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PROBLEM-BASED CHEMISTRY TEACHING: EVIDENCE FROM A CASE STUDY USING DIGITAL INFORMATION AND COMMUNICATION TECHNOLOGIES (DICT) AND THE SCIENCE, TECHNOLOGY, SOCIETY, AND ENVIRONMENT (STSE) APPROACH IN HIGH SCHOOL

ENSINO DE QUÍMICA BASEADO EM PROBLEMAS: EVIDÊNCIAS DE UM ESTUDO DE CASO COM USO DE TECNOLOGIAS DIGITAIS DA INFORMAÇÃO E COMUNICAÇÃO (TDICS) E ABORDAGEM CIÊNCIA, TECNOLOGIA, SOCIEDADE E AMBIENTE (CTSA) NO ENSINO MÉDIO

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ABSTRACT

This study analyzes the contribution of the Science, Technology, Society, and Environment (STSE) approach combined with Information and Communication Digital Technologies (DICT) in Chemistry teaching at the secondary education level. The research is characterized as a case study with a qualitative approach and descriptive nature, conducted with thirty-six students from a first-year class in a public school in Macapá, Amapá, Brazil. The activities were structured based on contextualized problem situations and integrated with the use of virtual simulations from the PhET platform and experimental practices using low-cost materials. The results indicated improvements in content assimilation, increased student engagement, and enhanced academic performance, although the class average reflects an intermediate level of learning. The study also observed the development of critical thinking, autonomy, and active student participation in the learning process. However, challenges related to school infrastructure, continuing teacher education, and learning difficulties among some students were identified. It is concluded that the integration of the STSE approach, digital technologies, and active methodologies contributes to a more contextualized form of teaching, supporting knowledge construction and the development of more critical and participatory students.

Keywords: Chemistry Teaching; STSE; Digital Technologies; Active Methodologies; Learning.

RESUMO

Este estudo analisa a contribuição da abordagem Ciência, Tecnologia, Sociedade e Ambiente (CTSA) associada às Tecnologias Digitais da Informação e Comunicação (TDICs) no ensino de Química no Ensino Médio. A pesquisa caracteriza-se como um

estudo de caso, de abordagem qualitativa e natureza descritiva, desenvolvido com 36 estudantes da 1ª série B de uma escola pública em Macapá/AP. As atividades foram estruturadas a partir de problemáticas contextualizadas e integradas ao uso de simuladores virtuais da plataforma PhET e práticas experimentais com materiais de baixo custo. Os resultados evidenciaram avanços na assimilação dos conteúdos, maior engajamento dos estudantes e melhoria no desempenho acadêmico, embora a média da turma indique nível intermediário de aprendizagem. Observou-se também o desenvolvimento do pensamento crítico, da autonomia e da participação ativa dos discentes no processo educativo. Entretanto, foram identificados desafios relacionados à infraestrutura escolar, à formação continuada dos docentes e às dificuldades de aprendizagem de parte dos estudantes. Conclui-se que a integração entre a abordagem CTSA, tecnologias digitais e metodologias ativas contribui para um ensino mais contextualizado, favorecendo a construção do conhecimento e a formação de estudantes mais críticos e participativos.
Palavras-chave: Ensino de Química; CTSA; Tecnologias Digitais; Metodologias Ativas; Aprendizagem.

1. INTRODUCTION

Advances in Digital Information and Communication Technology (DICT) have occurred at an accelerated scale, influencing various economic sectors and contributing to productivity in decision-making processes. In a global context, society has become widely connected, which facilitates the exchange of ideas and the proposal of solutions to problems of global scope. This movement has also significantly impacted the economic and educational sectors (Senna and Ribeiro, 2023).

In the current context, digital technologies have contributed to the development of more critical and questioning students, expanding their sources of knowledge beyond classroom instruction. This transformation reinforces the need to integrate Digital Information and Communication Technology (DICT) into teaching and learning processes, promoting greater interaction among students, teachers, and innovative educational tools (Souza *et al.*, 2021).

