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Utilization of multimedia resources in nuclear sciences communication within the Brazilian school environment

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Abstract: Brazil holds a promising future in nuclear technology, as evidenced by significant investments such as the construction of the Brazilian Multipurpose Reactor and the completion of the country's third nuclear power plant, Angra 3. However, scientific communication regarding the benefits and applications of nuclear technology still requires strengthening to enhance public acceptance. In this context, multimedia resources have proven to be an effective tool for promoting meaningful learning about nuclear technology among high school students. Following the lessons, 97.76% of students perceived a gain in knowledge about nuclear technologies, and 86.64% reported a more positive attitude towards nuclear science. Additionally, 84% of students expressed increased favorability towards radiation applications, and support for nuclear energy as a clean energy source rose from 43.84% to 84.88%. These results indicate that multimedia not only facilitated understanding of complex concepts but also contributed to a more favorable perception of nuclear technology among students. This outcome is crucial for fostering an informed culture regarding the importance of nuclear technology, ensuring that future professionals and decision-makers are well-acquainted with its benefits and applications.

Keywords: nuclear technology, scientific communication, multimedia, education.

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Utilização de recursos multimídia na comunicação das ciências nucleares no ambiente escolar brasileiro

Resumo: O Brasil possui um futuro promissor na tecnologia nuclear, evidenciado por investimentos significativos, como a construção do Reator Multipropósito Brasileiro e a conclusão da terceira usina nuclear do país, Angra 3. No entanto, a comunicação científica sobre os benefícios e aplicações da tecnologia nuclear ainda precisa ser fortalecida para aumentar a aceitação pública. Nesse contexto, os recursos multimídia provaram ser uma ferramenta eficaz para promover a aprendizagem significativa sobre a tecnologia nuclear entre alunos do ensino médio. Após as aulas, 97,76% dos alunos perceberam um ganho de conhecimento sobre tecnologias nucleares, e 86,64% relataram uma atitude mais positiva em relação à ciência nuclear. Além disso, 84% dos alunos expressaram uma maior favorabilidade em relação às aplicações das radiações, e o apoio à energia nuclear como uma fonte de energia limpa aumentou de 43,84% para 84,88%. Esses resultados indicam que a multimídia não apenas facilitou a compreensão de conceitos complexos, mas também contribuiu para uma percepção mais favorável da tecnologia nuclear entre os alunos. Esse resultado é crucial para fomentar uma cultura informada sobre a importância da tecnologia nuclear, garantindo que futuros profissionais e tomadores de decisão estejam bem informados sobre seus benefícios e aplicações.

Palavras-chave: Tecnologia nuclear, comunicação científica, multimídia, educação.

1. INTRODUCTION

Information and Communication Technologies (ICTs) have introduced a dynamic information transmission system into society. Technological advancements have directly impacted the processes of planning, production, organization, and dissemination of information. In the midst the Covid-19 pandemic, various educational institutions intensified their studies to explore new ways of disseminating knowledge. They incorporated multimedia technologies that are increasingly prevalent in people's daily lives, encompassing content in the form of images, videos, and 3D media, among other formats [1,2].

The International Atomic Energy Agency (IAEA) establishes educational programs on nuclear science for both education and training purposes. These courses are offered online and have emerged as an appealing alternative to build and enhance the knowledge of students and professionals regarding the applications of radiation [3,4]. Based on its courses, the IAEA recommends and supports the use of multimedia directly in instructional materials. Digital educational resources are advocated for the development of courses targeting various audiences, including prospective or current technical personnel and operators of research reactors, as well as students and those interested in the fundamental concepts of reactors. Diverse courses can be designed to improve knowledge transmission and contribute to the popularization of nuclear science, disseminating understanding throughout society [4,5].

The level of knowledge about nuclear technologies and radiation applications directly impacts public acceptance. The absence of accessible scientific communication regarding nuclear science favors narratives shaped by historical prejudices, which hinder balanced discussions about the benefits of nuclear technologies. In this context, scientific communication is crucial in conveying technological advancements to the public, highlighting their impact, applications, and implications. An informed and engaged public can support the advancement of nuclear technology, contributing to the creation of a favorable environment for research, funding, and the implementation of innovative solutions. However, public acceptance of nuclear energy is directly influenced by the quality of scientific communication. One of the strongly recommended resources for optimizing scientific communication is multimedia [6].

