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CTSA Approach in the Educational Context: Implementation of a Paper Recycling Process and Development of Sustainable Entrepreneurship

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Abstract:
Background: *This experience report presents a project integrating paper recycling and social entrepreneurship within an elective course at a Full-Time Municipal School (EMTI) in Fortaleza's Municipal Network. The primary objective was to document the methodological trajectory and the outcomes of the initiative, promoting CTSA (Science, Technology, Society, and Environment) education and fostering the development of competencies and skills as proposed by the Brazilian National Common Curricular Base (BNCC) and the Fortaleza Curriculum Reference Document (DCRFor) among students of Middle School.*
Materials and Methods: *The project comprised practical recycling workshops, research on entrepreneurship concepts, and the creation of a digital platform (website/virtual gallery) for exhibiting student-produced items. Activities were designed to integrate technical, social, and environmental learning while engaging students in hands-on experiences aligned with CTSA educational principles.*
Results: *The intervention resulted in increased student participation, enhanced critical thinking, strengthened environmental awareness, and improved technological and social skills. Students demonstrated greater autonomy, collaborative engagement, and the capacity to connect scientific knowledge with practical, socially relevant actions.*

Conclusion: *The experience confirms the effectiveness of the CTSA approach in developing conscious and engaged citizens. Integrating sustainability practices with social entrepreneurship fosters meaningful learning, reinforces competencies established by the BNCC, and contributes to comprehensive science education.*

Keywords: *CTSA education, paper recycling, social entrepreneurship, science teaching, BNCC competencies.*

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I. Introduction

The contemporary scenario is characterized by a rapidly advancing scientific and technological development, which exerts a profound and multifaceted impact on both individual and collective spheres of society. A constant and substantial transformation of everyday practices is observed, driven by technological progress occurring at increasingly shorter intervals. In this dynamic context, it becomes imperative to educate individuals who possess a high level of qualification, sharp critical thinking skills, and well-developed social awareness. Such individuals must be capable of interacting responsibly and ethically within their sociocultural environment, contributing to collective advancement and well-being.

Within this framework, scientific education assumes a crucial and irreplaceable role in the cultural development of modern society. As postulated by Martins (2020), the universalization of scientific education is not merely a goal but an academic consensus, with few or no innovative arguments that could challenge the relevance of democratizing scientific knowledge.

In this perspective, schools play a central role in disseminating scientific and technological knowledge and in fostering active citizenship. Science teaching, structured and systematized within the curriculum, constitutes a subject of scientific investigation in itself. Various studies (Lima & Maués, 2006; Rosa et al., 2007; Da Costa Ramos & Da Silva Rosa, 2008; Da Silva Augusto, 2007) highlight the difficulties faced by teachers in developing environments conducive to the construction of scientific and technological knowledge. Furthermore, Martins (2020, p.19) points out that traditional school programs, often centered on canonical science, have progressively become demotivating from the students' perspective, presenting a hermetic and dogmatic conception of science frequently disconnected from students' cognitive interests and reality.

Effective scientific education, therefore, requires methodologically planned and structured actions. The objective of such actions is to ensure the intrinsic interrelations between Science and Technology through the use of cooperative and active methodologies, enabling students to perform a critical-reflective analysis of reality. In this context, the CTSA (Science, Technology, Society, and Environment) educational approach demonstrates significant potential for generating promising outcomes.

In a scenario of increasing technological development and socio-environmental challenges, the CTSA movement acquires substantial relevance. Education assumes a key function in fostering critical and emancipatory thinking, contributing to the formation of individuals prepared to face contemporary challenges.

The rationale for this investigation is grounded in the evident relationship between the themes of recycling/entrepreneurship and CTSA education, manifested in the connection between environmental education, scientific knowledge, and the exercise of citizenship.

II. Material And Methods

This study adopted the qualitative research paradigm as proposed by Creswell (2021). Qualitative research collects data within natural settings, where participants experience the phenomenon firsthand. Accordingly, "it is not possible to avoid personal interpretations in the analysis of qualitative data" (Creswell, 2021, pp. 186–187), rendering the researcher a central figure in data collection and interpretation. The analysis was conducted inductively, recursively, and interactively, following a circular and progressive dynamic that frequently returns to the data for refinement.