In 2019, the world witnessed the rapid spread of the SARS-CoV-2 virus, which reached all continents and triggered a public health crisis. To contain the spread of the virus, several countries adopted emergency measures, including the suspension of activities essential to the population and the implementation of "lockdown," characterized by strict restrictions on circulation. This strategy, applied on a global scale, constituted a measure to slow transmission, and preserve healthcare systems (Senhoras, 2020).

The first case of COVID-19 in Brazil was reported on February 26, 2020, in the state of São Paulo, subsequently spreading across all regions of the country and impacting economic, social, and educational sectors. This scenario required planning and rapid responses from the government, aiming to mitigate the effects of the pandemic and protect the population. In this context, the need to incorporate digital tools into school environments became evident, and this adaptation contributed to the implementation of synchronous classes (De Lima Yamaguchi, 2021).

The use of mobile phones and electronic devices has become a subject of debate among teachers and specialists regarding their allowance or prohibition in the school environment. However, significant challenges persist in the incorporation of innovative

technologies into the teaching and learning process, particularly concerning the lack of adequate training for teachers, coordinators, and technical staff (De Souza Welyczko, 2025). In this context, continuing education becomes essential for the development of competencies that promote autonomy in a society undergoing constant technological transformation. Without such support, the integration of technologies remains limited, compromising their potential impact on contemporary education (Barros and Vieira, 2021).

The use of technologies enables the expansion of pedagogical methodologies and contributes to students' understanding of the content addressed, making classes more dynamic and functional. However, resistance is observed among teachers and students, associated with the lack of continuing education. In this context, adequate training promotes greater interaction and reduces the initial apprehension related to the use of teaching platforms, encouraging their use in a conscious and responsible manner. Additionally, it helps minimize risks associated with improper exposure, verbal violence, and inappropriate use of writing. From this perspective, the incorporation of technologies should be understood as an integral component of teaching practices (Bittencourt and Albino, 2017; Akram *et al.*, 2022).

2. THEORETICAL FOUNDATION

2.1. The Areas of Natural Sciences and Mathematics

Approaches in the fields of Natural Sciences and Mathematics in the teaching and learning process are essential for understanding phenomena present in students' daily lives. However, students

experience difficulties in assimilating these contents, often associated with the predominance of traditional pedagogical practices, which limit the development of critical thinking and the comprehensive formation of learners (Gomes *et al.*, 2025). In this context, the National Curriculum Parameters for Secondary Education (PCNEM) aim to overcome a fragmented and linear education, encouraging integration among disciplines and valuing students' experiences. Complementarily, the National Curriculum Guidelines (OCN) for Secondary Education (Pedro and De Santana, 2025) emphasize the use of technological resources as a pedagogical strategy, particularly in Chemistry teaching, expanding learning possibilities and articulating scientific knowledge with students' reality (Silva and Da Costa, 2026).

In the current context, the use of technological resources by teachers in the educational environment enables the presentation of content in a more accessible manner, contributing to greater student engagement and interest in the classroom, since technology is present in their daily lives. Thus, the topics addressed in different subjects tend to foster increased student participation (De Macedo Carvalho, 2025). In Chemistry teaching, it is important to consider the realities of students and their communities, incorporating social, technological, and environmental aspects present in their daily contexts (Silva and Da Costa, 2026). In this perspective, students assume an active role in the learning process, developing their own ideas and workable solutions to problems, while also enhancing their observational skills and critical thinking, which contributes to more meaningful learning (De Almeida, 2024).

2.2. The Importance of Science, Technology, Society, and Environment (STSE) Approach in Chemistry Education

Students' perceptions of the fields of Natural and Earth Sciences are often associated with an elevated level of complexity. This characteristic partly stems from methodologies that do not establish a direct connection with students' daily lives, which hinders the articulation between scientific and empirical knowledge. Considering technological advances and the environmental challenges of the 21st century, it becomes essential to promote connections between teaching and the realities experienced by students (Cavalcante *et al.*, 2019; Silva and Da Costa, 2026).