Multimedia can be defined as electronic languages developed on a device capable of managing and processing information or data. Multimedia is the use of static resources such as texts, images, and photos, as well as dynamic resources like videos and animations, associated with each other to achieve a specific effect or result. The use of multimedia enables the production and utilization of various art languages, different means of communication, and expressions that are conceived, organized, and made available for reproduction across various technological platforms [7].

The use of multimedia in education should align with learning theories that study the effectiveness of these resources. Developed in 2009 by the American educational psychologist Richard E. Mayer, the Cognitive Theory of Multimedia Learning (CTML) posits the central thesis that "people learn more from words and images than from words alone." The theory establishes a relationship between multimedia development, considering the learners' mental processes and the content addressed. In other words, it creates an association between multimedia educational messages and their conception in the human mind [7].

The audiovisual resources employed in multimedia create interconnections between images and text, contributing to textual cohesion. An audiovisual production aligned with textual content establishes a relationship of complementarity and redundancy that enhances the understanding of the addressed topic. They are designed according to a linear sequence idealized by their creator; however, their reading does not adhere to a hierarchy of the elements presented. The broad concept of multimedia design encompasses everything from a brief presentation lasting a few minutes to a complete encyclopedia arranged in electronic language form [7,8].

Furthermore, it is important to consider studies on meaningful learning, such as those established by the American psychologist David Paul Ausubel. Meaningful learning can be defined as the active process in which the learner integrates and interprets acquired knowledge with their prior knowledge, attributing new meanings to their understanding, thereby expanding and updating their previous information. For meaningful learning to occur, three conditions must be met: the material must present content structured in a logical sequence to ensure significant learning; the learner must have the cognitive ability to relate prior knowledge with the knowledge being acquired; and the learner must consciously dedicate effort to learning the new content [8].

Multisensory presentations, in addition to being captivating the audience, enhance comprehension, allowing new ideas to be constructed from multiple perspectives and providing support for analytical thinking. However, the outcomes of using multimedia in information transmission depend on how the information and resources are organized. Multimedia has redefined communication methods in modern systems. In recent years, the application of multimedia resources in teaching and learning processes has become a subject of study [9,10].

With this perspective, this work aims to employ multimedia resources combined with teaching concepts in the scientific communication of the nuclear field to high school students. The goal is to promote a comprehensive, engaging, and meaningful understanding of nuclear concepts, as well as to stimulate the interest and involvement of students in this scientific domain. Furthermore, the study seeks to evaluate the effectiveness of these strategies in the students' learning process.

2. MATERIALS AND METHODS

The multimedia design was developed to be functional with the present educational content, following the Cognitive Learning Theory [7,8]. In the first stage, the themes to be addressed were defined. A comprehensive literature review was conducted, focusing on books authored by renowned experts in nuclear science. This review ensured that the content was accurate, up-to-date, and aligned with the current state of knowledge in the domain. The content was structured so that the information presented followed a logical order of knowledge construction, allowing students to progress at their own pace. The content was available online and free of charge to high school students.

The content was developed in a modular format, addressing six pillars of nuclear science knowledge, as outlined in Table I.

Table I: Content developed in the six pillars of nuclear science.

Corresponding Module	Content Covered
Module1	Introduction to Fundamental Concepts
Module 2	Nuclear Energy
Modulo 3	Nuclear Fuel Cycle
Module 4	Applications in Industry and Medicine
Module 5	Challenges of Nuclear Technology
Module 6	Advances and Future

Source: authors

The content of the modules was made available on an online platform, offering several advantages inherent to virtual learning environments. These include flexibility, where each student had their own login, allowing them to learn at their own pace, and accessibility from various devices, enabling participation regardless of location. Moreover, the platform's dynamic and interactive nature facilitated student engagement through multimedia resources, enhancing both interest and comprehension. This virtual environment supported continuous learning by allowing students to revisit materials as needed, promoting a deeper understanding and retention of the content.

