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Technology, Education, Society, and Renewable Energies: An Integration with Challenges and Possibilities in Science Education

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ABSTRACT
Interdisciplinarity in science education has established itself as a fundamental pedagogical approach to promote a more integrated, dynamic, and relevant education. In recent years, the combination of interdisciplinarity with the use of educational technologies has demonstrated significant potential to transform teaching practices, offering new possibilities for the development of complex competencies among students. This research adopted a qualitative approach of an exploratory and descriptive nature, aiming to understand the practices, challenges, and potentialities of interdisciplinarity mediated by technology in science education. The general objective of this research is to investigate how interdisciplinarity in science education can be enhanced through the integration of technology, education, and renewable energies, analyzing the main challenges and opportunities for pedagogical practice. Regarding the role of technology and the importance of renewable energies, it was observed that technological tools can facilitate the integration of knowledge, allowing educators to create more interactive and collaborative learning environments. Furthermore, knowledge about renewable energies proved essential for student engagement, especially when students recognize the strategic importance of their use in enabling national progress and, specifically in education, for promoting interdisciplinary projects and activities that connect theory and practice in innovative ways.

Keywords*: Interdisciplinarity; Science Education; Educational Technology; Pedagogical Practices.*

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I. INTRODUCTION

Interdisciplinarity in science education has emerged as an innovative and necessary approach in response to contemporary educational demands. This perspective transcends the fragmentation of school curricula, fostering integration across different areas of knowledge to address real-world problems in a more contextualized and meaningful manner. In the current context, characterized by rapid technological advancements, technology stands out as an essential tool to facilitate interdisciplinary pedagogical practices, enhancing student learning and engagement. Through the integration of science and technology, educators can explore topics such as sustainability, innovation, and solutions to global challenges, aligning school curricula with issues relevant to

society. However, this approach also presents challenges, including the need for specific teacher training, curriculum adaptation, and technological infrastructure in schools. This article aims to investigate the challenges and potentialities of this integration, contributing to reflections on how it can transform science education into a more dynamic, inclusive, and reality-connected space.

The research adopted a qualitative, exploratory, and descriptive approach, aiming to understand the practices, challenges, and potentialities of technology-mediated interdisciplinarity in science education. The general objective of this study is to investigate how interdisciplinarity in science education can be enhanced through the integration of technology and education, analyzing the main challenges and opportunities for pedagogical practice.

The specific objectives are as follows: Examine the fundamental concepts and main approaches to interdisciplinarity in science education, highlighting their relevance for the development of complex competencies in students; Analyze the role of technology in promoting interdisciplinary science education, focusing on how technological tools can facilitate knowledge integration and practical application; Identify and discuss the primary challenges and potentialities faced by teachers in incorporating interdisciplinary practices through the use of technologies, aiming to improve student engagement and comprehension.

This article is organized into four main sections. In the Introduction, the context of the topic is presented, emphasizing the relevance of interdisciplinarity in science education and the importance of integrating technology as a pedagogical tool. The Materials and Methods section describes the adopted procedure, explaining the literature review as the primary research strategy and the scientific sources utilized, with a focus on recent publications (from 2018 onwards). In the Theoretical Framework, the central concepts of interdisciplinarity and its approaches in science education are discussed, alongside an analysis of the role of technology in education and its potential for interdisciplinary integration. Finally, the Concluding Remarks summarize the study's key findings, highlighting both the challenges and opportunities in pedagogical practice, and propose pathways for future research and improvements in teacher training.

II. MATERIAL AND METHODS

The study titled Interdisciplinarity in Science Education: Challenges and Potentialities of the Integration between Technology and Education adopts a qualitative, exploratory, and descriptive approach, aiming to understand the practices, challenges, and potentialities of technology-mediated interdisciplinarity in science education. This article was developed based on a literature review, an essential procedure in scientific research to synthesize existing knowledge on the subject and identify gaps that can be explored. The literature review enables an understanding of theoretical and practical perspectives related to interdisciplinarity in science education, with an emphasis on the integration of technology and education, thereby contributing to the consolidation of the study's foundation.