From this perspective, the Science, Technology, Society, and Environment (STSE) approach as a pedagogical strategy is effective, as it emphasizes problem situations related to contemporary reality, promoting the development of critical thinking, student participation, and interdisciplinary dialogue between students and teachers. In this context, the teaching and learning process contributes to a more meaningful education aligned with contemporary demands (Cavalcante *et al.*, 2019; Gopal *et al.*, 2024).

The STSE approach seeks to bring students closer to the reality in which they are embedded, promoting collective discussions about problems present in their communities. In this way, students come to understand the relevance of scientific theories and their applications in society. In the educational context, it is essential that students recognize the importance of scientific knowledge in areas such as health, the environment, and climate change. Additionally, this approach encourages reflection on scientific advances and their impacts on society and the environment.

The use of this approach assigns the teacher the role of mediator, directing the protagonism to students in the learning process. An

analysis of the literature indicates active student participation in problem-solving and in the construction of new knowledge, which supports the development of autonomy and the consolidation of learning. In a globalized and technological context, it becomes essential to prepare students to address societal demands and challenges. From this perspective, the STSE methodology, by articulating scientific concepts with students' daily lives, enables not only content understanding but also the ability to apply knowledge in a critical and transformative manner in their realities (De Almeida, 2024).

3. METHODOLOGY

This study is characterized as a case study with a qualitative approach and a descriptive nature, conducted with the first year B class of secondary education at Escola Estadual José do Patrocínio (EEJP), located at Rua Operária nº 0203, in the municipality of Macapá, Amapá, Brazil. The institution offers education across three shifts, including elementary education, secondary education, and Youth and Adult Education. The class was selected due to the need to implement new pedagogical practices in Chemistry, Physics, and Mathematics, considering the difficulties students demonstrated in understanding abstract concepts and applying them to everyday situations. In response, the pedagogical coordination expanded the initiative to other subject areas, adopting a multidisciplinary approach.

The selection of the theme stemmed from the issue related to the use of mobile phones in the classroom and the possibilities of their use as a pedagogical resource in the students' educational process. The approach was based on the observation that, although mobile

devices are often associated with distraction and dispersion, they can serve as learning support tools when used in a guided manner. From this perspective, it was considered relevant to examine how digital technologies, with emphasis on mobile phones and learning platforms, can contribute to the development of knowledge and competencies required in the contemporary context. Thus, the discussion established a relationship between these practices and the strengthening of students' autonomy, critical thinking, and resilience in response to current demands. In this context, the Pedagogical Exhibition 2024 adopted as its thematic axis "Resilience in Times of Global Crises (RTCG)".

A total of thirty-six students from the institution participated in the study, organized into six groups of six members each. This grouping strategy fostered interaction among students, encouraging the exchange of knowledge and the collective construction of understanding. Moreover, it contributed to the development of critical thinking through dialogue, promoting reflection on the issues addressed. This dynamic is aligned with the Freirean conception of dialogical education, which emphasizes the problematization of reality as a starting point for meaningful learning (Freire, 1987; Saviani, 2021).

