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Does all plastic float? An investigative experimentation proposal for the study of polymers

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ABSTRACT

The presence of polymers is becoming increasingly naturalized in contemporary times. These compounds are found in a variety of materials regularly used for storing and preserving products and food. Moreover, they are essential in the composition of a wide range of industrial items, from the automotive and technological sectors to the food industry, and are even employed in household activities. For this reason, the study of polymers becomes relevant nowadays, and thus, developing pedagogical practices to support Science/Chemistry teaching is important in the teacher's work. In this regard, this paper presents an investigative experimentation proposal for the study of polymers through a strategy designed and developed with the use of alternative materials present in people's daily context. Nevertheless, it can be adapted and adjusted according to the conditions of each educational institution. The proposal begins with a problem situation, asking whether it is possible to identify types of polymers without their codes. To this end, it was articulated with the concept of density, complementing the initial question with another: does all plastic float? Based on this context, students are encouraged to reflect and perform practical activities that allow them to answer the proposed questions through investigative experimentation. This experimental strategy aims to support the teacher in understanding students' reasoning when facing the initial problem, the strategies employed to develop solutions, and the chemical knowledge mobilized during the experiment. Throughout the text, the methodological pathway of the investigative proposal is presented in a didactic way, with illustrations and connections to the theory of polymers and density. This strategy seeks to promote understanding of the different types of polymers, along with their classifications and particularities, recognizing the factors that characterize them, as well as their positive and negative impacts on our society, highlighting the importance of Science/Chemistry teaching in people's daily lives.

KEYWORDS: Investigative Experimentation. Chemistry Education. Polymers.

1 INTRODUCTION

It is increasingly common to find polymers in everyday life, as they are present in many materials used in people's daily contexts, serving different purposes such as storing and preserving products and food, composing various industrial materials (automotive, technological, food, among others), and/or even appearing in household utensils, for example. However, it is essential to reflect on how they are constituted, since they are very large molecules formed by several repeating molecular units, which are called monomers (Mano; Mendes, 2000; Souza; Silva; Yamaguchi, 2021).

Regarding chemical synthesis methods, polymeric materials can be obtained through two types of reactions, namely, addition reactions and condensation reactions. The choice of the reaction type depends largely on the chemical nature of the starting materials (functional groups present in these materials indicate the most appropriate reaction pathway). Among the most commonly used raw materials for polymer production are those derived from petroleum (Atkins; Jones, 2012; Muri, 2021). However, it is worth noting that polymers can also be obtained from other sources. Some polymeric materials are derived from agricultural products, such as the synthesis of polyesters derived from epoxy-esters present in sunflower oil (Santos *et al*., 2014).

In the addition polymerization process, the basic units (monomers) react with each other to produce a product consisting of long chains. In this case, the monomers are alkenes. For example, when monomers of ethene molecules are used in the process, these molecules bind to each other, forming a long hydrocarbon chain, so that each monomer (ethene) becomes a repeating unit. This process leads to the production of the simplest addition polymer, known as polyethylene, (CH_2CH_2). It is also worth mentioning that there are polymers derived from substituted ethene monomers, whose general formula is $CHX{=}CH_2$, where X may be an atom or a group of atoms. For example, in vinyl chloride ($CHCl{=}CH_2$), X corresponds to the chlorine atom (Cl). In propene ($CH(CH_3){=}CH_2$), X is the methyl group (CH_3). These substituted monomers give rise to polymers with the formula -($CHXCH_2$)n-, such as polyvinyl chloride (PVC), whose structure is -($CHClCH_2$)n-, and polypropylene, represented by -($CH(CH_3)CH_2$)n- (Atkins; Jones, 2012).

On the other hand, polymeric materials obtained through condensation reactions follow reaction mechanisms similar to those that occur in the formation of esters or amides. In these processes, the monomers involved have, as a structural feature, functional groups (such as carboxylic acid, alcohol, amine, among others) at their ends. An example is polyesters, formed by the union of monomers containing carboxylic acid groups with others that have alcohol groups. Poly(ethylene terephthalate) is a classic example of this type of condensation reaction. Its production occurs through the esterification of terephthalic acid (a dicarboxylic acid) with ethylene glycol (a diol) (Atkins; Jones, 2012; Muri, 2021).

Condensation polymerization involving monomers containing amide and carboxylic acid groups results in the formation of polyamides, commercially known as nylons. An example is nylon-66, a polymer formed from monomers of 1,6-hexanediamine (a diamine) and adipic acid (a dicarboxylic acid) (Atkins; Jones, 2012; Muri, 2021). In general, nylons have wide applications, ranging from engineering uses to fiber manufacturing, such as in clothing and tires, among others (MCMurry, 2009).

