A SUSTAINABLE APPROACH TO HIGH SCHOOL EDUCATION: BIOPLASTICS IN CHEMISTRY EDUCATION – PART I

UMA ABORDAGEM SUSTENTÁVEL PARA O ENSINO MÉDIO: BIOPLÁSTICOS NO ENSINO DE QUÍMICA – PARTE I

UN ENFOQUE SOSTENIBLE PARA LA EDUCACIÓN SECUNDARIA: BIOPLÁSTICOS EN LA EDUCACIÓN QUÍMICA – PARTE I

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Marcos Antonio Sousa Barros[1], Pedro Almeida[2]

ABSTRACT
This study aimed to promote environmental awareness among high school students through a didactic sequence exploring bioplastics made from corn starch, integrating chemical concepts with reflections on sustainability. The qualitative and exploratory research was conducted with a class of 34 students at the Federal Institute of Pernambuco – Ipojuca Campus, and involved the application of pre- and post-intervention questionnaires to analyze the evolution of knowledge regarding polymers, conventional plastics, bioplastics, and environmental impacts. The methodology included theoretical lessons, debates, and experimental activities aligned with the Science, Technology, and Society (STS) approach. The results demonstrated a significant improvement in the understanding of the concepts covered, highlighting the connection between theory and practice. The laboratory synthesis of bioplastic proved to be a highly effective teaching resource, promoting student engagement and consolidating learning. All participants reported a stronger connection between theoretical content and its everyday applications. Most students showed awareness of the importance of bioplastics as a sustainable alternative, emphasizing their biodegradability and renewable origin, but also pointed out challenges, such as production costs and technical limitations. It is concluded that the inclusion of socio-environmental topics in Chemistry education, combined with active methodologies, strengthens students' critical thinking and broadens their awareness of sustainable solutions. The study highlights the importance of innovative pedagogical practices that link science to real-world issues, preparing students for informed and responsible decision-making in the face of contemporary environmental challenges.

Keywords: Bioplastic. Chemistry Education. Environmental Education.

RESUMO
Este estudo teve como objetivo promover a conscientização ambiental entre alunos do ensino médio por meio de uma sequência didática que explora bioplásticos produzidos a partir de amido de milho, integrando conceitos químicos a reflexões sobre sustentabilidade. A pesquisa, de natureza qualitativa e exploratória, foi realizada com uma turma de 34 estudantes do Instituto Federal de Pernambuco – Campus Ipojuca, e envolveu a aplicação de questionários pré e pós-intervenção para analisar a evolução dos conhecimentos sobre

[1] Professor and Master in Environmental Technology. Instituto Tecnológico De Pernambuco (ITEP).
E-mail: marcosantonio@ipojuca.ifpe.edu.br.
[2] Bachelor's Degree in Chemistry. Instituto Federal de Pernambuco (IFPE). E-mail: pedro_hal@hotmail.com

polímeros, plásticos convencionais, bioplásticos e impactos ambientais. A metodologia adotada incluiu aulas teóricas, debates e atividades experimentais alinhadas à abordagem Ciência, Tecnologia e Sociedade (CTS). Os resultados demonstraram um avanço significativo na compreensão dos conceitos abordados, destacando a relação entre teoria e prática. A síntese laboratorial de bioplástico se mostrou um recurso didático altamente eficaz, promovendo o engajamento dos alunos e consolidando o aprendizado. Todos os participantes relataram maior conexão entre o conteúdo teórico e suas aplicações cotidianas. A maioria dos estudantes demonstrou percepção acerca da importância dos bioplásticos como alternativa sustentável, ressaltando sua biodegradabilidade e origem renovável, mas também apontou desafios, como custos de produção e limitações técnicas. Conclui-se que a inserção de temas socioambientais no ensino de Química, aliada a metodologias ativas, fortalece a formação crítica dos estudantes e amplia sua conscientização sobre soluções sustentáveis. O estudo reforça a relevância de práticas pedagógicas inovadoras que aproximem a ciência de problemáticas reais, preparando os alunos para tomadas de decisão fundamentadas e responsáveis frente aos desafios ambientais contemporâneos.

Palavras-chave: Bioplástico. Ensino de Química. Educação Ambiental.

RESUMEN

Este estudio tuvo como objetivo promover la conciencia ambiental entre estudiantes de secundaria mediante una secuencia didáctica que explora los bioplásticos producidos a partir de almidón de maíz, integrando conceptos químicos con reflexiones sobre la sostenibilidad. La investigación cualitativa y exploratoria se llevó a cabo con una clase de 34 estudiantes del Instituto Federal de Pernambuco, campus Ipojuca. Se aplicaron cuestionarios antes y después de la intervención para analizar la evolución del conocimiento sobre polímeros, plásticos convencionales, bioplásticos e impactos ambientales. La metodología adoptada incluyó clases teóricas, debates y actividades experimentales alineadas con el enfoque de Ciencia, Tecnología y Sociedad (CTS). Los resultados demostraron un progreso significativo en la comprensión de los conceptos abordados, destacando la relación entre la teoría y la práctica. La síntesis de bioplásticos en el laboratorio resultó ser un recurso didáctico muy eficaz, que promovió la participación del alumnado y consolidó el aprendizaje. Todos los participantes reportaron una mayor conexión entre el contenido teórico y sus aplicaciones cotidianas. La mayoría de los estudiantes comprendió la importancia de los bioplásticos como alternativa sostenible, destacando su biodegradabilidad y origen renovable. Sin embargo, también destacaron desafíos como los costos de producción y las limitaciones técnicas. La conclusión es que la incorporación de temas socioambientales en la enseñanza de la química, combinada con metodologías activas, fortalece el pensamiento crítico de los estudiantes y aumenta su conciencia sobre soluciones sostenibles. El estudio refuerza la importancia de prácticas pedagógicas innovadoras que acerquen la ciencia a los problemas del mundo real, preparando a los estudiantes para tomar decisiones informadas y responsables ante los desafíos ambientales contemporáneos.

Palabras clave: Bioplásticos. Enseñanza de la Química. Educación Ambiental.