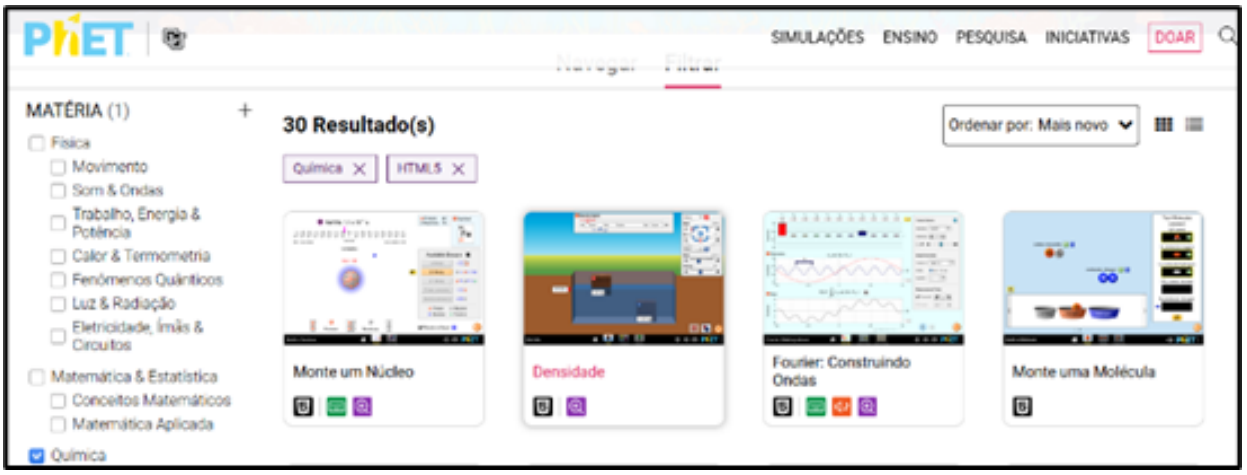
The teaching and learning process was developed systematically, encompassing the analysis of significant issues closely related to students' realities, such as the presence of unknown substances, electricity consumption in the district of Fazendinha, recurrent flooding and waterlogging, as well as the fire that occurred at the Boated Kiss nightclub and floodplain areas, among others. The selection of these themes aimed to integrate school content with concrete situations, promoting contextualization and expanding

students' critical understanding of social, environmental, and scientific phenomena.

The activities developed with the first year B students in the Chemistry subject were structured based on these themes and guided by the STSE approach. This proposal sought to promote the development of scientific knowledge articulated with students' daily lives. The main objective was to stimulate the resolution of real-world problems and foster critical reflection on social, technological, and environmental issues, contributing to the development of students capable of understanding and acting responsibly in a constantly changing context. The activities were planned with an emphasis on environmental preservation, the sustainable use of natural resources, and the analysis of technological advances and their impacts on society, establishing connections between chemical content and concrete issues experienced by students. Thus, the research methodology was grounded in the assumptions of the qualitative approach.

The content covered aimed to highlight the importance of Chemistry and its presence in students' daily lives, bringing theory closer to their lived reality. Some topics, however, presented a higher level of complexity, requiring the adoption of differentiated methodologies to support comprehension. For this purpose, the PhET Colorado platform (Figure 1) was used, providing interactive simulations capable of representing scientific phenomena in a dynamic and accessible manner.

Figure 1 - The PhET Colorado platform.



Available at: https://phet.colorado.edu/

Students conducted experiments after assimilating the content through the PhET platform, using low-cost materials. One of the groups conducted an experiment using red cabbage indicator to determine the acidic or basic nature of different substances.

Additionally, the theme of sustainable energy was addressed, in which one of the groups developed a model demonstrating how the system operates, as well as presenting its positive impacts on society and the environment.

4. RESULTS AND DISCUSSION

The data obtained from the first year B class indicated changes in the assimilation of Chemistry concepts, associated with experimental practices and the use of technological resources as tools to support student learning. The use of these resources demonstrated changes in students' academic performance and behavior, reflected in greater engagement in classes, especially in practical activities and the use of virtual simulations. This process enabled students to formulate hypotheses, engage in discussions, and develop solutions to the proposed problems. Thus, learning became more contextualized and aligned with the guidelines of the National Curriculum Parameters for Secondary Education (PCNEM),

as established by Law No. 9,394/1996, the Brazilian National Education Guidelines and Framework Law (Alves *et al.*, 2021).

