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Artigo

3D MODELING AS A STRATEGY FOR INCLUSIVE CHEMISTRY TEACHING

MODELAGEM 3D COMO ESTRATÉGIA PARA O ENSINO INCLUSIVO DE QUÍMICA

EL MODELADO 3D COMO ESTRATEGIA PARA LA ENSEÑANZA DE QUÍMICA INCLUSIVA

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Rita de Cássia Ramos Queiroz de Freitas
Specialist in Chemistry Education
Institution: Faculdade Venda Nova do Imigrante
Address: Venda Nova do Imigrante, Espírito Santo, Brazil
E-mail: ritarqfreitas@gmail.com

Lília Raquel Fé da Silva
Doctorate in Animal Science
Institution: Universidade Federal do Piauí
Address: Teresina, Piauí, Brazil
E-mail: liliaraquelf@gmail.com

Radival da Costa Nery Junior
Master's in Mathematics
Institution: Universidade Estadual do Sudoeste da Bahia
Address: Vitória da Conquista, Bahia, Brazil
E-mail: radival.nery@ifbaiano.edu.br

Joel Augusto Moura Porto
Master's in Genetics and Molecular Biology
Institution: Universidade Estadual de Santa Cruz (UESC)
Address: Ilhéus, Bahia, Brazil
E-mail: joelaugustomp@gmail.com

Ronaldo Santos Guedes
Undergraduate in Agronomic Engineering
Institution: Universidade Federal do Recôncavo da Bahia
Address: Cruz das Almas, Bahia, Brazil
E-mail: ronaldosantos.guedes@gmail.com



Vivianne Cambuí Figueiredo Rocha
Doctorate in Veterinary Medicine
Institution: Universidade de São Paulo
Address: São Paulo, São Paulo, Brazil
E-mail: salvavi@yahoo.com.br

Maria Sandra Ramos Queiroz
Doctorate in Pharmaceutical Sciences
Institution: Universidade Federal do Rio de Janeiro (UFRJ)
Address: Rio de Janeiro, Rio de Janeiro, Brazil
E-mail: msandrarq@yahoo.com.br

Cassius de Souza
PhD in Medical Sciences
Institution: Universidade Estadual do Rio de Janeiro
Address: Araruama, Rio de Janeiro, Brazil
E-mail: prof.cassius.farmaciaviva@gmail.com

Fabio de Brito Silva
Undergraduate Student in Medicine
Institution: Faculdade União Araruama de Ensino
Address: Araruama, Rio de Janeiro, Brazil
E-mail: britofabio957@gmail.com

Maria Luiza Marques Martins
Undergraduate in Pharmacy
Institution: Universidade Estácio de Sá
Address: Cabo Frio, Rio de Janeiro, Brazil
E-mail: maria.luiza.m.m17@outlook.com

ABSTRACT: In order to guarantee the integration of Special Education in regular education schools, as recommended by the Law of Guidelines and Bases, adaptations of methodologies and teaching resources are necessary to enable the active participation of all students in the teaching-learning process. 3D printing technology has proven to be a viable resource for this purpose and is gaining more and more space in the area of education. This device contributes to modernizing educational spaces through products that are within the reach of teachers and students. In the case of the Chemistry curricular component, due to its essentially abstract nature, the use of this technology helps teachers in producing more contextualized classes. This study aimed to print specific molecular models in 3D, in order to contribute to the promotion of Chemistry teaching from an inclusive perspective. 13 kits were created with 10 pieces each of carbohydrate, hydrogen, oxygen and nitrogen molecules. After production, the printed kits were delivered to teachers at Escola Estadual Governador Luiz Viana Filho in the 1st and 2nd year classes of high school and at IF Baiano, Campus Guanambi. According to the teachers' reports, this material is capable of contributing to improving the effectiveness of chemistry teaching, both for the students mentioned above and for those who do not have specific needs.



KEYWORDS: special education, teaching methodologies, teaching resources, science.