The second stage involved the creation of presentations and accompanying multimedia resources for each theme. The presentations were customized with interactive layouts, incorporating images, graphs, GIFs, videos, and animations relevant to the content. The lessons were organized into information blocks, divided according to the theme, as shown in Fig. 1.

Figure 1: Example of one of the presented lessons on the topic of isotopes.

Source: authors

The educational content was designed in a modular format, where each new topic introduced was followed by corresponding activities within the virtual environment. These activities comprised questions directly related to the material covered, aiming to assess students' comprehension of the subject matter. The quizzes were structured to verify the learning outcomes, requiring students to achieve a minimum score of 60% to progress to subsequent modules. If a student did not meet this threshold, they were required to revisit the learning materials and retake the assessment, with the option to repeat the process as many times as necessary until the learning objectives were met. This approach ensured that students had a solid understanding of the content before advancing, thereby reinforcing the learning process. Additionally, a questionnaire was formulated to evaluate student satisfaction and their new perspectives on nuclear science after acquiring the knowledge provided in the course.

In the third stage, contact was established with schools to implement the proposed lessons. This involved coordinating with educational institutions to schedule and conduct the classes, ensuring that the content reached the intended audience effectively. For each class where the content was taught, a dedicated teacher was responsible for supervising the students' learning process throughout their engagement with the module content. However, despite the teacher's supervision, the virtual environment was designed with clear instructions on how the learning activities should be conducted, allowing students to navigate the material independently. Furthermore, the platform included a communication channel where students could ask questions, seek clarification, or report any technical issues they encountered, ensuring that the learning experience remained smooth and well-supported.

Finally, in the last stage, the questionnaire responses were analyzed. This analysis aimed to assess the impact of the course on students' understanding of nuclear science and their overall satisfaction with the content. The findings from these questionnaires provided valuable insights into the effectiveness of the educational approach and the extent to which the students' perceptions had shifted.

By meticulously structuring the methodology in these stages, the project aimed to deliver comprehensive and engaging educational content, assess its impact on students, and contribute to the broader goal of enhancing public understanding and acceptance of nuclear science.

3. RESULTS AND DISCUSSIONS

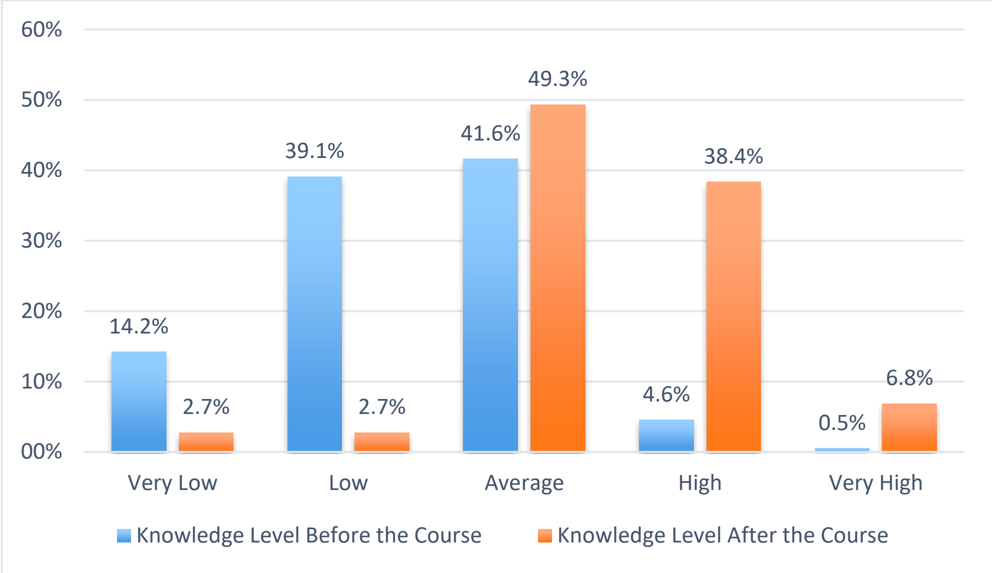
The content was presented to a total of 228 students. These students belong to 4 different schools located in the metropolitan region of the city of Belo Horizonte (MG): Cidade dos Meninos São Vicente de Paula, Escola Estadual Henrique de Souza Filho, Escola

Estadual José Bonifácio Nogueira, and Escola Estadual Menino Jesus de Praga. The average time spent by students to complete the presentations and going through all modules was about 3 hours.