Regarding technological characteristics, polymers can be classified as thermoplastics or thermosets. Thermoplastics are polymers that can be melted by heating and solidified by cooling, allowing them to be repeatedly molded. On the other hand, thermosets cannot be molded. This is due to their elastic characteristics, provided by the presence of double bonds in their polymeric matrix. In relation to mechanical behavior, polymeric materials can be divided into rubbers (elastomers), plastics, and fibers (Muri, 2021).

Among the wide range of polymers, plastics stand out. The term originates from the Greek word plastikos, which refers to their ability to be molded. Moreover, they are synthetic, organic materials, mostly derived from petroleum (Piatti; Rodrigues, 2005).

Thus, due to their high flexibility, they can be molded and recycled, further expanding their scope of use, since these materials are of great importance in people's daily lives. The plastics industry emerged around the 20th century, producing synthetic materials. The first plastic was created in 1907, in the United States of America (USA), by Leo Hendrik Baekeland (Callapez *et al*., 2020).

According to Canevarolo Júnior (2002), plastics have wide applications in different sectors of society, ranging from simple items, such as bags, PET bottles, pens, and pencils, to highly sophisticated materials used in automotive engineering, healthcare, and laboratories. This versatility highlights their importance in both everyday activities and advanced technologies.

For this reason, learning about plastics in Basic Education is essential, as they are present in students' contexts. Thus, an investigative experimentation proposal with polymers was developed using alternative materials. In this study, alternative materials are considered to be all common products and objects from everyday life that can be adapted for use in experimentation proposals. For example, glassware such as beakers, watch glasses, and pipettes can be replaced by cups, saucers, and syringes, respectively. Additionally, other materials employed may be accessible and widely used everyday items, such as soap, vinegar, washing powder, milk, bleach, fruit, among others (Silva, 2016). However, it is essential that the teacher pays attention to their properties in order to avoid risks of corrosion or damage to the materials used in the experiment. Takarada and Aires (2020) highlighted that the construction of chemical knowledge, when related to students' contexts, enables greater meaning in learning, arousing greater interest and motivation toward scientific knowledge.

In this sense, this article presents such an investigative experimentation proposal and highlights its importance as one more strategy for teaching Science/Chemistry. It is important to note that the proposal was used and (re)adapted for students at a public school in the interior of Bahia. However, the focus of this text is to disseminate the elaboration of this proposal in order to foster a didactic discussion on the study of polymers, as well as the relevance of using investigative experimentation in the teaching process.

2 THEORETICAL FRAMEWORK

In nature, it is possible to find both natural and synthetic polymers. In the case of natural ones, that is, those occurring in nature, examples include cellulose, cotton fibers, proteins, silk, etc. In the case of synthetic polymers, that is, those artificially produced, examples include polyethylene (PE), polypropylene (PP), poly(ethylene terephthalate) (PET), poly(vinyl chloride) (PVC), among others (Spinacé; Paoli, 2005).

Thus, it is important to emphasize that the study of polymers is a relevant topic to be taught in Basic Education. In this sense, it is highly significant that it be approached in a way that develops in students the ability to "[...] identify and recognize the importance of polymers to society, considering their environmental implications" (Espírito Santo, 2009, p. 72).

To identify the types of polymers, the proposal was built with a focus on the physical properties of matter, since these "[...] can be measured without altering the identity and composition of substances" (Brown *et al*., 2016, p. 11). Among these properties, density was chosen, as it "[...] is widely used to characterize substances" (*ibid*., p. 19).

It is worth highlighting that density is extremely useful in several contexts. One example is its use in chemical calculations, especially in situations involving the conversion of the mass of a liquid into its corresponding volume or vice versa (Engel *et al*., 2012). Moreover, this property is fundamental in quality control, allowing verification of product compliance with established technical standards.

In the case of fuels sold at stations in Brazilian territory, density is an essential parameter for quality control. The National Agency of Petroleum, Natural Gas and Biofuels (ANP) regulates, for example, the density of Hydrated Ethanol Fuel (EHC) as a means of detecting adulteration. Resolution ANP no. 905 of November 18, 2022 (Brasil, 2022), establishes that the maximum permitted water content in EHC is 7.5% (mass). When the added water exceeds this limit, the density of the fuel is altered, which can be detected by a densimeter (an instrument that measures the density of liquid substances).

The difference in density constituted the principle that guided the design of the experimentation proposal, since less dense materials float while denser ones sink in a given system. Thus, when the density of a given solution is known, and by observing whether the material sinks or floats, it is possible to determine whether they are denser or less dense, respectively (Brown *et al*., 2016).