RESUMO: Com o intuito de garantir a integração da Educação Especial nas escolas do ensino regular, conforme recomenda a Lei das Diretrizes e Bases, são necessárias adaptações de metodologias e recursos didáticos que possibilitem a participação ativa de todos os estudantes no processo de ensino-aprendizagem. A tecnologia de impressão 3D tem se mostrado um recurso viável para essa finalidade e ganha cada vez mais espaço na área da educação. Tal artifício contribui para modernizar espaços educativos através de produtos que estejam ao alcance de docentes e discentes. No caso do componente curricular Química, em razão do seu caráter essencialmente abstrato, o uso dessa tecnologia auxilia professores na produção de aulas mais contextualizadas. Este estudo teve como objetivo imprimir modelos moleculares específicos em 3D, a fim de contribuir com a promoção do ensino de Química em uma perspectiva inclusiva. Foram elaborados 13 kits com 10 peças cada das moléculas de carboidrado, hidrogênio, oxigênio e nitrogênio. Após a produção, os Kits impressos foram entregues aos professores da Escola Estadual Governador Luiz Viana Filho nas turmas de 1ª e 2ª anoo do ensino médio e do IF Baiano, Campus Guanambi. Conforme relato dos professores, esse material é capaz de contribuir com a melhoria na efetividade do ensino de química, tanto para os alunos supramencionados, quanto para aqueles que não possuem necessidades específicas.

PALAVRAS-CHAVE: educação especial, metodologias de ensino, recursos didáticos, ciências.

RESUMEN: Para garantizar la integración de la Educación Especial en las escuelas de educación regular, tal como lo recomienda la Ley de Lineamientos y Bases, son necesarias adaptaciones de metodologías y recursos didácticos que permitan la participación activa de todos los estudiantes en el proceso de enseñanza-aprendizaje. La tecnología de impresión 3D ha demostrado ser un recurso viable para este fin y está ganando cada vez más espacio en el ámbito educativo. Este dispositivo contribuye a modernizar los espacios educativos a través de productos que están al alcance de docentes y estudiantes. En el caso del componente curricular de Química, por su carácter esencialmente abstracto, el uso de esta tecnología ayuda a los docentes a producir clases más contextualizadas. Este estudio tuvo como objetivo imprimir modelos moleculares específicos en 3D, con el fin de contribuir al fomento de la enseñanza de la Química desde una perspectiva inclusiva. Se crearon 13 kits con 10 piezas cada una de moléculas de carbohidratos, hidrógeno, oxígeno y nitrógeno. Después de la producción, los kits impresos fueron entregados a los profesores de la Escola Estadual Governador Luiz Viana Filho de 1º y 2º año de secundaria y



del IF Baiano, Campus Guanambi. Según los informes de los profesores, este material es capaz de contribuir a mejorar la eficacia de la enseñanza de la química, tanto para los estudiantes mencionados anteriormente como para aquellos que no tienen necesidades específicas.

PALABRAS CLAVE: educación especial, metodologías de enseñanza, recursos didácticos, ciencia.

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1. Introduction

According to Law No. 12,796 of April 4, 2013, special education is the modality of school education preferably offered in the regular education network, for students with disabilities, global developmental disorders, and high abilities or giftedness. However, primarily according to Brazilian legislation, the Salamanca Statement (1994), a resolution of the United Nations drafted at the World Conference on Special Education in Salamanca, Spain, in 1994, established the principles and policies of Standard Procedures for Equalization of Opportunities for Persons with Disabilities. At present, it is still considered one of the most important documents aimed at social inclusion.

In light of this framework, in Brazil, the current legislation for the educational inclusion of persons with disabilities seeks to guarantee access, permanence, and academic success for all students, regardless of their physical, intellectual, sensory, or emotional conditions. Some important legal landmarks in this regard can be described by the following provisions. The Law of Guidelines and Bases of National Education (LDB), Law No. 9,394/96, guarantees access to regular school and the provision of special education, preferably in the regular education network. It also provides for the



adaptation of the curriculum, methodologies, and assessments to meet the needs of students with disabilities (Brazil, 1996).