The evaluation process was developed based on planning and guidance from the pedagogical coordination in conjunction with teachers, considering students' active participation, written assignments, presentations during the Pedagogical Week, and the analysis of bimonthly grades. This process aimed to assess not only academic performance but also students' engagement, autonomy, and critical thinking skills. In this context, the exchange of experiences and the sharing of ideas play a relevant role in problem-solving, considering the individual characteristics of students, as each learner presents unique traits (Minayo, 2012; Zamiri and Esmaeili, 2024).

This approach proved relevant for the implementation of curriculum content, in alignment with the guidelines of the Brazilian National Common Curricular Base (BNCC). From this perspective, its principle is oriented toward human development through the articulation between educational theory and practice, contributing to students' civic formation. Furthermore, it promotes the development of competencies related to learning to be, to know, to do, and to live together. In this context, the Pedagogical Week contributed to expanding students' understanding of themes related to their daily lives, while also enabling the construction of new knowledge through activities involving planning, organization, and practice.

Students presented contributions grounded in events of national and international relevance, highlighting the environmental disaster in Mariana, global warming, the fire at the Boated Kiss nightclub, and discussions on alternative sources of clean energy. The selection

of these themes enabled the articulation of school content with social issues, fostering students' critical and reflective development in relation to matters of collective impact. In this process, the school assumes a relevant role as a space for knowledge construction, encouraging the proposal of creative and socially responsible solutions by students (Mackedanz *et al.*, 2010; Matsuo and Silva, 2021).

In this context, it is essential that pedagogical practices are aligned with current themes and the social environment to promote meaningful learning. Mackedanz *et al.* (2010) emphasize the importance of teacher mediation in selecting content that supports a more contextualized and interdisciplinary education at the secondary level, contributing to student development.

The analysis conducted based on the STSE approach enabled the integration of science and technology in the teaching and learning process. Thus, students engaged in dynamic and interactive activities using the PhET Interactive Simulations platform, developed by the University of Colorado (United States), as a resource to explore scientific concepts. The use of the simulator provided access to a wide range of virtual simulations focused on Science, Mathematics, and Technology , allowing students to explore complex concepts in a visual and dynamic manner. From this perspective, the adopted methodology fostered experimentation and investigation in a safe and accessible environment, stimulating curiosity and engagement. This resource enabled the visualization of phenomena often considered abstract or difficult to understand, promoting the connection between theoretical and practical learning.

In this scenario, the use of educational simulators proved effective in addressing learning difficulties and strengthening the connections between scientific knowledge and students' daily lives. This approach contributed to the development of investigative skills and to the appreciation of active methodologies, expanding student protagonism in the school environment. According to the literature, the integration of digital technologies in education enhances the formative process, stimulates curiosity, and supports the active construction of knowledge, as it allows students to assume a more participatory and autonomous role in the learning process (Freires, 2024; Viega *et al.*, 2025; Da PaixãO, 2026).

Students often perceive curricular components in the fields of Exact Sciences and Mathematics as challenging due to the complexity of their approaches, including formulas and mathematical calculations, which may result in lower academic performance. Another factor associated with student performance is anxiety, which has increased in recent times. This issue is not limited to the exact sciences, as it affects all disciplines, especially during assessment periods, when anxiety combined with fear can hinder the learning process and performance, leading to cycles of frustration.

From this perspective, the use of diverse pedagogical resources becomes relevant for improving students' academic performance. The incorporation of digital technologies and experimental practices constitutes a strategy that contributes to content assimilation. The effectiveness of this approach can be observed in Table 1, which presents the progression of students' individual grades across academic terms. This analysis indicated improvements in

performance, demonstrating the contribution of the STSE approach combined with the use of digital technologies.

Table 1 - Analysis of the application of STS (Science, Technology, Society and Environment) and digital technologies in the bimonthly periods.

