Intermolecular forces: a methodological proposal of teaching based on experimentation

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1 INTRODUCTION

Most high school students consider chemistry to be one of the most difficult subjects to understand. Whether by its very specific language, by abstraction, with glasses, or even by the way it is transmitted: in a repetitive and decontextualized way, being only memorized by the student and with practical applications far from everyday life. The fact is that the teacher has the great challenge of transposing the difficulties through a methodology that combines theory and practice, demystifies chemistry, and brings the macroscopic world closer to the microscopic, contributing to a better understanding of chemical concepts. Based on this assumption, this work aims to suggest a methodological proposal for the teaching of intermolecular forces, a content that is usually addressed in high school, which suggests joining theory to practice through contextualization and experimentation, to reduce learning difficulties. Thus, based on the student's previous knowledge, some questions and problem situations were mentioned in a dialogued class to verify possible difficulties in the applicability of the concepts, contents understood, or erroneously applied toys as concepts learned superficially. The activities were developed in two different schools, the activity described as Psychedelic Milk was applied in a public school in the city of Caetité- Bahia in a class of 1st year of high school with 22 students, while the activity Elevador de Naftalina, was applied in a public school in the city of Novorizonte- Minas Gerais in two classes of the 3rd year of high school with 47 students. During the execution of both activities, some conceptual difficulties were observed, both regarding the correct understanding of the concept and its application in daily life. Despite the conceptual errors presented, the objective of the proposal is not to end the initial conceptions and force scientific knowledge, instead, to make the reconstruction of their previous knowledge, with assimilation and accommodation of new experiences and knowledge to these conceptions, enabling the construction of scientific concepts. It is punctuated that for the success of the work it was fundamental to know the mistakes presented by the students and use them as a starting point for the development of approaches that contributed to the conceptual evolution of the students. Concerning intermolecular forces, the need to differentiate them from chemical bonds was highlighted, as well as investing in approaches that favored their association with the properties of substances.

2 METHODOLOGY

Considering the importance of the student's communication, their previous knowledge, and doubts, the activity was initiated through a classroom dialogue with the active participation of the students. The content intermolecular forces were approached from the use of images and concepts highlighted in a presentation of PowerPoint. During the class, the students were well-involved and participatory. They demonstrated to know the concept of chemical bonds, but presented some conceptual errors about intermolecular forces, leaving to understand that for them the chemical bonds and the intermolecular forces were the same force. All questions and doubts that arose and were explicit at the time of the class were problematized for the students to seek these answers and thus build knowledge.

The next stage of the work began with the division of the room into teams of four students. All experimental work was carried out in stages, seeking in each their survey information, reflections, and concepts.

First, each team put milk on the plate, and at that moment they were asked: What is the milk made of? What forces keep water molecules together? In this moment of dialogue, the students did not demonstrate difficulties and answered correctly the questions raised. Later, they were instructed to add drops of food coloring to milk and were asked: Why does the dye float in milk? Why doesn't the dye homogenize with milk? Is there anything to prevent this mixture from being homogeneous?

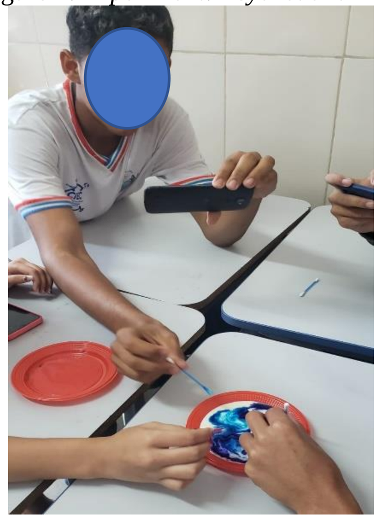
Figure 1: *Experiment: Psychedelic milk, a moment of practice*

Source: Researcher (2022)

The students demonstrated what they knew about the concepts of mixtures, but it was in this phase, a difficulty related to the concept of homogeneous and heterogeneous mixtures. In this case, the students classified the mixtures correctly but did not know how to answer because some are heterogeneous and others were homogeneous. Moreover, it was observed that the students demonstrated to believe that intermolecular forces act only in homogeneous mixtures, thus not existing intermolecular forces in heterogeneous mixtures. On the surface tension, most of the students pointed out to be the same, the one responsible for the floating of the dye in the milk.

The students then used a detergent-soaked cotton swab and touched various points in the mixture. This was the moment of greatest animation and admiration. Students were asked about the following situations: What happens when the detergent comes into contact with the mixture? Why can the detergent homogenize the mixture? Why can the detergent remove the fat from a pot and only wash it with water can't? All questions were answered correctly, demonstrating that the content was learned by the class.

Figure 2: *Experiment: Psychedelic Milk*



Source: Researcher (2022)

The second activity developed with the students was the experiment "Mothballs Elevator", this, includes mothballs, which is a chemical called naphthalene. This substance placed inside a container with vinegar is positioned at the bottom of this liquid substance. When we add baking soda ($NaHCO_3$) to vinegar and water, we see that naphthalene begins to rise to the top of the container with vinegar and water, and then descend again, so successively as we add baking soda. This phenomenon occurs by the presence of gas (CO_2), which interacts with the wall of mothballs allowing it to become less dense than water, following to the surface of the mixture and returning to the bottom when gas bubbles burst on the surface. The process is repeated until the concentration of carbon dioxide decreases significantly (PERUZZO and CANTO, 2006).