The National Policy on Special Education in the Perspective of Inclusive Education, elaborated in January 2008, defines guidelines for the education of persons with disabilities, global developmental disorders, and high abilities or giftedness, with the aim of promoting access, participation, and learning of these students in regular school. On the other hand, Decree No. 7,611/2011 regulates the National Policy on Special Education in the Perspective of Inclusive Education, establishing norms for the implementation of Specialized Educational Assistance (SEA) and the training of teachers for inclusive education.

The aforementioned legislation, among other normative documents, constitutes the legal framework that seeks to guide public policies and inclusive educational practices in Brazil, ensuring the full exercise of the right to education for all people, regardless of their differences and specific needs; it is expected that educational settings capable of guaranteeing equal education for all will be created.

Furthermore, the data presented by the National Institute for Educational Studies and Research Anísio Teixeira (Inep) in the 2023 school census reflect the results of these policies. These effects can be observed in the reduction of the presence of the target audience of special education in special or exclusive classes. In 2019, they accounted for 7.3% of enrollments; whereas, in 2023, this number reduced to 5.0%, meaning that 96,446 students, aged between four and 17 years old, stopped attending exclusive classes to attend regular schools (Inep, 2023).

It is observed that with the inclusion of this target group in regular schools, debates on this topic have gained importance, reflecting the scenario that points to the need for the school community to be prepared to embrace the diversities that enter these spaces. Nevertheless, Barbosa and Bezerra (2021) affirm that professionals in institutions feel unprepared for



this demand and that the debate on this issue is still not common in all realities. Among these contexts, it is possible that the learning difficulties encountered by students with hearing impairments who comprehend and interact with the world through visuospatial experience, as well as for students with visual impairments who interact in a tactile-auditory manner, stem from the lack of physical accessibility in school environments, the unavailability of adapted materials, and the non-inclusive education training of professionals, which constitute important limiting factors and hinder the education process (Coelho, Abreu, 2018).

In this scenario, considering Chemistry teaching as an essentially abstract science that requires skills to support spatial cognitive operations, constructions of mental models are necessary, such as those representing molecular geometries. According to Barbosa and Bezerra (2021), these geometries are based on three dimensions; however, in some cases, they are presented to students only in two-dimensional form. This occurs due to the lack or inadequacy of materials, whereby one of the few resources used to demonstrate spatial arrangements is the textbook, leading to difficulties in comprehension by students.

However, Cader and Costa (2010) emphasize that the chemical education of deaf or blind individuals can be supported by the use of three-dimensional utensils in the construction of objects and didactic materials that can assist in the teaching-learning process. In these cases, a viable option is the use of 3D printing technology, which is related to active learning and can be used in the recreation of experimental activities, molecular models, and geometries, enabling the construction of concrete materials in appropriate sizes, as support for the images presented in books, as well as for the elements and contents exposed in theories within the classroom (Bonachela, 2021).

Means like these, according to Freitas and Paz (2021), foster a sense of inclusion by these students in the teacher's methodology and are essential



in the pursuit of knowledge. Basniak and Liziero (2017) further assert that the use of these methodologies enables students to better understand and grasp the content taught in class more quickly, thus being extremely relevant for Chemistry teaching, both for students with hearing or visual impairments and for those who do not have these disabilities.

Thus, this research aimed to print specific molecular models in 3D, in order to contribute to the promotion of Chemistry teaching from an inclusive perspective.

2. Methodology

This research was based on the development of didactic materials to be used in the teaching of natural sciences and chemistry in basic education, aimed at students with hearing or visual impairments in high schools in the municipality of Guanambi, BA. The investigation was primarily grounded in a literature review, which explored descriptive studies on the difficulties faced by students with visual impairments in the learning process of school subjects.

The reviewed studies provided a solid foundation for understanding these difficulties and identifying possible solutions applicable to the target community. One of the initial issues highlighted was the difficulty faced by students with visual impairments in classroom environments, such as the inability to interpret graphs and understand geometry when teaching is based solely on the use of chalkboard and chalk.

2.1 Definition of Molecular Models

A literature review was conducted to identify the most challenging chemical concepts for students, especially those with specific needs. Specific molecular models were selected to represent the concepts clearly and



tangibly, considering their curricular relevance and their potential to facilitate understanding.