In this sense, according to Silva and Rabelo (2017), polymers are materials with specific properties, which classify them into different types. In addition to the aforementioned properties, polymers have greater resistance to corrosion and a low processing temperature, which allows them to replace glass, leather, wood, and metal, among others. Therefore, although they may contribute very positively, they can also cause serious environmental problems, especially regarding inadequate disposal (Lima; Souza, 2011).

Given this, it is important to implement contextualized teaching, which uses students' everyday tools and situations, enabling the construction of more critical, reflective, and conscious scientific knowledge. "Understanding the relationships between daily life and society means having the knowledge of how to act upon it" (Takarada; Aires, 2020, p. 220). In this sense, understanding the positive and negative aspects of polymeric materials makes it possible to comprehend their impacts on society and favors their proper and conscious use, especially at the time of disposal.

From this perspective, the potential of investigative experimentation was explored. According to Silva, Machado and Tunes (2019, p. 209), "investigative experiences seek the solution of a question that will be answered through the performance of one or more activities." Thus, in this type of experimental proposal, it is necessary to consider a problem situation or a question to arouse students' interest in something that effectively belongs to their context. With the teacher's mediation, students begin to organize their prior conceptions, developing action plans and conducting experiments to solve the proposed problem.

Complementing this understanding of investigative experimentation, Suart (2014) highlighted that, although solving the proposed problem is important, the path constructed by students, with teacher mediation, is even more relevant. This is because it involves intellectual, argumentative, and interactive processes that culminate in the construction of knowledge. This type of approach can assist students in the process of action and reflection, overcoming structured "recipe-like" experiments (Silva; Machado; Tunes, 2019; Suart, 2014). In addition to this reflection, Camillo and Graffunder (2021) emphasized that, beyond experimental activities fostering greater scientific knowledge—since they relate theory to practice—they also enable the development of logical reasoning and familiarity with scientific language.

In addition, based on various authors (Silva; Machado; Tunes, 2019; Silva, 2023; Suart, 2014; Zompero; Laburu, 2011), inquiry-based teaching presents great potential. Among these, the development of certain students' cognitive skills can be highlighted, such as the creation of methods, formulation of hypotheses, elaboration of strategies to solve problems, interpretation of data, and communication of the results obtained, among others. Furthermore, this approach fosters the improvement of logical reasoning, scientific writing, and the capacity for interaction and collaboration between the subjects (students and teacher) during the process of knowledge construction. Therefore, it is essential that, when planning an experimentation proposal for a chemistry class, it is designed to promote the development of the ability to think.

3 THE FIRST STEPS OF THE RESEARCH: GENERAL ASPECTS OF THE METHODOLOGY USED

This article was written under a qualitative approach (Mineiro; Silva; Ferreira, 2022), considering the subjectivity of the researchers regarding the planning and elaboration of a didactic strategy for pedagogical purposes. The focus consisted of the development of didactic material for science education and, as a scope, an investigative experimentation proposal was designed (Silva; Machado; Tunes, 2019).

The aforementioned authors point out that experimentation must be an activity that stimulates "[...] a constant relationship between doing and thinking" (Silva; Machado; Tunes, 2019, p. 198), and that it should also articulate a relationship between scientific concepts and the experiment (theory–practice relationship). Moreover, Suart (2014) stated that an experimentation proposal with an investigative conception stems from a problem situation, of interest to the student, so as to encourage them to seek possible solutions, reflecting and analyzing possible ways of interpreting the results obtained. In this strategy, students' participation is active, in which the teacher mediates the construction of knowledge, and error is considered relevant in fostering learning.

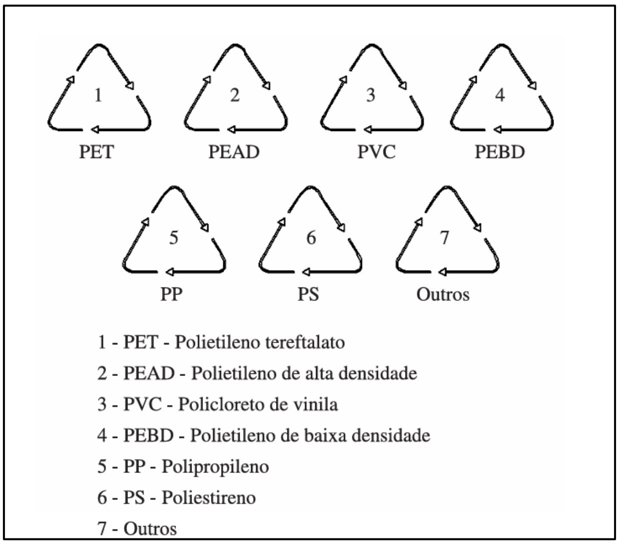
Another concern regarding the construction of the strategy was that it could be adapted to different educational contexts, with or without laboratories and equipment. Considering that some schools do not have laboratories (Silva; Machado; Tunes, 2019; Silva, 2023; Suart, 2014), the use of low-cost materials available in people's contexts was proposed. In this sense, this text presents an investigative experimentation proposal with alternative materials.