2.1 Organization of the Literature Review

The review was systematically organized into steps, ranging from the definition of keywords to the critical analysis of the selected works. The keywords used for the search included interdisciplinarity in science education, educational technology, renewable energies, and interdisciplinary pedagogical practices. The searches were conducted in recognized scientific databases, such as Scopus, Web of Science, SciELO, Zenodo, and Google Scholar.

2.2 Investigated Scientific Sources

Only works published between 2018 and 2024 were included in the review, ensuring the information's relevance and alignment with the most recent trends in the field. The analyzed sources comprised: - Scientific articles: Empirical and theoretical studies investigating interdisciplinary practices in science education mediated by technology. - Books and book chapters: Academic publications discussing theoretical and methodological foundations regarding interdisciplinarity and technological education. - Official documents: Guidelines and public policies related to education, focusing on technological integration and the promotion of interdisciplinarity.

All sources were evaluated for relevance, originality, and methodological rigor, ensuring the reliability of the data used to construct the study. This systematic approach allowed the identification of challenges and potentialities of interdisciplinarity in science education, providing a solid foundation for the reflections presented in this article. By consolidating insights from recent academic literature and public policies, the review highlights how the integration of technology can serve as a catalyst for interdisciplinary practices. Additionally, it emphasizes the importance of addressing challenges, such as resource limitations, teacher training, and curriculum alignment, to fully realize the potential of this approach in fostering a meaningful and impactful science education.

III. THEORETICAL FRAMEWORK

The theoretical framework of this article addresses the main concepts and approaches related to interdisciplinarity in science education, with a special focus on the integration between technology and education. The first subsection, Interdisciplinarity in Science Education: Concepts and Approaches, discusses the theoretical foundations of interdisciplinarity, emphasizing its relevance for the development of students' complex competencies. Different models of knowledge area integration will be explored, highlighting the advantages of this approach in developing critical and creative thinking, as well as problem-solving skills, which are essential in the contemporary educational environment.

The second subsection, Technology as a Tool for Interdisciplinary Integration in Science Education, analyzes how technological tools can facilitate interdisciplinary practices, offering resources that enable the connection of theories from different disciplines in a more dynamic and interactive manner. Various educational technologies used in science education, such as simulation software, online learning platforms, and multimedia resources, will be discussed, as well as how these tools can enhance students' understanding by integrating content from multiple knowledge areas.

The third subsection, Challenges and Potentialities in Teaching Practice: Integration of Science and Technology, focuses on the challenges teachers face when implementing interdisciplinary pedagogical practices mediated by technology. Challenges such as teacher training deficiencies, lack of infrastructure in schools, and resistance to changes in teaching methodologies will be addressed. At the same time, the potentialities that emerge with the adoption of these practices will be analyzed, such as increased student engagement, the promotion of more meaningful learning experiences, and the preparation of students for the challenges of the contemporary world.

The fourth subsection discusses renewable energies, reinforcing the commitment to scientific education and sustainable development, in order to prepare students to face global challenges and actively contribute to building a more balanced and sustainable future. At the same time, the potentialities that emerge with the adoption of these practices will be analyzed, such as the increased engagement of students, the promotion of more meaningful learning, and the preparation of students for the challenges of the contemporary world. This theoretical framework aims, therefore, to provide a broad and current overview of the aspects of interdisciplinarity in science education, discussing both the possibilities for pedagogical innovation and the obstacles that need to be overcome for the effective integration between science and technology in education.

3.1 Interdisciplinarity in Science Education: Concepts and Approaches

Interdisciplinarity in science education is a pedagogical approach that promotes the integration of different areas of knowledge to address complex themes holistically. This practice aims to overcome the fragmentation of knowledge, providing students with a broader and more connected understanding of natural and social phenomena.

According to Fazenda and Godoy (2014), interdisciplinarity is a process involving dialogue, interaction, and cooperation among disciplines, enabling knowledge to be articulated in a meaningful context. A central concept of this approach is the connection between scientific knowledge and practical societal issues such as sustainability, health, and technological innovation. In science education, interdisciplinarity facilitates the development of competencies such as critical thinking, problem-solving, and creativity, which are essential for addressing contemporary challenges. For instance, by integrating physics, biology, and technology in projects on renewable energy, students can explore both the scientific foundations and the social and environmental impacts of the proposed solutions (Carvalho et al., 2020).