2.2 Design and Development of Molecular Models

Using Autodesk's Fusion 360 software, selected 3D molecular models were created, ensuring accuracy and fidelity to the real chemical structure. Through these models, adaptations were made to ensure they were tactile and visually accessible, considering the possibility of use by students with different sensory needs.

The 3D printing of the molecular models was carried out in the IF Maker laboratory at IF Baiano, Campus Guanambi. The 3D models were converted into files compatible with the available printers.

2.3 Validation of Molecular Models

Usability tests were conducted with a pilot group of students, including those with and without specific needs, IFBA students, Campus Guanambi - BA. Simultaneously, qualitative feedback through interviews was collected regarding the effectiveness of the molecular models in understanding chemical concepts and facilitating the teaching-learning process.

2.4 Implementation in Educational Environments

The printed molecular models were provided to high school chemistry teachers at Escola Estadual Governador Luiz Viana Filho (two classes: each with 1 deaf student, one in the first year and one in the second year) and at the Federal Institute of Education, Science, and Technology Baiano Campus Guanambi (Class with students served by the Center for Assistance to People

with Specific Needs - NAPNE), accompanied by support materials and instructions for their application in the classroom.

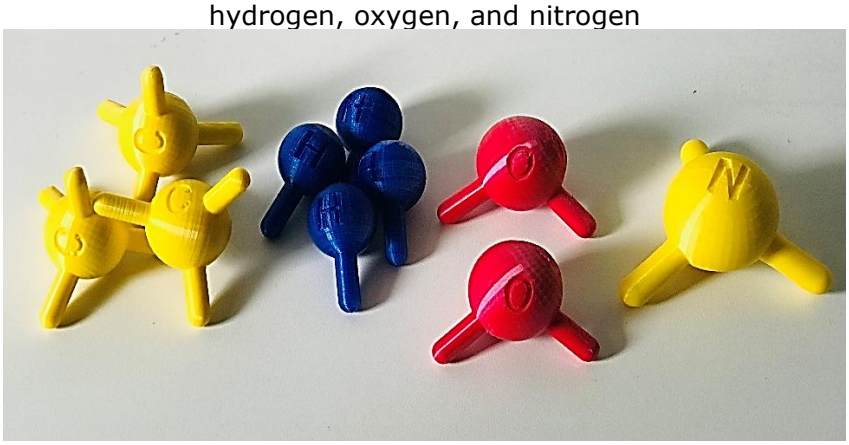
The implementation of the molecular models in Chemistry classes was monitored to assess their impact on student engagement and performance.

3. Results and Discussions

The results obtained from the implementation of the printed molecular models highlighted the significant benefits of this innovative approach to teaching Chemistry, especially in the context of educational inclusion.

Through the questionnaire with the chemistry teachers at IF Baiano, the molecular geometries to be constructed were defined, taking into account their importance in the study of chemistry (Figure 1).

Figure 1. Kit with the molecules produced by 3D printing: carbon, hydrogen, oxygen, and nitrogen



Source: Authors.

Based on the feedback from teachers during the delivery of the kits, it is believed that this material can contribute to reducing the difficulties encountered by students and teachers in the teaching-learning process of chemical concepts. With a focus on students who require inclusive teaching aids with tactile and visuospatial characteristics.

Thirteen kits of 10 pieces each were crafted. Each kit comprised: 3 carbon molecules, 4 hydrogen molecules, 2 oxygen molecules, and 1 nitrogen molecule (Figure 2). Initially, a batch of kits was provided for evaluation by teachers, students, and other professionals involved in the teaching process at IF Baiano. The suggested adaptations were incorporated into the subsequent batches.

Figure 2. Molecules produced by 3D printing.



Source: Authors.

The kits were used in Chemistry classes for both the 1st and 2nd-year high school students at Escola Estadual Governador Luiz Viana Filho and for the class with students served by the Center for Assistance to People with Specific Needs (NAPNE) at IF Baiano, Guanabi campus. Through interviews conducted after the classes, teachers and students reported their experience with the kits and suggested adjustments according to their needs. For example, incorporating Braille writing systems for identification and



increasing the size of the pieces. The latter adjustment is justified to ensure that, considering that in many situations the teacher would not have sufficient time to allow all sighted students to touch the pieces, they can still be visualized even from a distance.

