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INVESTIGATIVE ACTIVITIES IN SCIENCE TEACHING: THE USE OF PROBLEM-BASED LEARNING WITH HIGH SCHOOL STUDENTS

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ABSTRACT

This work aims to present the results of a chemistry class held with students from the three high school grades. The learning of chemistry concepts was evaluated based on the contribution of experimental class in the process of understanding the chemical phenomena studied. The results demonstrated that Chemistry can be better understood if viewed as a visual science, but the interconnection between macroscope, microscope and symbolic levels needs to be sought to provide better understanding and positively influenced to student formation. The contextualization of knowledge proved to be a useful tool, since it aroused student's interest in better understanding how it was possible to associate chemistry seen in the classroom with the processes and chemical phenomena that occur in everyday life.

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INTRODUCTION

Chemistry studies the composition of matter, its constitution and the transformations it undergoes, actively participating in the scientific and technological development of humanity (Buonfiglio, 2011). In the school context this science can contribute to broaden the understanding of nature and technological processes by enabling students to develop skills such as being able to argue, think critically, issue opinions and propose solutions (De Oliveira et al., 2015; Sebastiany et al, 2015). However, often this same knowledge when approached in class is reduced to the resolution of exercises in which the student learns a certain concept solely to apply it in activities proposed by the teacher (De Oliveira et al., 2015; Guimarães, 2009). To approach chemistry in a strictly conceptual way usually results in the disinterest of the subject by the students and also makes the learning process extremely theoretical and often distant from the contextualization with daily life. The link between the concept approached in class and its application outside of it ends up not being generated, which in turn makes learning Chemistry uninteresting. In this context, it is recognized by some researchers in the teaching field that the lack of connection between what is taught in the classroom and the student's experience outside of it (Pozo; Crespo, 2000; Sobes; Vilches, 2000; Acevedo, 2004, Guimarães, 2009; Sebastiany et al, 2015) makes it difficult for the student to perceive an interconnection between knowledge and its practical reality in everyday life and that as a negative result he ends up seeing Chemistry as something unrelated to the environment in which he lives (Guimarães, 2009; Villas-Boas et al., 2010; De Lima; Alves, 2016; Sebastiany et al., 2015). Which is actually a paradox, because Chemistry is present in several scenarios of the environment in which the student interacts daily (Da Silva; Da Rosa, 2013; Chacon et al., 2015).
Thus, the challenge of integrating conceptual teaching and experimentation is constant and requires solid and prior planning by the teacher. For Silva and Machado (2008), learning chemistry has become very difficult for our students and probably one of the causes of this difficulty is associated with the lack of a didactic conception capable of promoting the association between the theoretical and practical aspects addressed in the discipline. According to Alves (2007), when only theoretical chemistry classes are used, they become monotonous, making it difficult for students to understand what generates disinterest in the content being taught.

Alberti and collaborators (2015) also emphasize that when learning is significant it alters cognitive structures of the one who learns, modifying pre-existing concepts and promoting new connections between concepts. Another aspect to be considered is that teachers often show no interest in using experimental classes as learning tools (Sebastiany et al., 2015), since many schools sometimes do not have appropriate physical space and if they do, the difficulties come up against the lack of equipment, glassware or reagents (Calil, 2009). Simple experiments, with accessible materials being well planned, can contribute to the active learning of students, besides awakening a taste for research and reverting the picture of monotonous and essentially expository classes generally used in the teaching of chemistry. For Galiazzi and Gonçalves (2004) the inexistence of a laboratory at school is not a justification for the predominance of the expositive classes. The use of alternative materials can, according to the authors, supply a great part of the needs related to their lack, making the teaching and learning process more profitable. Many of these experiments can be developed in the classroom itself in order to involve the effective participation of the students, arousing their curiosity for the study of chemistry (De Lima; Alves, 2016). An interesting alternative to the approach of teaching Chemistry using active learning can be done through problem situations. According to DeBoer (2006) investigative teaching has as main objective to involve students in investigations, questions and scientific problems so that they solve activities under the supervision of the teacher.