Participant observation, as described by Peruzzo (2017), was employed as the primary data collection strategy. The researcher recorded behaviors and activities in field notes, immersing in the daily routines of the participants without the obligation to return the results to them. As the course instructor, the researcher-participant was able to capture emergent information, thereby enabling students greater freedom of expression.

For systematic data recording, a structured observational protocol was used, consisting of a single-page layout divided by a central line. Descriptive notes (including dialogues and emotions) were separated from reflective notes (analytical considerations of the researcher), following the model established by Sari and Bogdan (1992).

III. Literature Review

Scientific education plays a fundamental role in contemporary cultural development, and its relevance is widely recognized and reinforced by educational guidelines such as the Brazilian National Common Curricular Base (BNCC) and the Fortaleza Curriculum Reference Document (DCRFor). The BNCC emphasizes the development of essential competencies, including scientific inquiry, critical thinking, creativity (General Competence 2), and the ability to act with autonomy, responsibility, and sustainability (General Competence 10).

Complementarily, the DCRFor reinforces the formation of critical, creative, collaborative, and digitally responsible individuals, highlighting principles such as contextualization, interdisciplinarity, and student protagonism. It also emphasizes integrative themes such as environmental education and digital culture, with both documents converging on the necessity of pedagogical practices that connect learning to the students' socio-environmental realities.

Within this framework, the CTSA (Science, Technology, Society, and Environment) educational approach emerges as a pedagogical methodology with considerable potential. "The CTSA movement originated in the twentieth century, particularly after World War II, with discussions focusing on the social consequences of scientific and technological innovations" (Moraes & Araújo, 2012, pp. 39–40), and has progressively gained prominence in the Brazilian educational context. This approach has also been the subject of multiple research lines in undergraduate and postgraduate programs (Muniz dos Santos et al., 2020).

The CTSA framework posits that teaching methodologies should be characterized by contextualization and transversal integration. This implies that instruction should not be confined to specific content but intentionally developed in social contexts, aiming to deepen students' understanding of the interrelationships among Science, Technology, Society, and Environment. Through this approach, learners are encouraged to actively seek knowledge, critically position themselves regarding contemporary issues (Santos, 2007), and engage in responsible citizenship, with strong consideration for environmental responsibilities.

> As a meaningful interrogation of reality is implemented, the educational institution promotes experiences and stimulates critical thinking regarding the multiple possibilities—existing, ecologically desirable, and non-ecological—for inhabiting, living, and coexisting in the world from a socially and environmentally responsible perspective (De Moura Carvalho, 2013, p. 121).

The central aim of scientific education from a CTSA perspective is the integrated understanding of science, establishing explicit connections with technology and analyzing its impact on society and the environment. This perspective seeks to provide students with applied scientific training that enables them to develop essential competencies for engaging with their context and to perceive and act consciously and critically in everyday issues. Such an approach facilitates comprehension of the ethical and social impacts of science and technology, significantly contributing to the formation of participatory and engaged members of society.

III. Description of the Experience

3.1 Context

The present experience was conducted at a Municipal Full-Time School (EMTI) located in the Conjunto Ceará neighborhood – District 3, in Fortaleza, Ceará, Brazil. This institution is part of the network managed by the Municipal Department of Education (SME), which oversees the Municipal Education System of Fortaleza.

The school serves approximately 600 students, encompassing grades 6 through 9 of Elementary Education. The institution has robust and well-equipped infrastructure, covering a total area of approximately 4,790 m², including specialized educational spaces. Notable facilities include laboratories for subjects such as mathematics, chemistry, biology, and computer science, providing students with advanced educational and technological resources. Additionally, the school houses a well-stocked library, comprehensive food service facilities including a kitchen and cafeteria, an auditorium for events and presentations, and a sports complex featuring a covered multi-purpose court and changing rooms. Administrative and pedagogical spaces essential for school operation, such as teachers' rooms, pedagogical coordination offices, the secretary's office, and the principal's office, complement this structure.

The pedagogical approach adopted by EMTIs in Fortaleza, as outlined in the EMTI Informative Guide (2023), is structured around three fundamental axes for the holistic development of students: Academic Excellence, Life Skills Development, and Competencies for the 21st Century.

3.2 Objectives of the Practice

This study aims primarily to share the methodological trajectory and outcomes of a paper recycling and entrepreneurship project conducted in an elective course at a public municipal school in Fortaleza.