Furthermore, both teachers and students emphasized the relevance of the printed molecular models as teaching tools. The perception of those involved in the teaching process that these models helped make chemical concepts more understandable and interesting is an important indicator of the practical utility of this approach. These considerations are corroborated by studies by Neto, Loubet, and Albuquerque (2021), which recognize molecular models as valuable resources that complement traditional classes and suggest that this approach can be easily integrated into the existing curriculum, enriching students' learning experience.

According to Barbosa and Moura (2013), active learning is affirmed when the teacher acts as a guide, supervisor, or facilitator of the learning process, rather than just a sole source of information and knowledge. Based on what these authors state, we understand that this research, by offering didactic material adapted to the classroom's needs, contributes to arousing teachers' and students' interest in innovation possibilities and brings the school closer to technological advances. Thus, through this tactile and visual approach to molecular models, supported by authors like Coppi *et al*. (2022) and Vasconcelos (2021), it is believed that students with specific needs, such as deafness or blindness, were able to participate more actively in activities.

However, it is worth noting that the ability of molecular models to provide a more accessible and inclusive learning experience for these students is an important achievement and highlights the transformative potential of 3D printing technology in education, contributing to overcoming traditional barriers to accessing content (Caruzo; Silva; Marcondes, 2023).

Furthermore, during the course of this work, progress was observed towards democratizing the use of 3D printing focusing on teaching, as even



though the equipment already existed at IF Baiano, they had not been used by the teaching degree courses.

The positive results presented in this study indicate the transformative potential of 3D printing technology in promoting inclusion and improving the quality of Chemistry teaching, providing more meaningful and enriching learning opportunities for all students and suggesting a lasting impact on the teaching-learning process in different educational contexts. This approach has the potential to transform the way scientific concepts are taught and learned (Toledo; Santos; Rizzatti, 2019).

In summary, the results of this research highlight the tangible benefits and the importance of integrating 3D printing technology into inclusive Chemistry teaching, aiming to promote a more accessible, engaging, and meaningful education for all students.

4. Conclusions

The successful implementation of printed molecular models in Chemistry teaching, as described in this research, provided substantial evidence of the transformative potential of 3D printing technology in promoting educational inclusion and improving teaching quality.

According to the teachers' reports, the use of printed molecular models resulted in a significant improvement in students' understanding of chemical concepts, as well as an increase in engagement and participation in the classroom, thus promoting educational inclusion. This approach provided a more tangible and visual way to explore scientific principles, stimulating students' curiosity and interest. This represents a significant advancement in ensuring that all students have equal access to quality education.

Furthermore, the positive feedback from teachers and students validates the effectiveness and relevance of printed molecular models as teaching tools. Both recognize that these resources facilitate the teaching-



learning process, highlighting their ability to make chemical concepts more accessible and interesting.

The results of this study point to significant potential for the expansion of the use of printed molecular models not only in Chemistry teaching but also in other disciplines and educational contexts. 3D printing technology offers unique opportunities for the creation of personalized and accessible educational resources, promoting a lasting impact on education quality.



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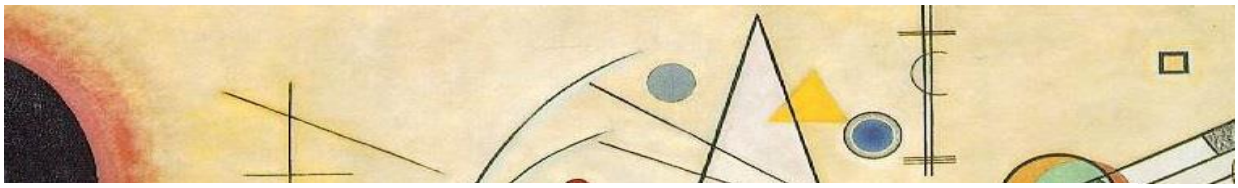
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