For the execution of the activity, the reagents and materials to be used in the practical class were presented, as well as the safety methods. Subsequently, the practice and observation of what was happening were performed, and the whole procedure was followed by the students and recorded by photos. To verify if the concepts were understood by the students, some questions related to the concepts and phenomena that were happening to verify the students' learning were applied. The practical class was conducted by the teacher in charge.

During the procedure of the experience, it was noticeable how interested the students were in the reaction because often the contents are approached in a decontextualized way and without meaning by the student, only following the programmatic content of the textbooks.

With the use of the practical class, it was possible to enable both the student and the teacher the ability to develop scientific reasoning, in which they will make use of their acquired knowledge in theory (BRAGA et al., 2021).

Figure 3: *Experiment: Mothball Elevator*

Source: Researcher (2022)

The experience helped students answer doubts, and question what was happening in practice, leading them to signify the concepts discussed in the classroom about density and intermolecular forces. Therefore, it is worth emphasizing the importance of practical activities integrated with the theory seen in the classroom, because it brings greater meaning to contents that are often not understood by students within the classroom and go unnoticed without due association with the reality of students. It is also noteworthy that the uses of practical classes help students in the development of scientific concepts, improving the understanding of the contents and associating the theory of the student's daily life making learning meaningful. It corroborates this thought, by Souza (2013) when he suggests that the experimental activity should offer conditions for students to raise and test their ideas and assumptions about the scientific phenomena that occur in their daily lives. In the same sense, Giordan (1999) states that by arousing interest in students, experimentation also contributes to a motivating character, is playful, and is linked to the senses.

3 CONCLUSION

The activities were first developed from a diagnostic conversation mediated by the use of images. The objective of this dialogue was to understand the concepts seized about the content and possible difficulties.

It is noteworthy that according to Ferreira, Hartwig, and Oliveira (2010), "no investigation is based on zero, that is, it needs knowledge that guides observation. In a proposal of investigative activity, it is necessary to explain the previous knowledge available about the activity, without which it becomes impossible to carry it out".

From the analysis of the answers, it was observed that many students associated chemical bonds with intermolecular forces, treating both as synonymous. According to Schmidt et al., most conceptual errors occur due to the lack of questions about the nature of different interactions, whether they have the same origin, and what energy is involved in the interaction, for comparison purposes.

According to Miranda et al., (2017)

> "The high level of abstraction of the theme leads to the use of different explanatory models for the conceptual understanding of existing Intermolecular Forces, making the subject complex and with the potential to generate alternative conceptions to scientific models." (Miranda, Braibante, Pazinato, 2017, p.1808).

The next step was the application of the experimental activity, developed in parts, and in each of the moments, questions were asked to identify possible conceptual errors. In this phase, it was noticed that the students had some correctly constructed concepts, but still presented some conceptual difficulties, such as the concept of mixtures being correctly placed, but the students presented difficulties in justifying why some mixtures are homogeneous and others heterogeneous. Some of them attributed the density difference as responsible for the heterogeneity of the mixtures. But when confronted with other mixtures with liquids of different densities that resulted in a homogeneous mixture, the students could not argue about the possible causes.

According to Rossi et al (2008) cited in Faria (2020), the concept of density cannot be discussed without addressing polarity, as this avoids conceptual errors in the understanding of phenomena associated with the interaction between substances. Given the conceptual errors scored, polarity was pointed out as responsible for the miscibility of the mixtures.

Another observation was that many students associate intermolecular forces with the homogeneity of mixtures, thus the presence of intermolecular force in heterogeneous compounds.

Despite the conceptual errors presented, the objective of the proposal is not to end the initial conceptions and force scientific knowledge, instead, to make the reconstruction of their previous knowledge, with assimilation and accommodation of new experiences and knowledge to these conceptions, enabling the construction of scientific concepts. Thus, despite the initial difficulties, the students were presented with situations in which they could perceive that there is an interaction between homogeneous and heterogeneous species, whether these interactions are stronger or weaker.

On this conceptual obstacle, Fernandes and Locatelli (2020), report:

> In the scope of intermolecular interactions, we can find several conceptions that, throughout school life, start to generate epistemological obstacles to chemistry teaching(...) Among the main obstacles, we can see the association between intermolecular interactions and mixtures, in which substances of different compositions start to present interactions between their various molecules, but the interactions between the molecules of the same substance are considered. Francisco Junior (2008) adds another alternative conception, which only has interactions between compounds that form a homogeneous mixture, and in the heterogeneous mixture, there are no interactions between the components that compose it. (Fernandes, Locatelli, 2020, p.6).

The analysis of the results obtained demonstrates the importance of choosing different methodologies for chemistry teaching. It was evidenced that the use of images, associated with the dialogued class and experimentation was fundamental for the identification of erroneous concepts and the construction of new knowledge.

According to Charlot (2000), knowledge is constructed through relationships that the individual makes with the world, with himself, and with other individuals, and is dependent on the personal desire of each subject, so school failure cannot be explained only by the social origin of the individual. Therefore, the planning of the teacher's actions is considered of paramount importance, using methodologies and presenting the contents in a way that makes sense to the students.

According to Gonçalves et al., (2021)

> Experimentation, when well structured and contextualized, is a promising strategy to transmit to students certain skills and competencies. The use of this strategy can lead students to an investigative character of science, the ability to work in groups, prepare reports, structure concepts, and establish relationships based on observations of daily life. (Gonçalves , Martinho, Rocha, Agostinho, Souza, 2021, p. 7896).

For the development of this activity, it was essential to know the mistakes presented by the students and use them as a starting point for the development of approaches that contributed to the conceptual evolution of the students. About intermolecular forces, the need to differentiate them from chemical bonds was highlighted, as well as investing in approaches that favored their association with the properties of substances.

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