Thus, the teacher in a first moment acts as a mediator creating and presenting to the students problem situations. As the class develops he can act to guide the students, but in no way should he influence more directly in solving the problem. Lima et al. (2008) considers the investigative activity as a strategy of diversification of the teaching practice, but it is centered on the student so that it can allow the development of student autonomy. According to the author, the proposed activity should allow students to have the opportunity to expose their ideals regarding the subject (Lima et al., 2008), which will lead to the construction of knowledge in a more autonomous way by the student so that he can reflect, discuss, report and argue on the subject (Azevedo 2004; Poletto, 2017). Thus, the objective of this work was to present the result of an investigation on the learning of chemical concepts from workshops held with high school students evaluating the contribution of the use of problem situations in the process of understanding chemical phenomena. The experiments were conducted using mostly simple, inexpensive and easy to obtain reagents.

METHODOLOGY

The chemistry workshop was held as part of the UCS Open Doors project, where the University of Caxias do Sul opens its doors so that high school students from the region's schools, as well as the community in general, can get to know the different teaching, research and extension environments that make up the university infrastructure and qualify the institution's actions. The activities were proposed to high school students from a private school in the city of Bento Gonçalves/RS. Three classes were attended, one consisting of 14 students from the first year of high school, another with 23 students from the second year and finally, 17 students from the third year, totaling 54 students. The workshop had demonstrative character.

The intention was to present the practice through a question related to the problem-situation to stimulate the students' curiosity and then show the phenomenon to the students. From the visualization of the experiment, it was aimed to verify if they were able to explain chemically what they had just observed.

In the workshop the proposed problem situations were the following:

Why are the acids dangerous?

Reagents: H_2SO_4 concentrate and Sugar

Glassware: Spatula, becker

Procedure: Put the sugar in the becker and then add the acid.

Fire is fire! Or is it magic?

Reagents: Candle and matches (or an automatic lighter)
Ask students to film the experiment.

Procedure: light the candle and then blow it out. Place the lit matchstick near the smoke released by the extinguished candle.

Fire in the water? Is it possible?

Reagents: Lighter fluid, Water and Phosphorus

Glassware: graduate cylinder

Procedure: Before the practice: Put some of the lighter fluid in the cylinder, shake it and make the fluid stay on the glass walls. At the time of the practice: put water in the cylinder. Shake and then fill the cylinder to the edge with water. Set fire to the edge of the glassware.

Fire in the water? Again?

Reagents: Sodium metal and water

Glassware: Knife, tweezers and becker

Procedure: perform the procedure in the chapel. Put some distilled water in the becker. Cut a piece of metallic sodium. Place the metallic sodium in direct contact with the water.

Sugar is fuel for rocket?? Seriously!

Reagents: Sugar and Potassium Nitrate

Materials: long matches or automatic lighter.

Procedure: perform the experiment outdoors. Place a sample of the sugar and potassium nitrate mixture on a stone or asphalt floor and set fire.

RESULTS AND DISCUSSION

In general, this work aimed to show high school students how it is possible to contextualize the chemistry learned in class with everyday life. The selection of contents was made based on the high school curriculum, that is, it contemplated contents present in all high school grades.

Why are acids dangerous?: The dehydration of sucrose by sulfuric acid, which many call "sugar monster", occurs because sulfuric acid is a powerful dehydrating agent. When sulfuric acid comes into contact with ordinary sugar, that is, sucrose, the acid removes hydrogen and oxygen atoms from sucrose, forming water, and consequently carbonizing the sugar, according to the reaction presented in Equation 1. As the reaction unfolds, the sugar darkens, which is indicative of the formation of solid carbon. The heat released in the reaction is enough to vaporize the water formed, which by leaving the becker creates empty spaces inside the carbon mass formed, which allows the volume to increase, resulting in the "sugar monster". The process is exothermic and besides the water vapor releases toxic vapors, so it should be performed by a teacher or technician who knows safety standards and in a chapel with a gas exhaust system

$$C_{12}H_{22}O_{11}\ (s) \xrightarrow{H_2SO_4} 12\ C\ (s) + 11\ H_2O\ (aq) \qquad (1)$$

With this practice several concepts were approached, such as chemical reactions, evaporation, exothermic and endothermic processes, handling of laboratory glassware, safety standards and also the correct way to add acid to water. The students of the three high school grades were able to describe well the phenomenon of chemical transformation. However, when asked how to equate the chemical reaction, only the third grade students were able to correctly assemble the reaction described in Equation 1. This result demonstrates that many students still need to better develop the association between the experimental result and its chemical representation, that is, the symbolic representation, since they all said they observed the formation of carbon and the release of water vapor, which are the two products obtained in the chemical reaction.