After completing the course, students responded to questionnaires assessing their knowledge and opinions regarding nuclear science. Assessing students' perceptions of their own knowledge level is of paramount importance, as this self-awareness allows them to reflect on their learning process and identify areas of progress or needed improvement. The self-report questionnaire provides valuable insight into each student's individual experience, capturing shifts in confidence and understanding of the topics covered. Although self-assessment is subjective, it plays a critical role in pedagogy by enabling students to recognize the impact of educational content on their comprehension.

Furthermore, students' perception of acquired knowledge can be considered an indirect yet meaningful indicator of teaching effectiveness, as it reflects their ability to integrate and retain information. When combined with other parameters such as engagement and content retention, the analysis of self-assessment data offers a comprehensive view of the methodology's success. In this study, the self-reported evaluations were complemented by formal assessments of student performance through activities and quizzes, which corroborated the improvement in both perceived and consolidated knowledge levels. The results are shown in Figure 2.

Figure 2: How students perceived their knowledge regarding nuclear science before and after the lessons.



Source: authors

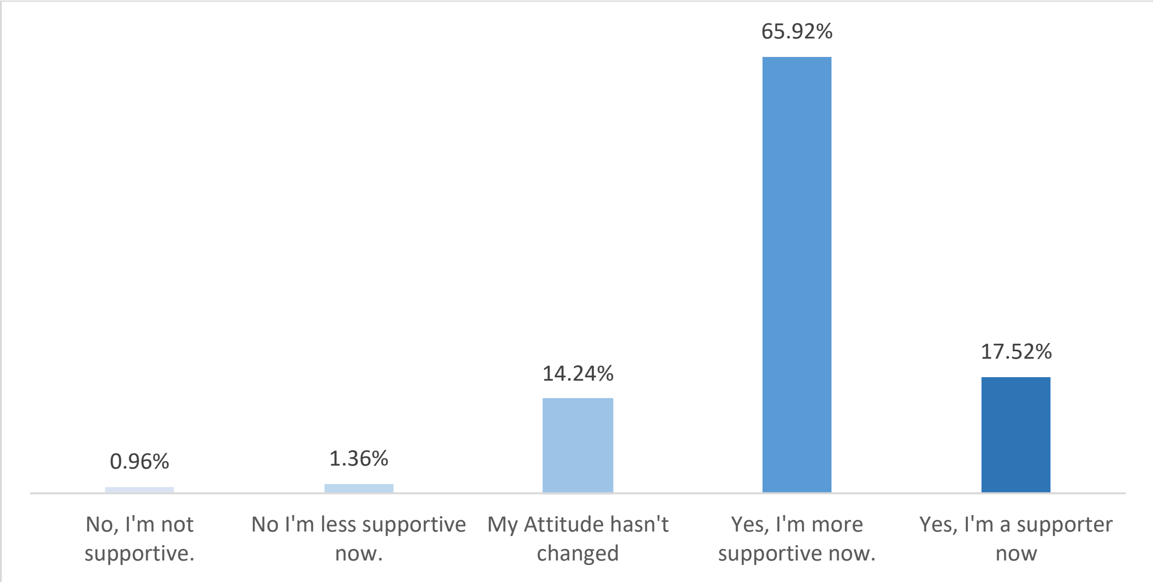
The analysis of students' self-perceived knowledge levels before and after the lessons indicates a significant improvement. Initially, 14.2% of students rated their knowledge as "Very Low" and 39.1% as "Low," with only 4.6% and 0.5% rating it as "High" and "Very High," respectively.

Post-intervention, the percentages of students rating their knowledge as "Very Low" and "Low" dropped to 2.7% each. Notably, 38.4% of students now rated their knowledge as "High" and 6.8% as "Very High." The "Average" category increased slightly from 41.6% to 49.3%.