The proposal was developed based on several references (Canevarolo Júnior, 2002; Roqueto, 2019; Silva; Machado; Tunes, 2019; Suart, 2014; GEPEQ, 2015), being adapted for qualitative use in a public high school. However, the teacher may adapt it to their reality, that is, nothing prevents it from also being carried out with conventional science laboratory materials, or from being implemented in teacher training courses and/or even at different stages of Basic Education (such as Elementary School, for example).

3.1 The Stages of the Investigative Experimentation Proposal: organization of knowledge, materials, and equipment

The technology of plastic manufacturing has advanced due to the extensive use of polymers in products, equipment, and industrial and domestic utensils, as previously highlighted. Consequently, there is a wide variety of polymers, which are organized and classified by different codes. It is worth noting that, in Brazil, this coding is established by the Brazilian Association of Technical Standards (ABNT) NBR 13230:2008 (Coltro; Duarte, 2013), as shown in Figure 1.

Figure 1 – Polymer Codes



Source: Coltro and Duarte (2013, p. 129).

These codes are used to identify the different types of polymers and also to better direct them for recycling (Coltro; Duarte, 2013). However, depending on how the packaging is found in nature, it may not be possible to identify its code. In view of this, the following problem situation was proposed: Is it possible to classify the type of polymer without the identification code?

To distinguish the type of material present, a physical property was used: density. According to Atkins, Jones, and Laverman (2018), density is the ratio between the mass and the volume of a given sample. Moreover, it is an intensive property, which does not depend on the size being analyzed, that is, the same material, whether large or small, will have the same density.

In the proposal, a Table was also prepared, based on Roqueto (2019), to serve as a reference for the students. Table 1 presents the densities of the samples and solutions used for their characterization.

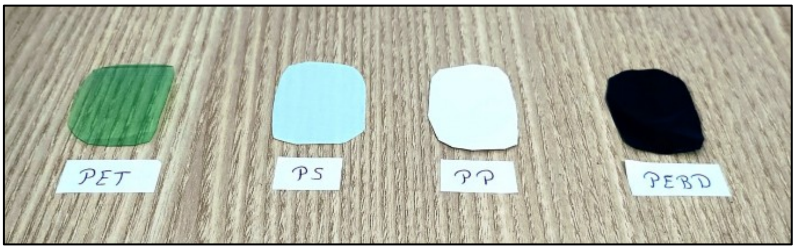
Table 1 – Densities of the samples and solutions

Polymers	**Density g/cm³**
Polypropylene (PP)	0.900 – 0.910
Low-density polyethylene (LDPE)	0.917 – 0.940
Polystyrene (PS)	1.04 – 1.05
Polyethylene terephthalate (PET)	1.29 – 1.40
Solutions	**Density g/cm³**
Water(H_2O)	1.0
Alcohol (C_2H_6O)	0.93
Water + Salt (H_2O + NaCl)	1.15

Source: Adapted from Roqueto (2019).

It is important to highlight that the proposal was developed from a qualitative perspective and with materials available in people's daily context. Therefore, approximately 200 milliliters (mL) of commercial ethanol solution 46°, potable water (tap water), and water with table salt (Sodium Chloride – NaCl)[1] were used, whose density values were close to those presented in Table 1. The polymer samples used were: greenish soft drink bottle (PET), disposable plate (PS), margarine container (PP), and black trash bag (LDPE). They are illustrated in Figure 2.

Figure 2 – Polymer samples used in the experimentation



Source: Authors (2024).

Three transparent cups, three spoons, a kitchen scale, and tweezers were also used. During the testing of the proposed experimentation, it was observed that polymer samples could not be transparent, as this hindered the visualization of the results due to the transparency of the solutions used (ethanol, water, and salt water).

Furthermore, it is noteworthy that this proposal can be adapted for the use of conventional laboratory materials, in case the teacher has access to glassware, equipment, and solutions in their institution. In this way, the cups may be replaced by 250 mL beakers, the spoons by glass rods, the kitchen scale by an analytical balance, tap water by distilled water, table salt solution by another with analytical grade NaCl PA, and commercial alcohol by an ethanol solution. As previously mentioned, this proposal may be adjusted for different educational contexts.