According to Pinto (2012) the teaching of chemistry satisfactory will occur when its teaching is able to show the student, in a clear, objective and interesting way, the intimate relationship between the theoretical knowledge and the experiments that led scientists to the discovery of this knowledge. Another aspect that must be associated with the learning of Chemistry is that it is a science of daily life that is intrinsically linked to the actions that are executed daily not only by great scientists, but also by the students themselves in daily tasks that contemplate, for example, the preparation of food and beverages. Pinto (2012) still emphasizes that through practical classes it is possible to give students the opportunity to know Chemistry better, discovering the close relationship of this science with nature that surrounds it.

Fire is fire! Or is it magic?: A candle and matchsticks are very simple tools, but they can serve to explain very well how the combustion reactions that occur with any kind of fuel, such as gasoline and ethanol, work. In this practice the students were asked to film the experiment. The candle was lit and soon after extinguished and the moment the phosphorus flame came into contact with the smoke released by the burning, the candle was lit again without the phosphorus stick flame touching the wick, as can be seen in Figure 1. The candle is made of paraffin, i.e., a hydrocarbon. As the combustion occurs carbonic gas and water are formed, but during the burning the paraffin evaporates and comes out together with the gases from the combustion. When the candle is extinguished a white smoke is formed. This smoke contains condensed paraffin. When the toothpick flame is put in contact with the smoke, the paraffin combusts acting as a bridge to the wick, lighting the candle again. In this practice the students of the three high school grades concluded, after watching the video recorded by them, that combustible gases present in the smoke were responsible for lighting the candle again. However, when asked who acted as the fuel and who was the oxidizer in this reaction, the first-year high school students had some difficulty in answering the question correctly, while the other grade students were able to answer correctly and even gave as examples the combustion reactions that occur in internal combustion engines, such as cars and trucks, evidencing the understanding and daily application of the phenomenon observed. It was evident that the previous knowledge of the students about the combustion reactions in automotive vehicles was essential to explain the problem situation. The students were able to identify the situation, besides correlating this situation to their previous knowledge, allowing them to work with day-to-day issues, articulating the concepts of daily life with scientific concepts (Goi; dos Santos, 2017). For Azevedo (2004) in the investigative activities, even if demonstrative, it is necessary the active involvement of students, seeking to discuss from their previous knowledge and even exploring phenomena before introducing them theoretically. This, in turn, ends up valuing not only the contents and concepts, but also developing autonomy and logical reasoning.

Fire in the water? Is it possible?: The main concepts approached in this practice were density, polarity and solubility. Lighter fluid consists of a series of apolar hydrocarbons that do not generate a heterogeneous mixture when added to water. However, a small amount of lighter fluid (about 5 mL in a 100 ml solution) was added and so students could not visualize very well the separation surface between the solute and the solvent. Cigarette lighter fluid has a lower density than water and thus constitutes the upper phase of the mixture. When a fire was set on the edge of the cylinder the fluid began to burn and a flame was produced just above the surface of the liquid. The first reaction of the students was astonishing, but soon after the students of the three grades found that some compound was mixed with water. Both first and second grade students responded that ethanol had been mixed with water, indicating that they lacked clarity in the concepts of polarity and solubility. When asked by the teacher if water and ethanol were mixed, the second year students were able to show that they both make a homogeneous mixture and this way, this mixture could not catch fire. However, the first year students were not able to evidence that it was a heterogeneous mixture and the deeper intervention of the teacher was necessary to clarify the phenomenon.

In a second moment, the second year students answered that gasoline could have been added to water. This response evidences that these students began to correlate polarity with solubility, probably based on the negative response given by the professor when they cited the addition of ethanol. Since the density of gasoline is lower than the density of water, this response is also consistent when considering the third concept evaluated in this practice, i.e., the density. The third grade students, right after observing the experiment, responded that it was a heterogeneous mixture and began to look for a surface of separation between the two liquids, which indicates a greater understanding of the chemical phenomenon observed