1 INTRODUCTION

The evolution of polymer research has driven the creation of innovative materials that play crucial roles in various sectors of society, such as plastic packaging and disposable utensils (THOMPSON et al., 2009). Synthetics are derived from fossil fuels produced by industrial procedures (PLASTICS EUROPE, 2020). The application of these is wide and versatile, involving the manufacture of industrial and domestic consumer goods. One of the most widely used polymeric substances by the industry and consumed in the world is polyethylene, a low-cost and highly durable thermoplastic used in the production of packaging, bags, garbage bags and plastic films (FECHINE, 2013). Studies have shown that the improper disposal of these synthetic materials is one of the main causes of environmental pollution, mainly related to aquatic environments such as the seas, rivers, lakes and streams, causing the death of several animals that inhabit these biotas. (CRUZ and NETO, 2018; FECHINE, 2013).

In this scenario, it is essential that the teaching of Chemistry is not limited to addressing scientific concepts in isolation, but that it also promotes the understanding of the social, ethical and environmental impacts associated with these advances. Education in Chemistry should, therefore, foster the development of students' capacity for judgment and decision-making, encouraging debate and critical reflection (SANTOS and SCHNETZLER, 2010). These same authors highlight that education for citizenship is, in its essence, an education for discussion, with the teacher playing a vital role in presenting problems and stimulating the search for varied solutions (SANTOS and SCHNETZLER, 2010)."

Recycling, biodegradation, and the use of biodegradable polymers have been used as a method to solve the problems and/or minimize the negative effects of the widespread use of plastics and the large volume of garbage deposited in landfills around the world (AZEVEDO et al., 2017; GUTERRES et al., 2020). Bioplastics appear as an alternative to the problem, they are produced from raw material derived from renewable sources and have been presented as a viable alternative for the replacement or alternative use of synthetics.

Among the sources of raw material, the use of cassava, pine nuts, banana fiber and what we will work on, which is corn starch (KAPPLER et al., 2019; BEGNINI et al., 2019; AVEZ.

The use of plastic materials is one of the great contemporary challenges, because, despite their numerous advantages, such as lightness, durability, versatility and cost-effectiveness, they represent a significant environmental threat when disposed of improperly. Plastic, being light and resistant, is widely used in products such as packaging, household items, and medical and electronic components. However, when not properly managed after use, plastic contributes to serious environmental problems (Jambeck et al., 2015). In Brazil, for example, it is estimated that 15 billion plastic bags are consumed annually, according to data from the Ministry of the Environment (2011). This highlights the need to combine education in Chemistry with sustainable initiatives, in which the teaching of chemistry can contribute to the development of critical and scientific sense that will equip the citizen seeking techno-scientific solutions that reduce environmental impact. EDO et al., 2017).

Thus, the active participation of students needs to be seen as a process of conquest and development (DEMO, 1988). Participation should not be seen as something granted, but rather as something to be built, emphasizing the importance of inserting environmental education (EE) at all levels of education to promote environmental citizenship. Farias and Freitas (2007) emphasize that, in order for there to be an awareness, resulting in a significant change in the attitudes of individuals, it is necessary that they understand the consequences of environmental degradation and act consciously and collectively.

In this context, the Science, Technology and Society (STS) movement, as highlighted by Chrispino (2017) and Cutcliffe (2003), proposes a science education that forms citizens capable of making informed decisions, considering not only scientific knowledge, but also their interactions with society, the environment and ethical and cultural aspects. The National Curriculum Parameters (PCN) reinforce this approach by stating that teaching articulated with science and technology allows students to understand and evaluate the relationship between human intervention in the environment and sustainable development (BRASIL, 2002).

Therefore, the insertion of themes such as bioplastics in the teaching of Chemistry presents itself as a viable alternative to unite scientific knowledge with citizen practice, stimulating students to reflect on sustainable solutions and socio-environmental responsibility. The Didactic Sequence (DS) approach according to Zabala (1998) provides a structure for teachers and students to achieve these objectives in an organized way, bringing Chemistry closer to everyday life and promoting meaningful and critical learning.

2 OBJECTIVES

2.1 GENERAL OBJECTIVE

Promote environmental awareness, through a didactic sequence, among high school students, exploring sustainable alternatives, such as bioplastics that can be produced from renewable materials such as corn starch.

2.2 SPECIFIC OBJECTIVES

- Develop a didactic sequence (DS) for the teaching of chemistry in a theoretical and experimental way, contemplating the content of synthetic polymers and Bioplastic.
- To evaluate the applicability of the proposed didactic sequence in a class of the 1st grade of high school at the Federal Institute of Pernambuco – Ipojuca campus.
- Validate the methodological proposal (DS) presented through the analysis of the questionnaires applied before and after the action, according to the Content Analysis proposed by Bardin, 2011.

3 THEORETICAL FOUNDATION

This work is based on a relevant literature review, based on research and works that address the use of bioplastics in the teaching of Chemistry, as well as legal and curricular documents. Authors such as Azevedo et al. (2017), Kappler et al. (2019), and Cruz and Neto (2018) provide the theoretical basis on biodegradable polymers and the environmental impact of synthetic plastics, discussing sustainable alternatives, such as bioplastics, as a way to minimize damage to the environment. In addition, the contribution of the studies of Santos and Schnetzler (2010) and Farias and Freitas (2007) offers a look at environmental education and the importance of integrating social and ethical issues into the teaching of Chemistry.

In addition to the contributions of authors, the work is also based on legal and curricular documents such as the National Curricular Guidelines for Chemistry Courses, the National Common Curricular Base (BNCC) and the Law of Guidelines and Bases of National Education (LDB), which provide guidelines on the teaching of Chemistry and environmental education in Brazil.

This chapter is structured in 4 subtopics, with the aim of facilitating the understanding of the categories of analysis and providing an insight into environmental education and the importance of integrating social and ethical issues into the teaching of Chemistry. The chapter will be divided as follows: 3.1 Bioplastics and Their Properties; 3.2 Environmental Impacts of Synthetic Plastics and the Teaching of Chemistry; 3.3 Environmental Education in the Teaching of Chemistry and the Didactic Sequence in the Formation of Critical Citizens; 3.4 Teaching Methodologies: Science, Technology and Society (STS)

3.1 BIOPLASTICS AND THEIR PROPERTIES

Bioplastics are polymeric materials produced from renewable sources, such as corn starch, sugarcane, cassava, and cellulose. Unlike conventional plastics, which are derived from petroleum, bioplastics have properties that allow them to decompose under natural conditions or in industrial composting facilities, minimizing environmental impacts (Kappler et al., 2019). In addition, its production uses plant biomass, which contributes to the capture of carbon dioxide during the life cycle of the plants used, reducing net greenhouse gas emissions (Amorim, 2019).