4 LINKING THEORY AND PRACTICE: PRESENTING THE METHODOLOGICAL COURSE OF THE EXPERIMENTAL PROPOSAL

The investigative experimentation proposal developed and presented in this text can be used by teachers at different stages: before starting the content, during its development, or at the end as a review and reinforcement of scientific concepts about polymers. Moreover, it was designed as an open-ended experience, that is, one "[…] in which the phenomena are observed and the students, under guidance, are able to relate them to a theory (theory-experiment relationship)" (Silva; Machado; Tunes, 2019, p. 205). For better organization, the description of the experimental proposal was divided into some steps, according to the framework of Silva, Machado, and Tunes (2019, p. 209-210):

> a) Proposing a problem […].
> b) Identifying and discussing students' ideas […].
> c) Developing possible action plans […].
> d) Experimenting with what was planned […].
> e) Analyzing the recorded data […].
> f) Answering the initial question […].
> g) Handling the waste generated […].

Thus, in the first step, a problem was proposed from an initial question: Is it possible to classify polymers without their identification code? And to address it in articulation with the concept of density, it was complemented with another inquiry: Does all plastic float? Throughout this article, the remaining steps will be presented didactically and illustratively, aiming to make this investigative experimental proposal applicable for teachers at different levels and modalities of education.

In the second step, the teacher may identify and discuss with the class the ideas related to the problem situation. It is essential to understand students' prior knowledge about the initial problematization, and in case of misconceptions, the teacher should act as a mediator to overcome conceptual gaps and promote new reformulations (hypotheses). One suggestion would be to divide the students into groups, in order to foster dialogue and the mobilization of knowledge. In this article, the concept of density was proposed as a tool to identify the previously mentioned polymer samples.

In the third step, students must develop, based on the hypotheses built, possible methodological paths to solve the issue (action plans). It is essential that the teacher monitor the process, in order to avoid the use of methods that would not work and that are already described in the scientific literature, as well as to prevent accidents and minimize waste of materials and reagents (Silva; Machado; Tunes, 2019; Silva, 2023; Suart, 2014). In this study, an analysis of density differences in distinct systems is proposed as a strategy for problem-solving.

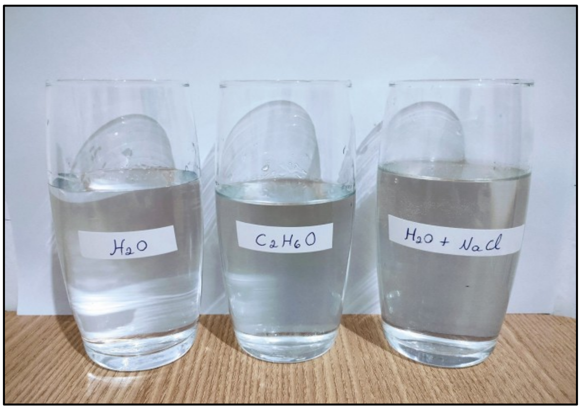
The fourth step corresponds to conducting the experiment, when students must implement what was planned, testing the hypotheses formulated. During this phase, in addition to acting as a mediator, the teacher may suggest “readings on theoretical and conceptual aspects related to the hypotheses raised” (Silva; Machado; Tunes, 2019, p. 209). Careful observation and detailed recording of the observed phenomena are fundamental to support the next step of the investigative experimental proposal.

The fifth step consists of organizing and analyzing the data obtained experimentally, based on scientific knowledge. These records are essential for learning scientific language and for the use of systematization tools, such as charts, graphs, and tables. Given its complexity, this step requires the teacher’s mediation, who plays a key role in articulating the experiment with chemical content.

In this study, steps four and five were developed in an integrated way, emphasizing the relationship between theory and practice, so that the teacher may clearly perceive this articulation. In addition, reflections that go beyond the resolution of the investigated situation were included, addressing broader issues, such as environmental aspects, which may emerge from the investigative experimental proposal. Thus, a step-by-step process is presented, articulated with theoretical explanations, configuring one possible way of implementation by teachers.

Initially, the three transparent cups were separated and labeled with the chemical formulas of the solutions that would be used: potable water (H_2O), commercial ethanol 46° INPM (C_2H_6O), and potable water with table salt (H_2O + NaCl). Then, approximately 200 mL of each solution was added to the respective cups[2] (Figure 3). In addition, the use of transparent cups was necessary to facilitate the visualization of the experiment, as can be observed in the illustration below.

Figure 3 – Solutions used in the experimental proposal



Source: Authors (2024).