A secondary objective was to actively promote CTSA education, establishing a close connection between environmental education, scientific knowledge, and the full exercise of citizenship, in alignment with the competencies proposed by BNCC and DCRFor.

A further specific and highly relevant objective was the development of a digital platform—a website/virtual gallery—to exhibit the handcrafted products created by the students. This objective integrated concepts of entrepreneurship and computer literacy, expanding the technological and social inclusion dimension of the CTSA approach, and enabling students to engage with the digital world while generating value through sustainable practices.

3.3 Strategies and Activities Implemented

The project was carried out over 28 sessions of 55 minutes each, within an elective course, involving a group of 38 students from Cycle I (6th and 7th grades) of Elementary Education II.

Project activities were carefully planned and executed in distinct phases:

- **Initial Phase:** The project proposal was presented to the students, addressing two key dimensions: the scientific-historical and the social entrepreneurship aspects. This phase included reading and discussing texts on environmental awareness and the history of paper production, as well as viewing audiovisual records of children's entrepreneurship experiences to inspire and contextualize the work.
- **Material Collection:** In the second session, students were encouraged to collect cardboard boxes. These were then decorated with blue paint and the universal recycling symbol, and strategically placed throughout the school as selective paper collection points. The collected material at the end of each day was stored in plastic containers, serving to sensitize students about rational use and waste prevention.
- **Recycling Workshops:** Five practical paper recycling workshops were conducted in the school laboratory. Required materials included various types of paper, water, containers, a blender, screens/mesh for sheet formation, non-woven fabric (TNT), spatulas, pigments, and adhesives. Initially, teachers demonstrated the entire procedure, after which students were divided into teams to independently execute the recycling process, fostering collaborative work and hands-on learning.
- **Production and Digitization:** After the recycling workshops, students dedicated two computer lab sessions to research and select the products to be produced from recycled paper. Selected items included bookmarks, notebook and agenda covers, mobiles, and playful objects. Four sessions were then devoted to crafting these products, which were subsequently photographed to develop the digital exhibition platform.
- **Website Construction:** In the computer lab, students planned and built the digital exhibition platform using Google Sites over four sessions. The intuitive interface and pre-configured templates facilitated collective engagement, allowing students to acquire practical computer and technological skills.
- **Conclusion:** Throughout the project, students were intensively engaged with concepts of social entrepreneurship and environmental awareness, emphasizing how everyday practices can impact society and contribute to resolving socio-environmental issues. In the final phase, students presented the created products and the digital platform in the school auditorium, reporting comprehensively on the entire development process.

3.4 Resources Utilized

The project required diverse resources:

- **Materials:** Various types of paper (newspapers, magazines, used sheets), water, containers for maceration and mixing, a blender for pulping, screens/mesh for sheet formation, non-woven fabric (TNT) for water absorption, spatulas, pigments for coloring, and adhesives for finishing. Cardboard boxes were used for selective collection.
- **Technological:** The school's computer lab, with internet access, was central. Google Sites was chosen for the creation of the digital gallery due to its ease of use and customization options. Cameras were used to visually document the students' products.
- **Pedagogical:** Texts and didactic materials were used for discussions on environmental awareness and the history of paper. Audiovisual records of children's entrepreneurship experiences provided inspiration. A structured observational protocol was essential for systematic data recording. Continuous teacher mediation was crucial for guiding students throughout all project stages.

3.5 Challenges Encountered

A notable challenge was the students' lack of prior training in using computational resources. While the integration of digital tools, such as Google Sites, enriched the learning process, it required a period of adaptation and instruction to ensure effective utilization. Continuous and qualified teacher mediation proved critical for the project's success. Guiding students through digital platform construction, comprehension of entrepreneurship and CTSA concepts, and overcom

IV. Discussion and Analysis

The experience reported in this project provides practical evidence of the effectiveness of the CTSA (Science, Technology, Society, and Environment) educational approach within the school environment. This initiative aligns consistently with the perspective that science education should empower students to engage critically with society, develop a deep understanding of the world, and exercise full citizenship, as outlined in educational guidelines (Brazil, 2017). The harmonious integration of scientific and technological knowledge with social and environmental issues—central to the CTSA perspective—proved particularly promising. This approach not only fostered increased student participation but also promoted the development of competencies and skills that extend beyond the traditional curriculum, preparing learners for the complex challenges of contemporary society.