According to European Bioplastics (2016), bioplastics can be classified into three main categories:

1. Biodegradable and bio-based: Such as polylactic acid (PLA) and polyhydroxyalkanoates (PHA).
2. Biodegradable, but not bio-based: These include materials that decompose quickly but are not renewable sourced.
3. Not biodegradable, but bio-based: Like green polyethylene, derived from sugarcane ethanol.

Bioplastics play a crucial role in mitigating environmental impacts associated with the overuse of petrochemical plastics. Its ability to biodegrade prevents the formation of microplastics and reduces the accumulation of waste in marine and terrestrial ecosystems. According to Cruz and Neto (2018), this characteristic is especially relevant in a global scenario of uncontrolled plastic pollution.

Another significant environmental benefit is the circular economy promoted by bioplastics. Compostable materials can be converted into organic matter and used as fertilizer, closing the product's life cycle and reducing dependence on landfills (InnProBio, 2015). In addition, bio-based bioplastics capture carbon dioxide during their production, helping to neutralize industrial emissions (Amorim, 2019).

The transition to bioplastics also generates positive impacts on the economy. The bioeconomy, driven by the production of these materials, has generated jobs in sectors related to agriculture, research and development. According to the Biopolymer Platform (2019), the growth in bioplastics production capacity has attracted global investments and encouraged technological innovation.

In addition, the production of bioplastics reduces dependence on fossil resources, strengthening local economies and promoting economic sustainability. Philp et al. (2012) point out that advances in biotechnology and materials engineering have made bioplastics more economically competitive, with the potential to gradually replace petrochemical plastics in various industrial sectors.

Bioplastics have wide applications, ranging from food packaging and plastic bags to medical devices and automotive parts. The versatility of these materials is due to their physical and chemical properties, which can be adjusted according to the purpose of the product (Lackner, 2015).

Kappler et al. (2019) highlight that improving the mechanical strength and thermal stability of bioplastics is key to expanding their commercial applications. For instance, PLA has been widely used in disposable packaging and household items due to its rigidity and transparency, while PHAs have application in medical implants and biodegradable films, due to their biocompatibility.

The inclusion of bioplastics in the Chemistry curriculum promotes not only technical learning, but also environmental awareness. Practical activities, such as the synthesis of bioplastics from starch or agricultural residues, allow students to understand the chemical principles involved and the environmental implications of their choices (Santos and Schnetzler, 2010). Santos and Schnetzler (2010) argue that teaching should encourage students to propose innovative solutions and to critically reflect on the impacts of the consumption and disposal of plastic materials.

In addition, the inclusion of the theme in the educational context reinforces the importance of sustainability in science and technology. According to Bazzo et al. (2009), scientific literacy integrated with environmental issues prepares students to make informed and conscious decisions, aligned with the challenges of the twenty-first century.

Bioplastics represent a viable and sustainable alternative to conventional plastics, offering benefits ranging from reducing environmental impacts to promoting the bioeconomy. Despite technical and economic challenges, advances in science and technology indicate a promising future for these materials (Gibbons et al., 1994). By connecting scientific research to sustainable development, bioplastics reinforce the role of Chemistry in building a more balanced and conscious world. As Gibbons et al. (1994) point out, contemporary science must be understood in its social and environmental context, promoting a more harmonious interaction between technological progress and the preservation of the planet.

3.2 ENVIRONMENTAL IMPACTS OF SYNTHETIC PLASTICS AND THE TEACHING OF CHEMISTRY

Synthetic plastics, due to their durability and low cost, have been widely used in various industries (Thompson et al., 2009). However, this durability, which is an advantage from a functional point of view, becomes a major environmental challenge. According to Thompson et al. (2009), the resistance of plastics to degradation is one of the main reasons for their persistence in the environment, resulting in accumulation in ecosystems and worsening global pollution.

Souza et al. (2021) corroborate the increase in plastic production, especially in recent years, highlighting the relationship between an economic advantage and the benefits of materials:

Global plastics production has increased dramatically from 2 million tons in 1950 to 335 million tons in 2016. The increase in the production and consumption of plastics comes from the low cost/benefit of these materials, population growth and also the development of industrial, medicinal and agricultural activities, with the purpose of improving the quality of human life

Synthetic polymers are present in our daily lives today because they allow us to solve a large number of problems in industry, agriculture and services, since even money has been made of plastic (Galembeck et al., 2001).

Plastics are materials derived from macromolecules called polymers, which are formed by repeating smaller units called monomers. Polymers can be natural, such as DNA and cellulose, or synthetic, such as polyethylene and polyester (Galembeck et al., 2001). Monomers, in turn, are small molecules that, through polymerization processes, bind together forming long and structured chains.

The presence of these materials, especially in the twentieth century, brings a series of applications. As Wan (2001) points out:

The importance of these materials can be observed by looking around us and seeing the amount of objects made of plastics that we use, sustaining an intense industrial activity, and many jobs. Synthetic polymers changed the face of the chemical industry: surpassing in value chemotherapy drugs, fertilizers, and dyes, polymers became the industry's main source of revenue in the second half of the 20th century, and created a strong link between chemistry and matter science and engineering.

From the point of view of polymer properties, they can be classified into two main groups:

1. **Thermoplastics:** Polymers that soften when heated and can be molded repeatedly. Examples include polyethylene (PE), used in plastic bags, and poly(ethylene terephthalate) (PET), which is widely used in bottles.
2. **Thermorigids:** Polymers that, after molding, cannot be remodeled, such as bakelite, used in pan handles, and epoxy resins (Franchetti and Marconato, 2003).

In addition, plastics have a wide variety of properties, depending on the type of polymer used, such as stiffness, transparency, and mechanical strength (Mortimer et al., 2000).

Wen (2001) highlights the large size of the polymer petrochemical industry both in terms of facilities, uses and employability:

Synthetic polymers are present in our daily lives today because they allow us to solve a large number of problems, whether in industry, agriculture or services, since even money has become made of plastic. These materials are manufactured by a large and vigorous petrochemical industry, which accounts for about half of the chemical industry worldwide. Its manufacture and transformation guarantee the employment and livelihood of millions of people, including many Brazilians

The degradation resistance of synthetic plastics is one of the main reasons for their persistence in the environment, resulting in accumulation in ecosystems and worsening global pollution (Thompson et al., 2009). The decomposition of these materials is slow and, during this process, the formation of microplastics occurs, which enter the food chain, impacting marine fauna and, eventually, humans (Jambeck et al., 2015).