Student	1° bimonthly	2° bimonthly	3° bimonthly	4° bimonthly	Tota
1	12,5	12,5	2	0	27
2	12,5	12,5	15	20	60
3	12,5	13	7	0	32,5
4	18,9	10,1	3	0	32
5	12,8	12,5	11	21	57,3

⚠ Esta tabela possui muitas colunas e foi cortada para impressão. Para visualizá-la completa, acesse o artigo original em: https://revistatopicos.com.br/artigos/problem-based-chemistry-teaching-evidence-from-a-case-study-using-digital-information-and-communication-technologies-dict-and-the-science-technology-society-and-environment-stse-approach-in-high-school?noblockage

Source: Authors (2025)

Table 1 shows an improvement in the class performance over the academic terms. However, the overall arithmetic mean was 54.09 points, indicating an intermediate level of learning. Although students demonstrated improved academic performance through the STSE approach combined with the use of digital technologies, there is a need to incorporate additional pedagogical strategies to

further enhance the teaching and learning process in a more comprehensive manner.

Academic performance does not depend exclusively on cognitive factors, as it is also influenced by social, individual, structural, and emotional aspects present in the school environment and in students' social contexts. In this sense, collaboration among teachers, students, and different sectors of the institution becomes essential for the improvement of pedagogical practices that promote motivation and students' cognitive development.

Data analysis shows that Student 11 achieved the highest academic performance compared to other members of the class (Table 1). This result, as well as those of students who passed, indicates their ability to keep up with the proposed activities and to assimilate the content. In this context, students can serve as references for one another, encouraging collaborative study practices, which contribute to collective development and to strengthening social interactions within the school environment.

On the other hand, the lowest score observed (Student 1) indicates that some students experience difficulties in assimilating the content. This outcome may be associated with several factors, such as lack of adaptation to the adopted methodology, learning gaps, or lack of interest in the proposed activities. Therefore, it is important to emphasize the need for pedagogical interventions, particularly through remedial support and individualized follow-their enabling students to overcome these difficulties and achieve the learning objectives.

According to the results obtained, 69.44% of the students passed, while 30.56% remained in remedial status, indicating that a sizable portion of the class still experiences difficulties in consolidating the content throughout the academic period. This scenario shows that, although most students met the minimum approval criteria, weaknesses persist in the teaching and learning processes. This evidence reinforces the need to implement differentiated pedagogical actions and continuous support strategies capable of addressing the diverse educational needs of students. The adoption of active methodologies, individualized monitoring, and the diversification of teaching practices can contribute to strengthening learning and reducing performance disparities. Furthermore, systematic monitoring of results throughout the academic year becomes relevant for the early identification of difficulties and the implementation of pedagogical interventions, supporting student development and improving overall class performance.

5. CONCLUSION

The present study demonstrated that Science, Technology, Society, and Environment (STSE) combined with the use of Information and Communication Digital Technologies (DICT), contributes to Chemistry teaching by promoting the articulation between scientific content and students' daily lives. The use of tools such as PhET Interactive Simulations enabled the visualization of chemical phenomena, supporting concept comprehension and increasing student engagement in the proposed activities. The integration of experimental practices, technological resources, and the STSE approach resulted in improvements in academic performance and student engagement, while also fostering the development of critical thinking and autonomy in the learning process.

Despite the observed advances, challenges remain that limit the consolidation of these practices in the school environment, particularly regarding infrastructure, continuing teacher education, and resistance to the adoption of new methodologies. These factors highlight the need for investment in educational policies that promote teacher qualification and expand access to digital technologies within the school context.

The results indicate that the adoption of methodologies integrating the STSE approach and DICT can contribute to a more contextualized form of teaching aligned with contemporary demands. However, it is important to emphasize the need for further studies that deepen the analysis of these practices in different educational contexts, to expand their applicability and better understand their long-term impacts. Thus, the proposed approach represents a relevant pedagogical alternative for Chemistry teaching, as it supports the development of students with enhanced critical, reflective, and participatory capacities in addressing the challenges of contemporary society.

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