Interdisciplinary approaches are varied, including project-based learning, problem-based learning (PBL), and design thinking. These methodologies encourage collaborative work, where students take an active role in knowledge construction. Furthermore, the use of digital technologies, such as virtual simulations and interactive platforms, enhances the connections between disciplines and facilitates the understanding of abstract concepts through practical applications (Latorre-Cosculluela, Orús, & Toledo, 2020; Soares et al., 2022).

However, implementing interdisciplinarity in science education faces challenges, such as the need for specific teacher training and curricular reorganization. Teachers require support to develop interdisciplinary competencies and adopt strategies that coherently integrate content. Despite these obstacles, interdisciplinary teaching remains a promising approach, aligned with the demands of innovative and transformative scientific education in the 21st century.

3.2 Technology as a Tool for Interdisciplinary Integration in Science Education

Technology plays a crucial role in promoting interdisciplinarity in science education, acting as a mediator in the integration of different areas of knowledge. Technological resources, such as educational software, virtual laboratories, and collaborative learning platforms, enable connections that transcend traditional disciplinary boundaries, enriching students' educational experiences (Schuhmacher & Schuhmacher, 2023).

According to Moran (2020), the strategic use of technology in education not only facilitates the understanding of complex concepts but also fosters innovation and critical thinking. Among the main technological applications is the use of digital simulations and 3D modeling tools to study scientific phenomena, such as molecular behavior or the environmental impact of industrial processes.

Table 1 presents various examples of technologies applied to interdisciplinary integration in science education. These resources allow students to analyze real-world problems, linking fields such as chemistry, biology, and mathematics. Furthermore, robotics and programming exemplify how technology enables practical integration between exact and human sciences, promoting skills such as problem-solving and teamwork (Andrade & Binotto, 2020; Souza, Falcão, & Mello, 2021).

By leveraging these tools, educators can create dynamic and interactive learning environments that emphasize the interconnectedness of scientific concepts, thereby enhancing students' engagement and preparing them to address contemporary challenges effectively.

Table 1 – Examples of Technologies to Interdisciplinary Integration is Science Education

Technology	Application	Disciplines Involved	Benefits
Virtual simulations	Study of the water cycle in different ecosystems	Biology, Geography, and Physics	Dynamic visualization of complex phenomena
Remote laboratories	Chemical experiments conducted through online platforms	Chemistry and Technology	Access to safe and cost-effective experiments
3D printers	Creation of anatomical models for studying the human body	Biology, Physics, and Arts	Practical and visual learning
Programming and robotics	Development of prototypes for sustainable energy solutions	Physics, Mathematics, and Engineering	Practical integration and problem-solving
Augmented reality (AR)	Exploration of solar systems or microscopic organisms	Astronomy, Biology, and Technology	Interactivity and immersion in learning

Source: Duque (2023)

The integration of these technologies into the interdisciplinary context not only motivates students but also fosters active learning, where knowledge is constructed collaboratively and meaningfully. However, their application requires careful planning and teacher training to ensure their efficient use. When well-integrated into the curriculum, technological tools not only enhance pedagogical reach but also prepare students to face the challenges of an increasingly digital and interconnected world (Duque, 2023).

3.3 Challenges and Potentialities in Teaching Practice: Integration of Science and Technology

The integration of science and technology in education presents both an enriching opportunity and a significant challenge for teachers. On one hand, it enables the application of innovative approaches that promote active and collaborative learning. On the other hand, it demands substantial changes in teaching practices, including adaptation to new digital tools, the development of technological competencies, and the restructuring of traditional teaching methods.

As highlighted by Viana (2023), Technological Pedagogical Content Knowledge (TPACK) is essential for the effective implementation of this integration. Among the potentialities of integration are the development of 21st-century skills, such as critical thinking, creativity, and digital literacy. The use of digital technologies, such as learning platforms, scientific simulations, and collaborative tools, allows students to explore content in a more dynamic and interactive manner.

Furthermore, the combination of science and technology facilitates addressing real-world problems, such as climate change or sustainable innovation, connecting school learning to the broader social context. Readers are advised to consult Table 2 below.