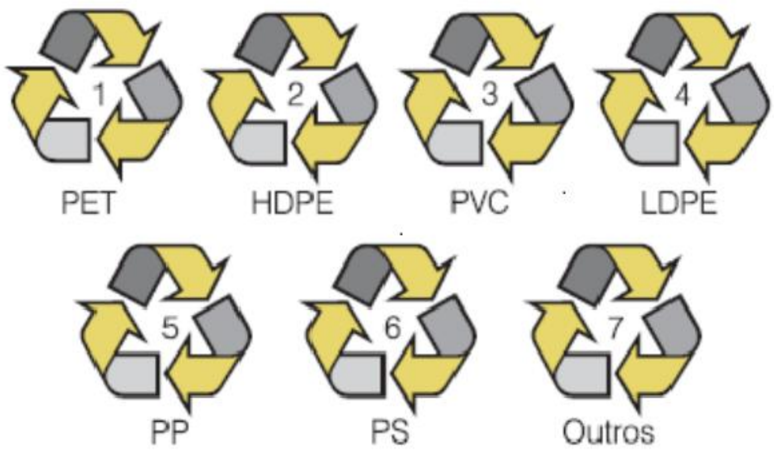
Still in the work of Wen (2001), it should be highlighted that a fundamental component is the life cycle of the material that goes from its breeding site to disposal and this is the origin of the demonization of a fascinating product such as plastics due to irresponsible anthropic actions, in the words of wen:

Plastics and rubbers also cause environmental problems, like all other products of human activity. For this reason, we must always pay attention to its life cycle, that is, the set of stages that make up its history, from the moment its raw material (oil) is extracted from the Earth, transformed and recycled, to its disposal or destruction by burning or degradation in the environment, transforming itself back into simple substances such as carbon dioxide, water, coal, etc. The irresponsible use and disposal of plastics and rubbers ended up creating synthetic polymers of the world. These problems are due to the durability of synthetic polymers in the environment, not their toxicity, and so we see plastic bottles, tires, disposable diaper scraps and packaging making rivers, lagoons and beaches ugly. This pollution caused by plastics is not a defect of plastics per se, but a manifestation of bad education of individuals, collective stupidity and lack of responsibility on the part of companies and representatives of public power. Bad manners, because the final culprit is always a person who has used plastic and has not bothered to dispose of it correctly

In Brazil, legislation requires that polymers be identified on packaging or products through a symbology to facilitate their selection in the disposal and recycling process (Franchetti and Marconato, 2003). The numbering follows its own established symbology (Figure 1).

Figure 1

Recyclable plastic conditioning – Identification and symbology



Source: ABNT (1994).

Where:

1. PET – poly(ethylene teref thalate) – soft drink bottles, water, vinegar, detergents. 2 - HDPE (HDPE) 2 - HDPE (HDPE) -
2. HDPE (HDPE) high density polyethylene – detergent containers, fabric softeners, bleaches, milk, conditioners, shampoos, engine oils.
3. PVC Polychloride (vinyl) – kites, bathroom curtains, meal trays, covers, floors, linings.
4. LDPE (LDPE) – low-density polyethylene – films, grocery bags, snack packaging.
5. PP – polypropylene – containers for storing food (Tupperware), carpets, pudding, yogurt and mineral water packaging.
6. PS – polystyrene – water and coffee cups, packaging protector (styrofoam), printer cartridge protector.
7. Others: PC, PU, 7 - Other ABS – polycarbonate, polyurethane and Acrylonitrile butadiene styrene. The PC is used in the manufacture of baby bottles, home covers, eyeglass lenses, bullet shields; PU is used in soles, shoe heels, stops, wheels, bumpers; and ABS is used in doorknobs, appliance housings, corrosive chemical pipes (Anon, 1997; Zanini and Kukababy sites)

The impacts of synthetic plastics go beyond the pollution of the seas and include improper disposal, which overloads dumps and landfills, and the contamination of soils and waterways by chemicals released during their degradation (Sobral et al., 2011). Studies indicate that the ingestion of microplastics can cause damage to human health, such as inflammation and bioaccumulation of toxic substances, in addition to affecting marine biodiversity (Alimba; Faggio, 2019). According to Geyer, Jambeck and Law (2017), only a small fraction of plastic waste is recycled, while most of it accumulates in landfills or is dispersed into the environment, exacerbating the problem.

Bioplastics have gained prominence as innovative and sustainable alternatives to conventional synthetic plastics, which are mostly derived from petroleum. Unlike traditional polymers, which have high persistence in the environment and cause significant ecological impacts, bioplastics can be produced from renewable sources, such as corn starch, sugarcane and agricultural waste, in addition to having biodegradable potential. This characteristic places them as a central element in discussions about sustainability and responsible technological development (Souza et al., 2021; Franchetti and Marconato, 2003).

As highlighted by Mortimer et al. (2000), bioplastics exemplify how science and technology can be directed to mitigate environmental problems. Its production from renewable resources contributes to reducing dependence on fossil fuels and reducing greenhouse gas emissions. In addition, the possibility of biodegradation, under specific conditions, offers a partial solution to the problem of plastic waste accumulation, especially in aquatic ecosystems, where microplastics have caused severe damage to marine fauna (Jambeck et al., 2015).

However, the sustainability of bioplastics goes beyond their biodegradability. It is necessary to evaluate the complete life cycle of these materials, considering everything from the cultivation of raw materials to final disposal. Studies have shown that while bioplastics have a reduced environmental footprint in many respects, challenges remain. For example, its large-scale production can compete with agriculture for food, raising ethical and economic questions about the use of natural resources (Chrispino, 2017).

The Science, Technology, Society and Environment (CTSA) approach offers a valuable perspective to explore the topic of bioplastics in chemistry education. According to Santos and Mortimer (2002), the integration of this subject in the classroom allows students to understand the connections between scientific advances, technological innovations and their social and environmental impacts. Through experimental activities such as the synthesis of starch-based bioplastics, students not only learn about the chemical processes involved, but also reflect on the feasibility and limitations of these materials. Azevedo et al. (2017) point out that practical experiences broaden students' understanding and promote richer debates on sustainability.