Figure 1. Student lighting the candle at a distance

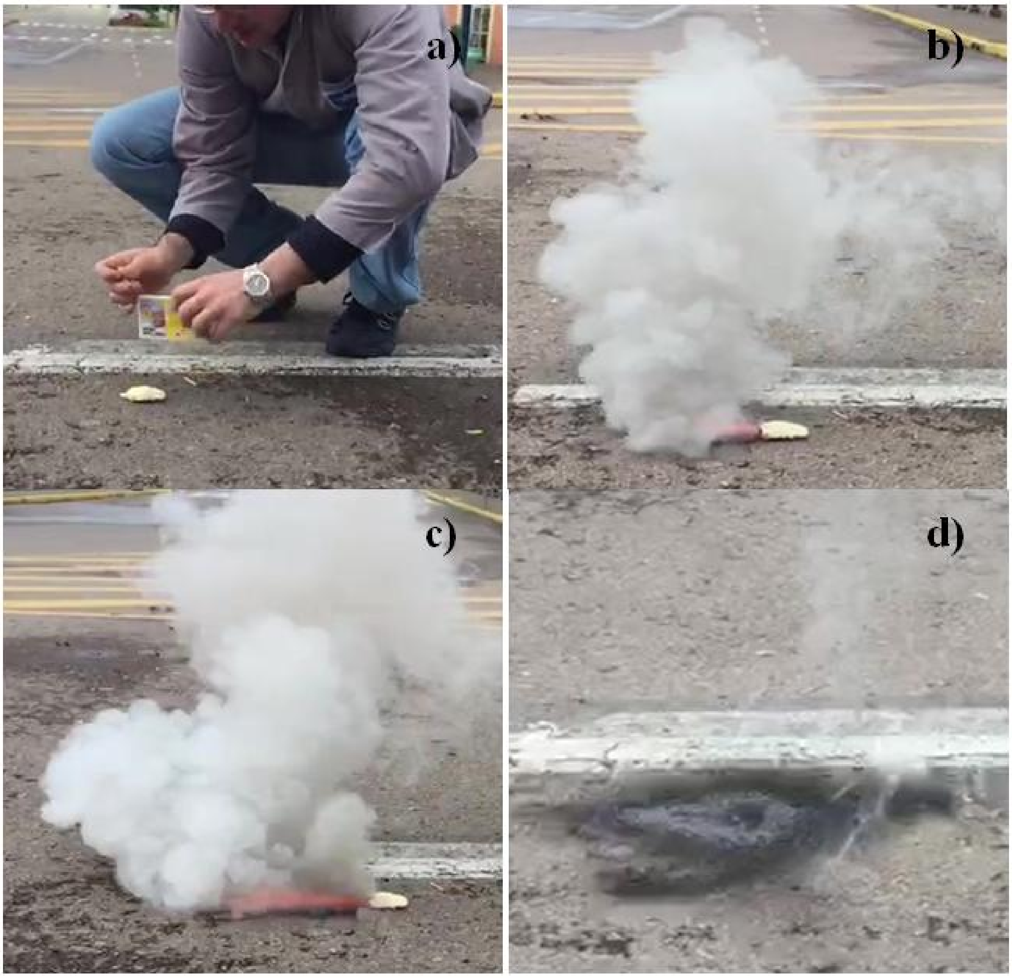

Figure 2. Process of firing rocket fuel before ignition (a), 1s after ignition (b), 2s after ignition (c) and 5s after ignition (d)

in relation to the second grade students. When asked by the teacher what liquid could have been added to water, some answered gasoline, but most answered that it could be an apolar liquid, evidencing the understanding of the experiment. Finally, the third grade students were asked which compound could constitute the superior phase of the mixture and the answer in unison was "the lightest", proving that the interrelation with the density of the liquids was also assimilated. The didactic-investigative character that the problem situations provided to the students, besides generating amazement and curiosity, led the students to ask themselves the "why" of that phenomenon, stimulating them to discover and understand the chemical contents approached (De Lima; Alves, 2016). Cardoso and Colinvaux (2000) evaluate that with the participation of the teacher the student will be able to discuss their doubts and observations, generating a relationship of greater confidence between teacher and student that will act as a facilitator of the learning process.

Fire in the water? Again?: The addition of metallic sodium in water is a practice widely used by chemistry teachers since some sparks can be produced due to the large amount of energy released in the reaction. The reaction that occurs is represented in Equation 2.

$$2\ Na\ (s) + 2\ H_2O\ (aq) \rightarrow 2\ NaOH\ (aq) + H_2\ (g)$$

The concepts worked on in this experiment were indications of the occurrence of chemical reaction, reactivity, valence electrons, electronic distribution and chemical bonds. The students of the three grades observed the formation of small sparks, as well as the release of bubbles, soon associated by them with the release of gas, besides the release of heat and they were able to associate these evidences with the occurrence of a chemical reaction. However, no student could explain clearly why sodium has such a reactive behavior in water.