The idea from this point was to qualitatively verify the density of the polymer samples in each solution. According to Roqueto (2019, p. 60), “[...] chemical properties are more difficult to test because they require the destruction of the plastic” through combustion, which produces toxic substances. Therefore, according to the aforementioned author, a simple strategy to characterize the types of polymers would be through “[...] tests related to physical properties (rigidity, density, thermal conductivity, softening and/or melting temperature)” (ibid.). Thus, the proposal was designed based on density. To begin, it is proposed to add the polymer samples to the first solution (H_2O), stir with a spoon, and observe what happened (Figure 4).

Figure 4 – Polymer samples in the potable water solution

Source: Authors (2024).

From Figure 4, it can be observed that the samples from the soda bottle and the disposable plate sink, while those from the margarine container and the trash bag float. Considering that the density of potable water is close to that shown in Table 1, that is, 1 g/cm³, it can be deduced from the experiment that two samples (soda bottle and disposable plate) are denser than water and may be composed of PS and PET, while the other two samples (margarine container and trash bag) are less dense than water and may be composed of PP and LDPE.

Next, it is necessary to characterize both the samples that are less dense and those that are denser than water. For this purpose, the other two solutions are important: commercial alcohol and salt water. The choice of commercial ethanol is due to its density, which is lower than that of water, allowing the separation of the samples that floated. On the other hand, the table salt (NaCl) solution was used because its density is higher than that of water, making it possible to differentiate the samples that sank (Roqueto, 2019; GEPEQ, 2015).

To distinguish the samples that floated, they were added to the commercial alcohol solution (C_2H_6O) and then stirred with a spoon. The result can be observed in Figure 5.

Figure 5 – Polymer samples less dense than water in the commercial ethanol solution

Source: Authors (2024).

Figure 5 highlights the first characterization of the polymer samples, as the margarine container floats while the trash bag sinks. This moment can be discussed by the teacher, since people usually imagine that all trash bags float; however, in this specific case, it sank due to its density. There is also an opportunity to discuss the difference between mass and density, as bags or trash bags are relatively “[...] lighter when compared to wood, metals, and ceramics” (Piatti; Rodrigues, 2005, p. 27), and the expectation was that it would float. At this point, by engaging in dialogue with students, the teacher can expand the discussion by considering the variables that are important in the immersion or emersion of objects in a given liquid. Furthermore, this would be the ideal opportunity to address some concepts that are often misunderstood. For example, it is very common to confuse the terms mass, weight, and density.

In this sense, it is likely that some students, when conducting the experiment presented in this manuscript, would expect a different result, as they might establish the following correlation: “lighter” material floats; “heavier” material sinks. However, as shown in Figure 5, the heavier material does not always sink. In fact, it was the trash bag sample, relatively lighter, that sank. Therefore, these students were probably attributing the same meaning to the terms “weight” and “mass.” That is, a “lighter” object (associated with lower mass) floats; a “heavier” object (associated with greater mass) sinks. But this is not quite correct!

It is important to emphasize that “mass” and “weight” are not the same thing. Mass is “the measure of the amount of material in an object” (Brown *et al*., 2016, p. 16). On the other hand, according to Brown and colleagues (2016, p. 16), “the weight of an object represents the force exerted on the mass by gravity.” Therefore, when a person says that an object sank because it is “heavier,” from a conceptual standpoint, this is mistaken. The correct statement would be that the object is denser than the other. Remember that density is defined as “the amount of mass per unit volume of a substance” (Brown *et al*., 2016, p. 19). Notice that density is a property that relates mass and volume. Thus, mass and volume, when considered separately, cannot be used as criteria to predict whether a certain material will float or not.

For example, when one incorrectly states that iron is heavier than air, what is actually meant is that iron has a greater density than air. It is important to emphasize that one kilogram (kg) of air has the same mass as one kilogram of iron.

However, iron occupies a smaller volume, and therefore has a higher density, making it denser than air (Brown *et al*., 2016). This example reinforces that mass, just like volume, when considered separately, cannot serve as a robust criterion to determine whether an object will float or not. Therefore, the object with lower density will float, and the one with higher density will sink.

In some situations, the shape of objects can influence flotation. Certain objects, due to their shape, can float even though they are denser than water. In these cases, at first, they do not sink because they cannot overcome the surface tension of the water. Examples include a razor blade and a sheet of aluminum foil (Mortimer; Machado, 2008). It should be noted that, if these objects overcome the surface tension of the water, they will inevitably sink, since their density is greater.

In this regard, the fact that the trash bag sample sank was unexpected, which makes it a fundamental aspect of an investigative experimental proposal, as it develops students' logical reasoning and cognitive skills regarding scientific knowledge (Silva; Machado; Tunes, 2019; Silva, 2023; Suart, 2014), and also "[...] encourages them to (re)think new alternatives for solving the initial problem" (Silva, 2023, p. 49). Since the density of commercial ethanol 46° is 0.93 g/cm³ (Table 1), the material that floats (margarine container) is composed of the PP polymer, while the trash bag is composed of LDPE. Thus, even without the codes, it is possible to characterize the type of polymer based on density differences.