The inclusion of bioplastics in the school curriculum goes beyond the transmission of scientific concepts. It promotes the formation of critical citizens, capable of evaluating the ethical and social implications of their choices. As stated by Palacios et al. (2001), understanding that science and technology are not neutral, but shaped by values and interests, is essential for students to become active participants in the construction of a sustainable future.

Thus, by addressing bioplastics in Chemistry teaching, it is possible to contextualize science in the daily lives of students, connecting theory to practice and encouraging responsible decision-making. This approach, as highlighted by Souza et al. (2021), transforms learning into a tool for social and environmental engagement, aligning itself with contemporary challenges and the demands of a world in constant transformation.

Chemistry education should play an essential role in raising awareness about these impacts and training critical citizens who can propose solutions. The course allows not only to explain the scientific foundations related to plastics, but also to contextualize them in the daily lives of students, awakening a critical view of the consumption and disposal of these materials. Teaching centered exclusively on scientific discourse, without the proper social, technological and environmental context, can result in a distorted view of science, without creating critical citizens whose scientific knowledge enables them to read and understand the world around them. As Santos and Mortimer (2002) state, scientific knowledge should be understood as an instrument for the critical reading of students' daily reality, promoting an integrated view of science, technology and society.

An example of this is the possibility of addressing, in the classroom, the properties of polymers and the chemical processes of recycling, as demonstrated by Franchetti and Marconato (2003). In addition, the study of the environmental impacts of plastics can be combined with debates on social responsibility and sustainable development, promoting the formation of more conscious citizens. According to Santos and Schnetzler (2010), "the teaching of chemistry should go beyond concepts and develop skills so that students understand environmental problems and propose solutions based on scientific knowledge".

The inclusion of topics such as biodegradability and substitution by bioplastics in pedagogical activities can expand students' understanding of sustainable practices. For example, Souza et al. (2021) demonstrated that using the STS approach to discuss marine plastic pollution not only improves students' scientific understanding but also encourages them to reflect on their own actions as consumers.

Several works exemplify the issue of the properties of polymers in the classroom. Studies such as those by Franchetti and Marconato (2003) propose experiments that use recyclable plastics to teach the physical properties of polymers, demonstrating the relationship between these materials and sustainability. Another work, conducted by Souza et al. (2021), explored marine plastic pollution in Chemistry classes through the STS approach, encouraging students to reflect on social and environmental impacts. Similarly, Silva et al. (2013) used case studies to address the concept of plastic degradation, leading students to reflect on the need for recycling.

The teaching approach based on the interconnection between science and society is reinforced by the Science, Technology and Society (STS) movement, which advocates the inclusion of environmental and social issues in the school curriculum (CUTCLIFFE, 2003). According to Chrispino (2017), "teaching that incorporates the STS context forms students who are better prepared to deal with the complexities of a changing world". Studies such as those by Pereira and Ferreira (2011) demonstrate that this approach promotes the understanding of the environmental impacts of polymers and encourages sustainable solutions, integrating the scientific dimension into the students' daily lives.

Incorporating this approach into chemistry teaching helps to contextualize the impacts of synthetic plastics and the importance of seeking more sustainable alternatives. This promotes a more integrated and practical education, which not only teaches chemical concepts, but also enables students to apply them in real situations and to think critically about environmental issues (PEREIRA; FERREIRA, 2011).

3.3 ENVIRONMENTAL EDUCATION IN THE TEACHING OF CHEMISTRY AND THE DIDACTIC SEQUENCE IN THE FORMATION OF CRITICAL CITIZENS

Law No. 9,795, of April 27, 1999 (BRASIL, 1999), which institutes the National Policy on Environmental Education, emphasizes as one of its basic principles the perception of the environment in its entirety. This vision requires a broad domain to be developed by the student, in which he can mix his popular knowledge with the scientific level. In addition, the Law of Guidelines and Bases of National Education (LDB, Law No. 9,394/1996) highlights the importance of training for the full exercise of citizenship and the understanding of the natural and social world, and environmental education is part of this training process. The National Common Curriculum Base (BNCC), in turn, reflects this integration, establishing environmental education as a cross-cutting theme and addressing competencies such as argumentation, problem solving, and socio-environmental responsibility (BRASIL, 2017).

Environmental education in the teaching of Chemistry is an essential pillar for the formation of critical and conscious citizens in relation to environmental problems. Santos and Schnetzler (2010, p. 39) emphasize that "science education must transcend the simple transmission of theoretical concepts, to promote students' awareness of environmental impacts and prepare them to make informed decisions". This view is crucial for students to understand the relationship between science and environmental challenges, encouraging the development of critical and proactive postures.

The integration of environmental education into school curricula is a strategy that aims not only at teaching scientific concepts, but also at reflecting on sustainable practices. According to Farias and Freitas (2007, p. 48), "the significant change in students' attitudes happens when they understand the processes of environmental degradation and the consequences of their actions, adopting more conscious and collective behaviors". In this context, topics related to bioplastics and sustainable alternatives are fundamental, as they allow students to reflect on how Chemistry can contribute to solving environmental problems.

The Didactic Sequence (DS) approach, proposed by Zabala (1998), emerges as an effective methodology to address complex themes in a structured and engaging way. This methodology organizes the content in a sequential and integrated way, providing a gradual and meaningful construction of knowledge. Zabala (1998, p. 52) observes that "DS allows the teacher to organize the teaching stages in such a way that students understand the content in a continuous and interconnected process, fostering the development of critical thinking and autonomy".

In chemistry education, the implementation of a DS on the topic of bioplastics can include practical activities, such as experiments that demonstrate the synthesis of biodegradable plastics from corn starch, debates on the advantages and limitations of biodegradable materials, and analyses of case studies that address the environmental impact of synthetic polymers (Azevedo et al., 2017). Azevedo et al. (2017, p. 45) state that "the inclusion of experimental practices in the teaching of Chemistry not only helps in the understanding of chemical phenomena, but also engages students in the search for sustainable solutions".

Studies such as that of Oliveira and Santos (2015) show that the use of didactic sequences in the teaching of Chemistry promotes a greater understanding of the contents by students, in addition to encouraging critical reflection. In a study conducted with high school students, these authors observed that the use of DSs on environmental issues resulted in greater participation in the classroom and greater commitment to socio-environmental issues. Another example is the work of Silva and Carvalho (2018), who used didactic sequences to teach organic chemistry and observed a significant increase in student performance in practical and theoretical activities.

