes a privileged space for promoting sustainable economic development and for enabling the cultural change required to form environmentally responsible societies.

IV DISCUSSION AND CONCLUSION

The intersection among Education, Scientific Design, and the energy transition has offered a reflective path on how knowledge can drive sustainable and socially responsible actions. Scientific Design, by bringing together science, creativity, and innovation, emerged as a methodological reference capable of linking knowledge production to current sustainability needs, positioning itself as a key component for critical and interdisciplinary learning. This made it possible to understand education as a fundamental arena for acquiring competencies that support a culture of sustainability.

All research objectives were achieved, showing that educational mediation guided by Scientific Design enhances the promotion of the energy transition and prepares proactive citizens to face environmental and technological challenges. The findings highlight the importance of pedagogical practices that integrate science, creativity, and social responsibility, reinforcing education's role as an agent of cultural and environmental transformation.

Regarding the first thematic axis, *Education, sustainability, and energy transition: formative and social dimensions*, the study found that educational actions focused on sustainability help expand critical awareness and encourage proactive engagement in socioenvironmental transformation. This section emphasized that education, by integrating values such as equity and environmental respect, strengthens responsible citizenship aligned with sustainable development.

In the second axis, *Scientific Design as an element linking science, creativity, and innovation*, and based on Table 1 – Relationships among Scientific Design, innovation, and education, the results showed that the intersection between creation, inquiry, and educational practice supports the development of more active and cooperative learning environments. The relationships illustrated in the table show that Scientific Design functions as a bridge between knowledge generation and its social application, enabling the emergence of innovative solutions in the educational field.

Finally, the axis *Educational strategies and competency development for a sustainable energy transition*, grounded in Table 2 – Suggested educational strategies for developing competencies related to the sustainable energy transition, underscored the need to integrate technical, socioemotional, and ethical training into student learning. The proposed strategies offer concrete possibilities for incorporating energy issues into curricula and confirm that education is fertile ground for consolidating transformative practices. Future studies are encouraged to explore the application of Scientific Design in educational policies more broadly and to examine how these methodologies influence teacher training and the advancement of a culture of sustainability.

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