The same reasoning applies to the other two samples denser than water. Once again, they need to be added to the table salt solution and stirred with a spoon. Figure 6 illustrates what occurred in the investigated system.

Figure 6 – Polymer samples denser than water in the saltwater solution

Source: Authors (2024).

According to Figure 6, the disposable plate sample floats while the soft drink bottle sinks. Referring once again to Table 1 (density values), it is noted that the sodium chloride solution has a density of 1.15 g/cm³. Thus, it is possible to deduce that the disposable plate is made of PS (less dense) and the soft drink bottle is made of PET (denser). Furthermore, at this stage of the experiment, the teacher may also raise an environmental issue regarding the oceans, namely, the fact that PET bottles, for example, sink in water and are ingested by marine animals. This fact was mentioned by Souza, Silva, and Yamaguchi (2021, p. 49):

> Studies have shown that the improper disposal of these synthetic polymers is one of the main factors responsible for environmental pollution, particularly in aquatic environments such as seas, rivers, lakes, and streams, causing the death of several animals that inhabit these biotas.

Improper disposal generates numerous environmental problems that affect health and the balance of ecosystems. To contribute to environmental education and engage students in sustainability training, the aforementioned authors developed a workshop for producing biodegradable plastic from cassava starch (Souza; Silva; Yamaguchi, 2021). As can be seen, this experimental proposal also enables interdisciplinary dialogue and fosters debates on environmental issues.

Returning to the experiment, after its completion and the detailed recording of all data obtained, the teacher can, together with the students, construct a table to compile the information gathered during the practice. As a suggestion, Table 2 was prepared.

Table 2 – Data obtained from the open investigative experimentation proposal

Samples	H_2O Solution	C_2H_6O Solution	$H_2O + NaCl$ Solution	Polymer characterization
Disposable cup	Floats	Floats	_____	PP
Garbage bag	Floats	Sinks	_____	LDPE
Soft drink bottle	Sinks	_____	Floats	PET
Disposable plate	Sinks	_____	Sinks	PS

Source: Authors (2024).

From the interpretation of the data, one reaches the penultimate stage, in which students, after going through the previous steps, are able to answer the initial question. The development of this proposal provides a fruitful path for the construction of knowledge, enabling students, with the mediation of the teacher, to analyze “the validity or not of the hypotheses raised, the methods used, and the resulting implications” (Silva; Machado; Tunes, 2019, p. 210).

It is considered that this strategy can be carried out by the students themselves with the mediation of the teacher. This process allows students to systematize their observations and reflect on them, articulating with the theory evidenced through the experimentation proposal (Silva; Machado; Tunes, 2019; Silva, 2023).

Finally, in the last stage, special care was taken with waste management. In this work, the polymer samples can be reused several times, allowing the teacher to repeat the experimentation proposal in different classes. In addition, the solutions used can be stored in suitable containers for reuse. This approach contributes both to reducing the generation of laboratory waste and to lowering the operational costs of conducting the experiment.

It is important to note that the polymer samples may be modified according to the local context. Based on some theoretical references, Table 3 proposes suggestions for replacing the plastics used in the proposal.

Table 3 – Suggestions for replacing the polymer samples

Polymers	Materials
PP	Guava paste container, requeijão cup, disposable cup.
LDPE	Industrial or food packaging films, some toys.
PET	Packaging for pharmaceutical products and also for cosmetics.
PS	Ice cream or yogurt container, disposable cups, combs.

Source: Barbosa *et al*. (2017), Canto (2004), Royer *et al*. (2005).

Thus, according to the reality of each educational institution, the polymer samples can be modified. Another precaution adopted in the elaboration of the proposal was to overcome merely reproductive experiments with a confirmatory character of the theory, that is, the aim was to go beyond practices such as simple ready-made recipes.

Finally, the proposal can also be discussed and expanded by taking into account certain social issues, such as the environmental degradation caused by the inadequate disposal of plastics. It may foster discussions on strategies to reduce pollution and raise awareness about the importance of recycling. This helps to overcome misconceptions about some environmental preservation solutions. For example, using floating nets in aquatic environments to contain polymer residues is not effective in salt water, since not all polymers float, as observed in the experimental proposal. Their presence in the water may lead to ingestion by aquatic species, causing problems and even death of the animals.

These considerations constitute suggestions for the exploration of the proposed experiment. Importantly, it can also be developed from an interdisciplinary perspective, in which scientific knowledge may be worked on in Chemistry, Biology, and Geography classes, through formative and integrated discussions to understand the challenges and perspectives of plastics in contemporary times.