This approach allows students to realize the relevance of scientific knowledge in real contexts and to reflect on the implications of their actions on the environment (Azevedo et al., 2017). The inclusion of experimental practices makes learning more dynamic and promotes the development of essential skills, such as problem-solving and informed decision-making (Silva and Carvalho, 2018).

In addition, environmental education based on experimentation and critical analysis contributes to the formation of citizens who not only understand scientific concepts, but are also able to apply them ethically and consciously in favor of the environment (Farias and Freitas, 2007; Oliveira and Santos, 2015). By addressing the use and production of bioplastics through experimental activities and contextualized discussions, students are encouraged to develop a more comprehensive and critical view of the role of Chemistry in the search for sustainable solutions (Silva and Carvalho, 2018).

3.4 TEACHING METHODOLOGY: SCIENCE, TECHNOLOGY AND SOCIETY (CTS)

The Science, Technology and Society (STS) movement proposes a significant restructuring of pedagogical practices, going beyond the traditional teaching of science, by integrating social, environmental and ethical issues into the teaching-learning process. This approach seeks to promote an education that not only imparts scientific knowledge, but also prepares students to make informed decisions about global challenges (Santos and Mortimer, 2002).

Chrispino (2017) states that, by adopting the STS perspective, science teaching should become a means of forming critical citizens who are aware of the role of science in the transformation of society, taking into account the complexity of environmental and social problems related to technology. According to the author, "Science teaching should be a means of forming critical and aware citizens about the role of science in the transformation of society, considering the complexity of environmental and social problems involving technology" (Chrispino, 2017, p. 572).

Since the end of World War II, the world has witnessed rapid scientific and technological expansion that has brought significant benefits, but also serious environmental and social problems, such as pollution and nuclear disasters. It was in this context that, in the 1960s and 1970s, the STS approach began to gain ground as a response to the traditionalist view of science, which often ignored the social and ethical impacts of its innovations (Santos and Mortimer, 2002). Studies in Europe and the United States have pointed to the need for a science that is more connected to society, emphasizing that scientific knowledge is not neutral, but rather influenced by values, political interests, and economic pressures (Palacios et al., 2003).

In Brazil, the incorporation of the STS perspective into teaching was driven by the educational reform of the 1980s, which began to emphasize the importance of addressing the social implications of scientific and technological development. Authors such as Krasilchik (1987) have highlighted that, during this period, school curricula began to include discussions about how science and technology influence and are influenced by society. This evolution was marked by innovative teaching materials, such as the "Modular Chemistry Units" project, which addressed issues such as environmental pollution and energy in an integrated way with the disciplines of natural sciences (Mortimer et al., 1999).

In the context of Chemistry, this translates into discussions about the effects of synthetic materials, such as plastics, and how science can contribute to mitigating their impacts on the environment. The STS methodology, by placing the student at the center of the learning process, challenges him to understand the interconnection between science, technology and society, allowing a deeper analysis of the role of each of these elements in the construction of knowledge (Gibbons et al., 1994). The teaching of bioplastics, therefore, fits naturally into this model, as it proposes to students the investigation of innovative solutions to social and environmental problems, aligned with the search for a technology that is not only effective, but also sustainable. As Cutcliffe (2003) points out, "it is essential that students understand that science does not occur in isolation, but is an integral part of society, and that their choices can directly affect the future of the planet and future generations" (Cutcliffe, 2003, p. 65).

Additionally, studies conducted by Pereira and Ferreira (2011) demonstrate that the use of STS methodologies in the classroom contributes significantly to the development of critical skills and the understanding of environmental impacts. Another example is the work of Oliveira and Santos (2015), which shows that activities based on the STS approach lead students to a greater understanding of socio-environmental challenges, in addition to promoting active engagement in the learning process. These studies reinforce that the integration of STS practices in the teaching of Chemistry not only enriches academic training, but also enables students to exercise conscious and responsible citizenship.

The STS approach, therefore, redefines teaching by promoting an integrated and contextualized education, empowering students to understand the implications of science and technology in an ever-changing world. By inserting topics such as bioplastics in the curriculum, teaching aligns with contemporary challenges and stimulates in students the desire to transform society through innovative and sustainable scientific solutions (Santos and Auler, 2011).

Another essential aspect of the history of the STS approach is its evolution from the demands for a more democratic and participatory science. Gibbons et al. (1994) point out that the production of scientific knowledge has come to be seen as a transdisciplinary process, in which different social actors, such as researchers, representatives of the productive sector and civil society, interact to solve complex problems. This model reflects the need for a science that not only generates innovation, but also contributes to sustainable development.

In chemistry education, the STS approach encourages the development of educational projects that address topics such as green chemistry and the development of new sustainable materials, such as bioplastics. These practices allow students to understand how scientific advances can be directed to minimize environmental impacts and meet social needs (Bazzo et al., 2009). Studies such as those by Santos and Auler (2011) emphasize that STS teaching promotes scientific and technological literacy, helping students to understand that science is inserted in social, political and economic contexts.

In addition, the inclusion of ethical issues in the teaching of Chemistry from the STS perspective allows a critical reflection on the impacts of excessive consumption and industrial production on the environment (Oliveira and Santos, 2015). The introduction of hands-on experiments, such as synthesizing bioplastics from starch or agricultural waste, provides students with an opportunity to explore sustainable solutions while discussing the challenges associated with implementing these technologies on a large scale. These activities, according to Bazzo et al. (2009), help to form citizens who are more aware and engaged with the construction of a sustainable society.

Thus, the STS approach continues to evolve, reaffirming its role as a milestone in science and technology education. Its implementation in school curricula promotes not only the acquisition of knowledge, but also the development of values and skills that enable students to face the challenges of the twenty-first century. By connecting science to everyday life and stimulating critical reflection, the STS methodology becomes a powerful tool to transform education into an agent of social change (Santos and Auler, 2011).

4 METHODOLOGY

The present work can be classified as qualitative, exploratory. According to Ludke and André (2014), qualitative research involves obtaining descriptive data and presupposes a direct contact of the researcher with the situation studied, which allows understanding phenomena in their complexity and depth. This approach was chosen due to the need to analyze students' perceptions of bioplastics and sustainability in a subjective and contextualized way, promoting a detailed analysis of interactions in the school environment.