The CTSA approach encouraged active student engagement and the development of a broad range of skills and competencies aligned with the BNCC. These included Knowledge (1) across various domains (chemistry, physics, biology, history, technology, entrepreneurship); Scientific, Critical, and Creative Thinking (2) through the investigation of recycling and the creation of solutions; Communication (4) in discussions and digital production; Digital Culture (5) in the use of tools such as Google Sites; Work and Life Project (6) through social entrepreneurship; Argumentation (7) in defending ideas during proposed activities; Empathy and Cooperation (9) in teamwork; and Responsibility and Citizenship (10) in fostering environmental awareness and collective actions.

Regarding the Natural Sciences, the project demonstrated strong alignment with both the Fortaleza Curriculum Reference Document (Fortaleza, 2024) and the BNCC, promoting essential competencies. The recycled paper production workshops provided students with direct and meaningful engagement with chemistry-related topics. Concepts such as substances/mixtures, chemical elements, chemical reactions, and chemical processes (sorting, grinding, sieving) as well as solvent/solute interactions were addressed in a practical and contextualized manner. Active engagement and genuine interest were observed among students, who successfully established clear connections between theoretical concepts and their everyday applications. This resulted in the development of specific Natural Science skills outlined in the BNCC, including investigating material transformations (e.g., EF06CI02, EF06CI03) and discussing conscious consumption (e.g., EF07CI05).

From a technological perspective, the integration of computational resources for the construction of the digital platform required prior student training, despite technology being a familiar element within the school context. Planning and building the website involved extensive dialogue and research, with teacher mediation being crucial for successful project completion. The use of these technological resources, however, significantly promoted social development. Students' routine social interactions are inherently linked to technology and digital devices; thus, when a specific objective, such as creating a digital platform, is intentionally introduced, technology acts as a catalyst. It stimulates reading and research practices, encourages investigative curiosity, enables students to become active agents in the knowledge construction process, and fosters the development of social skills within dialogical and collaborative contexts.

Critical reflections on the learning outcomes indicate that the experience substantially contributed to deepening students' understanding of their social and environmental context, fostering awareness of their role as active agents in environmental preservation. By connecting reflection on proper paper disposal and reuse with entrepreneurship concepts, students not only enhanced their creative capacities but also promoted cognitive development and transformed their social reality. Observed advancements include the acquisition of multiple competencies and engagement in sustainable and entrepreneurial practices.

The implications for other educational contexts are extensive, suggesting that the CTSA approach, when combined with practical and technological projects, can be replicated to promote a more engaging, relevant, and transformative education.

V. Conclusion

The project represented a pedagogical initiative that demonstrated the integration of CTSA (Science, Technology, Society, and Environment) educational principles with practical recycling activities and the development of social entrepreneurship. The culmination of this experience involved the creation of a digital platform (website/virtual gallery), which served as a space to showcase the handcrafted products produced by

the students. This process consolidated knowledge acquired across science, technology, sustainability, and citizenship, representing a tangible outcome of students' learning and engagement.

The contributions of this experience to the field are observable in multiple dimensions. The project promoted environmental awareness and the development of manual skills through recycling activities. Additionally, it fostered critical thinking, creativity, and problem-solving abilities, competencies outlined in the BNCC and DCRFor. The integration of social entrepreneurship concepts, with a focus on community impact, alongside the use of technological tools for constructing the digital platform, empowered students to act as active agents. They participated in knowledge construction and in transforming their social and environmental reality. By contextualizing science and technology education within real-world issues, the CTSA approach proved to be an effective pedagogical instrument for fostering a more sustainable and socially conscious society.

It is recommended to maintain and expand projects that integrate CTSA education with practical and technological activities, exploring new themes and extending their reach to other educational institutions at local and regional levels. To enhance the impact and sustainability of such initiatives, continuous teacher training is crucial. Educators who are well-prepared and up-to-date in CTSA methodologies and educational technology use are fundamental to successful implementation. Likewise, providing appropriate and accessible technological resources is essential for schools to carry out such projects effectively.

Therefore, the experience reported in this project underscores the importance of education aimed at forming critical, proactive citizens committed to building a more equitable and sustainable society. CTSA education, through innovative and contextualized practices, can serve as a pathway for social transformation and the construction of a more suitable world for future generations.

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