FINAL CONSIDERATIONS

Planning and developing proposals for investigative and open experimentation is not an easy task; it requires time, extensive study, and dedication. It is also challenging to design practices that can be adapted and adjusted according to the context of each educational institution.

In this work, a proposal for the characterization of polymers without the identification of their codes was presented, articulated with the concept of density. As highlighted throughout the text, students are the protagonists in the construction of their knowledge, while the teacher assumes the role of mediator.

Several strategies were explored, such as the review of concepts and challenges, with the aim of arousing students' interest in unraveling the problem and understanding the importance of scientific knowledge. Furthermore, the approach was articulated with the concept of density, demonstrating that Chemistry is a science that investigates the nature of matter (Atkins; Jones; Laverman, 2018; Brown *et al*., 2016) and makes it possible to relate concepts from

General Chemistry and Organic Chemistry. The interdisciplinary potential was also indicated by implementing discussions on environmental education.

This strategy aims to support teachers and researchers in the field of Science/Chemistry Education by offering another possibility to reflect on the importance of scientific knowledge in people’s daily lives, as well as by providing a differentiated strategy for teaching. Finally, it is worth emphasizing that the absence of adequately equipped laboratories is not an impediment to conducting experiments, especially in schools that lack such facilities. The proposed experiment presents possibilities for working with concepts through feasible experiments, making use of alternative materials, reagents, and equipment that are easily found in the context of teachers and students.

It is important to note that this experiment was presented with some possible solutions to an initial problematization. The teacher may adapt it to their educational context and even build with their students other possible questions and/or methodological paths to be used. What is most important is to provide a strategy that promotes critical thinking and student engagement in reflecting on scientific concepts based on their own context.

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TODO PLÁSTICO BOIA? UMA PROPOSTA DE EXPERIMENTAÇÃO INVESTIGATIVA PARA O ESTUDO DE POLÍMEROS

RESUMO

A presença de polímeros está se tornando cada vez mais naturalizado na contemporaneidade. Esses compostos estão presentes em uma variedade de materiais que são utilizados regularmente, com o intuito de armazenar e preservar produtos e alimentos. Além disso, eles são fundamentais na composição de uma ampla variedade de itens industriais, desde os setores automotivo e tecnológico até o alimentício, e são empregados até mesmo em atividades domésticas. Por isso, o conteúdo de polímeros torna-se relevante para os dias atuais, dessa forma, pensar em uma prática pedagógica para auxiliar o ensino de Ciências/Química torna-se importante no trabalho do professor. Nesse sentido, este texto apresenta uma proposta de experimentação investigativa para o estudo de polímeros, por meio de uma estratégia que foi planejada e elaborada com o uso de materiais alternativos presente no contexto das pessoas. Contudo, é possível adaptá-la e flexibilizá-la de acordo com as condições de cada instituição de ensino. A referida proposta se inicia com uma situação problema elaborada, indagando se é possível identificar os tipos de polímeros sem os seus códigos e, para isso, foi articulada com o conteúdo de densidade, cuja pergunta inicial foi complementada com o questionamento: todo plástico boia? Com base nesse contexto, os alunos são incentivados a refletir e realizar atividades práticas que permitam responder às perguntas propostas por meio de uma experimentação investigativa. Essa estratégia experimental tem como objetivo apoiar o professor na compreensão do raciocínio dos estudantes diante da problematização inicial, das estratégias empregadas para desenvolver soluções e dos conhecimentos químicos mobilizados na realização do experimento. Durante o decorrer do texto, o percurso metodológico da proposta investigativa é apresentado de forma didática com ilustrações e articulações com a teoria de polímeros e densidade. Essa estratégia pretende promover o entendimento dos diversos tipos de polímeros, juntamente com suas classificações e particularidades, compreendendo os fatores que os caracterizam, bem como o seu impacto positivo e negativo em nossa sociedade, destacando a importância do ensino de Ciências/Química no dia a dia das pessoas.

PALAVRAS-CHAVE: Experimentação Investigativa. Educação Química. Polímeros.

NOTE

1. Thirty grams of table salt were used, weighed on a kitchen scale. The calculation to obtain a density of 1.15 g/mL was made considering both the mass of sodium chloride and the water, as described below.

$$d = \frac{m_1 + m_2}{V}$$

$$d = \frac{30g \text{ de } NaCl + 200g\ H_2O}{200mL \text{ de } H_2O}$$

$$d = \frac{230g}{200mL}$$

$$d = 1{,}15\ g/mL$$

2. To measure the amount of solutions, a measuring cup commonly used in cooking recipes was employed.

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