The research is also of the exploratory type, as highlighted by Gil (2007), who defines this approach as ideal to provide greater familiarity with the problem under study. This choice was made because the theme of bioplastics in the teaching of Chemistry, with a focus on sustainability, is still little explored in pedagogical practice. The exploratory approach made it possible not only to investigate the students' initial perceptions, but also to build and test an innovative didactic sequence (DS), which contributed to the development of new ideas and intuitions on the subject. In addition, Triviños (1987) points out that this approach is particularly effective in providing detailed analyses of the interactions and phenomena observed in the field of study, allowing the researcher to interpret the nuances present in social and individual dynamics. This characteristic was essential for the present investigation, which sought to capture students' perceptions about bioplastics and sustainability in the teaching of Chemistry, promoting a significant connection between theory and educational practice.

4.1 DATA COLLECTION

Data collection was carried out through questionnaires applied before and after the presentation and application of the didactic sequence (DS). This methodology was adopted to capture the transformations in the students' understanding throughout the educational process. The questionnaires were applied to a class of the first year of high school at the Federal Institute of Pernambuco – Ipojuca Campus, located in the state of Pernambuco. The participating class belonged to the first year of the integrated mechanical technician, representing all the classes available at the institution for this level of education. The class was composed of 34 students.

The content worked on in the classes followed the guidelines of the Natural Sciences and its Technologies program of the Serial Evaluation System (SSA 1/2025), as established in the UPE manual – Triennium 2022/2024. Specifically, the topic addressed is aligned with item 10.2 of the program, which deals with natural and synthetic polymers, their properties, uses, environmental impact and polymer recycling. This alignment allowed the work to be contextualized in order to meet the objectives proposed by the SSA1 program, aimed at the first year of high school, integrating environmental issues into the teaching of Chemistry.

The questionnaires were organized in two stages: pre- and post-intervention. The first stage was aimed at identifying the students' previous knowledge about polymers, plastics, bioplastics and sustainability, highlighting that these ideas are fundamental for the development of the concepts that the work proposes. The second stage focused on the evaluation of expanded learning after the intervention. The application took place during the month of December 2024, involving theoretical classes on the introduction to polymers and practical activities related to the theme of bioplastics and their use as a pedagogical tool in the teaching of Chemistry.

The practical activities resulted in the manufacture of bioplastics using simple materials, such as corn starch, glycerin and food coloring, highlighting the vision of the production of materials from the students' daily lives. According to Demo (2002), the interaction between theory and practice is essential for the construction of knowledge, especially in the educational context.

The main objective of this work was to evaluate the impact of the activities on students' learning and environmental awareness, promoting critical thinking about the use of sustainable materials and their implications for the environment. In addition, it sought to strengthen the link between scientific concepts and their practical application, demonstrating the relevance of Chemistry in everyday life and environmental issues.

4.2 QUESTIONNAIRE

According to Marconi and Lakatos (1992), the questionnaire is a scientifically developed instrument, composed of a set of questions organized according to a predetermined criterion. It must be answered without the presence of the interviewer and aims to collect data from a group of respondents.

For Bardin (2011), content analysis occurs in three fundamental phases. The first, called pre-analysis, consists of organizing the material and reading the data selected for study in general. Then, the exploration of the material involves a detailed analysis of the questionnaires, allowing the identification of emerging indicators or themes. Finally, the treatment of the results, which includes inference and interpretation, aims to capture both the explicit and the latent contents present in the collected material.

Data validation followed the guidelines of Bardin (2011), applying the three essential stages of content analysis: pre-analysis, exploration of the material and interpretation of the results. These procedures made it possible to identify significant patterns in the data collected, evidencing the positive impact of the didactic sequence on the students' learning and environmental awareness. The results reinforced the potential of practical activities and reflective discussions as effective strategies for the teaching of Chemistry, contributing to the formation of critical citizens engaged with sustainability.

4.3 TARGET AUDIENCE AND PERIOD OF THE SURVEY

The research was developed with students in the first year of high school, enrolled in the sequential technical course of mechanics at the Federal Institute of Pernambuco – Ipojuca

Campus. The ages of the participants ranged from 14 to 16 years old, and the group consisted of 34 students.

The research program included a meeting lasting an average of two hours, planned to offer a balance between theory and practice. These meetings addressed a theoretical introduction to the topic, followed by experimental activities and guided discussions, all structured to maximize student engagement and promote a deeper understanding of the contents covered.

The participants belonged to an institution recognized for its interest in innovative pedagogical practices, which favored the implementation of the work. The organization of the activities included the formation of small work groups, a pedagogical strategy that, according to Vygotsky (2001), stimulates collaborative learning and the exchange of knowledge among students. This approach is especially effective in the development of social and cognitive skills, reinforcing the collective construction of knowledge (Demo, 2002).

In addition, the meetings were planned to include practical activities that explored the theme of sustainability in the students' daily lives. Our objective was to start from a theoretical-practical approach, inserting the manufacture of bioplastics using simple and renewable materials, such as corn starch, glycerin and food coloring, highlighting the relevance of the contents worked on in the daily life of the participants. This practice is aligned with the idea of Morin (2001), who defends the importance of interdisciplinarity in education, connecting science (what are polymers), technology (polymer manufacturing process), society (conscious use of these polymers) and the environment (sustainable future).

The research period took place in December 2024, covering an intensive schedule that ensured the articulation between theoretical concepts and their practical applications. This methodology allowed the analysis of the impact of the activities on the students' learning and environmental awareness, fostering reflections on the use of sustainable materials and their implications on the environment.

Finally, the research sought to consolidate the link between scientific concepts and their practical applications, demonstrating the importance of Chemistry in everyday life and in environmental issues, while strengthening the students' connection with the theme of sustainability. As Freire (1996) states, educational practice should promote student autonomy, stimulating critical thinking and social responsibility.

4.4 THE ELABORATION OF THE DIDACTIC SEQUENCE

To meet the objectives of the research, a didactic sequence was elaborated consisting of three main stages: prior survey of knowledge, educational intervention and final evaluation.

This structure was based on recent studies on active methodologies and the potential of bioplastics as an integrating theme in the teaching of Chemistry.

In the First Stage (Prior Knowledge Survey), students answered an initial questionnaire consisting of six open questions, whose objective was to map their previous knowledge about polymers, plastics, bioplastics and sustainability. This stage was essential to identify the students' initial conceptions, as Bardin (2011) points out, and the initial reading is indispensable for directing the content analysis.