These results demonstrate the effectiveness of the lessons in enhancing students' understanding of nuclear science, significantly shifting perceptions from lower to higher knowledge categories. The increase in the "High" and "Very High" categories underscores the depth of understanding gained, while the reduction in the lower categories highlights the broad impact of the educational program. This improvement is crucial for fostering informed public opinion and support for nuclear science and its applications.

In the questionnaire, students were also asked to evaluate their stance on research and developments related to nuclear energy and nuclear applications after acquiring knowledge in the nuclear field. They were queried on whether their attitudes had become more or less favorable. The results corresponding to this inquiry are illustrated in Figure 3 below.

Figure 3: How students perceived their knowledge regarding nuclear science before and after the lessons.



Source: authors

The data reveals a notable shift in students' attitudes towards nuclear energy and its applications following the educational intervention. Prior to the lessons, a minority of students, 0.96%, remained opposed to nuclear research and development, and 1.36% expressed a less favorable stance post-intervention. A substantial portion, 14.24%, reported no change in their attitude. However, the majority, 65.92%, indicated a more favorable perspective after the lessons, and 17.52% noted a significant positive shift in their attitude. These results underscore the effectiveness of the lessons in altering perceptions, suggesting that informed education can play a crucial role in fostering support for nuclear science and its advancements.

Students were also questioned about the significance of scientific outreach in the acceptance of nuclear technology. Approximately 89% of respondents believe that public disapproval is directly influenced by the lack of accurate information and the pervasive impact of misinformation. Furthermore, over 92% of students expressed the belief that with proper scientific outreach, it is possible to enhance public awareness about the importance of nuclear technology, thereby making the population more favorable towards its utilization.

The results of this study have proven to be promising, aligning with similar findings in other research conducted in countries like China and South Korea [11,12]. These findings demonstrate the effectiveness of well-structured educational interventions in enhancing students' knowledge and shifting public perception towards a more favorable view of nuclear technology. The consistency of these results across diverse cultural and educational contexts underscores the robustness of the methodology, suggesting its potential for broader application in various settings.

Furthermore, the results emphasize the pivotal role of effective communication and education in shaping public opinion on nuclear technologies. The data suggests that misinformation and a lack of awareness remain significant barriers to public acceptance. Addressing these challenges through comprehensive scientific outreach can foster a more informed and supportive public. This highlights the necessity of ongoing educational programs and public engagement initiatives to ensure the wide dissemination of accurate information about nuclear science, ultimately contributing to a more informed and accepting society.

These findings also highlight the critical role of effective communication and education in shaping public opinion on nuclear technologies. The data suggests that misinformation and lack of awareness are significant barriers to public acceptance. By addressing these issues through comprehensive scientific outreach, it is feasible to foster a more informed and supportive public. This underscores the need for continuous efforts in educational programs and public engagement initiatives to ensure that accurate information about nuclear science is disseminated widely, ultimately contributing to a more informed and accepting society.

4. CONCLUSIONS

Brazil has a promising future in nuclear technology. New investments are being made, such as the construction of the Brazilian Multipurpose Reactor and the completion of the country's third nuclear power plant, Angra 3. Despite these strides, there remains a critical need to enhance scientific communication to bridge the gap between technological advancements and public understanding. Effective dissemination of information about the benefits and applications of nuclear technology is essential for fostering greater public acceptance.

The present study has demonstrated that multimedia tools are exceptionally effective in facilitating meaningful learning about nuclear technology among high school students. By incorporating multimedia elements into the educational content, students were able to engage with and understand complex concepts related to nuclear science, including its history, benefits, operational principles, and associated risks. The significant shift in students' attitudes towards a more favorable view of nuclear technology underscores the effectiveness of multimedia as a pedagogical tool.

Today's students represent the next generation of professionals and decision-makers. Cultivating an informed perspective on nuclear technology is crucial for ensuring that future leaders and innovators appreciate its significance and potential. As such, the integration of multimedia resources in educational settings is a strategic approach to enhancing public knowledge and support for nuclear science. This approach not only addresses current informational gaps but also contributes to the formation of a well-informed public capable of making informed decisions regarding the future of nuclear technology in Brazil.

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