The concepts associated to this practice were difficult to understand by the students. With the intervention of the teacher, questioning in which group the sodium element is located in the periodic table and also with the help of a periodic table only the third year students were able to understand by themselves the chemical explanation for the phenomenon they observed. The reports of some third-year students after receiving a periodic table were:

- Of course sodium is in group 1! (student A)
- What do you mean? (student B)
- Yes, he has an electron on the last layer, you see? (student A showing the periodic table to student B)
- Oh it's true, he wants to donate this electron to be stable. (student B)
- Of course! It makes him stable. (student C)

The greatest difficulty presented by students in this practice may be associated with the difficulty of understanding the three levels of chemistry. Chemistry can be understood as a science that has three levels of representation: the macroscopic, the microscopic and the symbolic (Pauletti et al., 2014). The macroscopic level corresponds to observable chemical phenomena, while the microscopic level concerns the movements and arrangements of molecules, atoms and electrons. While the symbolic level involves the formulas, equations and chemical structures. The students were able to understand the macroscopic level, but could not associate it with the microscopic level, thus making it difficult to understand the experiment. Sirhan (2007) points out that chemistry is an abstract science and that a peculiar difficulty for both teaching and learning can occur when integrating and transitioning between the macro, micro and symbolic levels. Rocha and Cavicchioli (2005) also report the difficulty students have in understanding Chemistry through the microscopic world and suggest the need for integration between the micro and macro levels so that students can properly visualize and interpret the chemical content addressed.

Is sugar rocket fuel? Seriously!: The mixture of sugar and potassium nitrate is generally used as a solid propellant, i.e., fuel for mini rockets in amateur rocket study groups (Foltran et al., 2014; Baldissera et al., 2016). Sugar (sucrose: C12H22O11) acts as a carbon source for the combustion reaction, while potassium nitrate, which can be replaced by potassium nitrate-based fertilizer, is the oxidizing agent. The main objective of this practice was to show the students that Chemistry is not a distant science from everyday life practiced in large research centers using sophisticated equipment and being exercised by renowned scientists, but it is inserted in our daily lives, however abstract it may seem to high school students. Figure 2 shows the process of burning the fuel in several stages after the ignition of the propellant. The astonishing reactions with the burning process went through the three classes. Many students could not believe that a mixture of sugar and potassium nitrate could produce a fuel capable of propelling a rocket. Here is the account of some first-year students, right after the teacher performed the third repetition of the experiment:

- It is not true! Do it again! (student A)
- I saw it three times and it was really cool! (student B)
- I don't believe you! I mean it! (student C)
- People, Chemistry is in our daily life, we just need to see it. (teacher)
- Professor, but how does it work? (student D questioning how the combustion process occurred).

The questions about how the propellant burning occurs and how this burning can serve as propulsion for rockets were numerous and came from all the classes evaluated. In this sense, Benite and Benite (2009) state that the use of the experimental class will only be valid if it awakens in the student the will to seek the understanding of the scientific theories that led to that phenomenon. Many times, the search for this understanding is intrinsically associated with perceiving the practical application of this knowledge, as is the case of rocket propellants. In this way, this practice has contributed to the teacher's full performance of his function, enabling the student to reflect and give practical meaning to what he has learned, based on daily applications of Chemistry. Ritter and Villas-Boas (2015) state that both Chemistry and Science taught at school should facilitate the understanding of students in relation to the experiences related to the phenomena that surround them in their daily lives, so that Chemistry and Science seen in school bring technological knowledge closer to everyday life, filling the gap left by teaching only based on exposure classes.

Conclusion

The methodology employed in this study was able to stimulate the active participation of the students, arousing their curiosity and interest, providing a motivating environment rich in new and challenging situations. This environment facilitated the development of the students' autonomy through the formulation of questions and hypotheses identifying the problem to be solved based on the observation of the chemical phenomenon. The use of problem situations enabled the student to participate actively in their learning process, abandoning the passive posture that many adopt in the exposure classes. The contextualization of knowledge aroused the interest of the students in knowing how it was possible to associate the chemistry seen in class with the processes and phenomena that occur in daily life. Chemistry can be better understood to be seen as a visual science, but methodologies that allow the exploration of this science in a visual dimension must be adopted from the use of multiple teaching strategies. The interconnection between the macroscopic, microscopic and symbolic levels needs to be sought. Thus, it is not only through experimentation that Chemistry will be better understood. Experimentation has contributed to an association between theory and practice, aiming that theory is always covered with meaning and contextualization.

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