Next, each pre-test question will be presented along with its specific objectives.

4.4.1 What do you mean by polymers?

This question seeks to explore students' prior knowledge about one of the fundamental concepts for understanding plastics and bioplastics. Polymers are macromolecules that play a central role in the chemistry of materials, and understanding their structure is essential for the didactic sequence.

Polymers are the structural basis of plastics and bioplastics. Knowing if students understand the concept is essential to prepare clear and contextualized explanations, adjusting the level of depth to the audience.

4.4.2 What do you mean by plastics? What raw material is used in its production?

To assess students' understanding of the origin and composition of conventional plastics. Here, the intention is to verify that students recognize the origin of plastics and their composition. This understanding is important to introduce the environmental impact and challenges related to the use of petroleum products.

4.4.3 What do you mean by sustainability?

Verify students' initial understanding of the concept of sustainability. The concept of sustainability is central to the discussion about bioplastics. Identifying students' perceptions allows you to connect theoretical topics to environmental and social reality.

This question explores students' ideas about a broad and essential concept. Sustainability involves practices that meet current needs without compromising future generations, and this initial understanding is necessary to contextualize the topic.

4.4.4 How do you think plastics impact the environment?

Investigate students' perceptions of the environmental impacts caused by plastics. This question sets the stage for discussion about the disadvantages of conventional plastics and the advantages of bioplastics as a partial solution.

This question seeks to assess students' level of awareness of the environmental impacts of plastics, such as pollution and persistence in the environment. It also sets the stage for discussing sustainable solutions.

4.4.5 Have you heard about bioplastics? Explain.

Identify students' prior knowledge about bioplastics. This question evaluates the students' degree of familiarity with the topic and directs the deepening of the explanations during classes.

It investigates whether students have any previous contact with the concept of bioplastics and how they perceive it. This helps guide explanations and adjust the level of complexity of the approach.

4.4.6 Do you believe that the use of bioplastics is a sustainable alternative? Explain.

Evaluate students' initial opinions on the feasibility of bioplastics as a sustainable solution. This question instigates critical reflections and points out possible gaps in understanding that can be addressed during classes.

Here, the objective is to encourage students to reflect on the possible advantages of bioplastics, both in terms of renewable raw materials and in terms of degradability. This question introduces an initial debate that will be deepened during the didactic sequence.

4.5 EDUCATIONAL INTERVENTION

The theoretical and experimental classes addressed fundamental concepts of polymers, highlighting their classifications and the differences between synthetic and natural polymers. It was critical for students to understand these concepts in order to lay the foundation needed to differentiate conventional plastics from bioplastics. Understanding the classifications and properties of polymers allowed students to understand how materials are composed and applied in everyday life, in addition to realizing the relevance of bioplastics as a sustainable alternative.

During the practical activities, the students participated in the production of simple bioplastics using corn starch, glycerin and food coloring. This moment was central to illustrating how chemical concepts can be applied in solving concrete environmental problems. It was essential to show that, from simple and accessible materials, it is possible to produce materials of a sustainable nature, connecting science and everyday life (BRASIL ESCOLA, 2021)

In addition, debates were held to encourage a critical view of the role of science in building sustainable solutions.

This approach sought to connect scientific advances to social and environmental demands, encouraging students to reflect on how the materials they use on a daily basis impact the planet. It was essential for students to understand the composition of plastics and bioplastics, realizing how science can offer sustainable alternatives (LIMA, 2019).

Demonstrate, with the help of a practical activity, how bioplastics can be produced from renewable and simple materials such as corn starch, water, glycerin and food coloring, encouraging student learning by promoting a critical discussion about the viability of bioplastics and the role of science in the search for environmental solutions. (BRASIL ESCOLA, 2021).

4.6 FINAL EVALUATION

After completing the activities, the students answered a second questionnaire similar to the initial one. The objective is to evaluate the evolution of students and their knowledge in relation to the concepts presented in the didactic sequence. This stage also included group discussions, in which students shared their perceptions and suggested practical applications for bioplastics in their routines.

Why do this? This approach allowed students to reflect on how they could incorporate bioplastics into their daily lives, strengthening the link between theory and practice.

In addition, reflections on the advantages and limitations of bioplastics were requested. This enriches the analysis of the results obtained, verifying whether the students have developed a balanced and critical view on the subject.

Next, we will see the post-test questions with their expected developments.

4.6.1 Explain in your own words what you understood about polymers.

To verify whether the students consolidated the concept of polymers after the educational intervention.

Justification: The answer demonstrates whether there has been an advance in the understanding of the structure of polymers, connecting theoretical and practical learning.

4.6.2 Explain what plastics and bioplastics are.

To assess students' ability to differentiate conventional plastics from bioplastics. **Rationale:** This differentiation is fundamental to understand the environmental advantages and limitations of bioplastics.

4.6.3 What are the main environmental impacts caused by plastic?

To understand if students build hypotheses about the problems caused by conventional plastics in the environment.

This question helps to assess whether environmental awareness has been effectively stimulated.

4.6.4 How can bioplastics reduce these impacts?

To verify how students perceive bioplastics as a system that can contribute to the reduction of environmental problems.

The answer attempts to characterize whether students understand the benefits of bioplastics in terms of biodegradability and use of renewable resources.

4.6.5 In your opinion, what are the biggest advantages and disadvantages of bioplastics?

To encourage students to critically reflect on the qualities and limitations of bioplastics.

This reflection demonstrates whether the students have acquired a balanced and grounded view on the subject.

4.6.6 Do you think bioplastics are a definitive solution to the environmental problems caused by plastics? Why?

Investigate students' critical thinking regarding the viability of bioplastics as a global solution.

The answer assesses whether students can recognize the limitations of bioplastics and consider them part of a set of solutions.

4.6.7 Give an example of how you would apply knowledge about bioplastics in your daily life

Evaluate the practical application of the knowledge acquired.

This question shows whether the content was meaningful and useful to students, encouraging behavioral changes toward sustainability.

This stage consolidated the lessons learned and reinforced the impact of the activities on environmental awareness and the practical application of scientific concepts.

4.6.8 What is your assessment of the class?

Evaluate the students' perception of the class.

This question allows you to check how students evaluate the relevance and quality of the class, providing information about the impact of the activities on learning and awareness on the topic.

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