Table 2: Main Challenges and Potentialities in the Integration of Science and Technology in Education

Aspect	Challenges	Potentialities
Teacher training	Lack of skills for the use of integrated technologies	Opportunity for continuous professional development through courses and training programs
School infrastructure	Limited access to equipment and connectivity	Implementation of computer labs and access to digital tools
Pedagogical planning	Difficulty in aligning curricula with technological demands	Curriculum flexibility to include interdisciplinary projects
Student engagement	Initial resistance to new methodologies	Increased engagement through interactive technological resources

Source: Vianna (2023)

Despite the challenges, the potential benefits outweigh the difficulties when strategic planning and institutional support are in place. Teaching practices can be transformed through partnerships between schools, universities, and technology companies, which provide adequate resources and training. In this way, the integration of science and technology fosters more contextualized and inclusive education, preparing students for a future marked by constant technological transformations (Santos, 2021).

3.4 Renewable Energy in Science Education: An Interdisciplinary Approach to Sustainable Education

Renewable energy plays a crucial role in today's context, marked by environmental challenges and the search for sustainable solutions to energy generation. In science education, integrating this theme enables an interdisciplinary approach that connects concepts from physics, chemistry, biology, and geography while addressing social and economic issues (Carvalho et al., 2020; Gonçalves, Lavor, & Oliveira, 2022).

Addressing renewable energy in science education not only fosters students' scientific literacy but also engages them in critical debates on sustainability, climate change, and the conscious use of natural resources. This theme encourages the development of critical thinking and problem-solving skills, which are essential for forming conscious and responsible citizens (Oliveira, Palheta, & Seabra, 2017; Adams & Nunes, 2022).

The use of educational technologies, such as digital simulations, virtual laboratories, and data visualization tools, can enrich learning about renewable energy, allowing students to understand the scientific principles underlying energy sources such as solar, wind, hydro, and biomass (Adams & Nunes, 2022).

Furthermore, interdisciplinary projects involving the construction of prototypes of renewable energy systems (e.g., small solar panels or wind turbines) can serve as practical and motivating strategies for teaching. Although integrating renewable energy into the school curriculum offers numerous potential benefits, challenges such as the lack of infrastructure, suitable teaching materials, and specific teacher training still need to be addressed (Oliveira et al., 2018).

In this regard, teacher training initiatives and the inclusion of updated content on renewable energy in initial and continuing education programs are critical to ensuring the effectiveness of this approach. Ultimately, teaching about renewable energy reinforces the commitment of science education to sustainable development, preparing students to tackle global challenges and actively contribute to building a more balanced and sustainable future (Chassot, 2016).

IV. DISCUSSION AND CONCLUSION

The research fully achieved the proposed objectives, contributing to the understanding of how interdisciplinarity in science education can be enhanced through the integration of technology and education. Throughout the study, it became evident that the interdisciplinary approach, when combined with the use of technologies, offers significant opportunities for fostering complex skills in students, such as critical thinking, problem-solving, and the ability to connect knowledge across different areas.

The analysis of the main interdisciplinary approaches, as well as the identification of their relevance in student development, showed that the integration of different fields of knowledge in science education not only enriches learning but also makes the educational process more dynamic and aligned with contemporary needs.

Regarding the role of technology and the importance of renewable energy, it was observed that technological tools can facilitate the integration of knowledge, enabling teachers to create more interactive and collaborative learning environments. Furthermore, knowledge about renewable energy proved essential for engaging students, especially when they recognize the strategic importance of its use to foster the country's progress and, specifically in education, to promote interdisciplinary projects and activities that connect theory and practice in an innovative manner.

However, the challenges identified, such as the lack of proper teacher training and the limited availability of technological resources in schools, are issues that must be addressed to fully exploit the potential of interdisciplinarity mediated by technology.

Finally, it is important to emphasize that, despite the advancements, the implementation of interdisciplinary practices with the use of technologies still requires structural changes in educational policies and educator training.

The research suggests that future investigations could focus on empirical studies that more deeply analyze the application of interdisciplinarity in the context of different education systems, especially in public schools, and the real impact of these practices on student performance. Additionally, exploring the development of continuous teacher training programs, specifically aimed at using technologies in interdisciplinary education, would be a relevant strategy to overcome the identified barriers.

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