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TEACHING CHEMISTRY: A RELATIONSHIP BETWEEN THEORY AND PRACTICE

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Abstract: This article proposes a comparison between a theoretical and experimental class referring to the assembly and operation of a galvanic battery, for students of the third grade of high school. There were learning issues in the two researched modalities and the importance of laboratory classes. The presence of chemistry in the lives of individuals and its interaction with the environment infer the importance of its learning for the formation of the citizen. Therefore, chemistry classes at school are important for the relationship between the reality of students and social chemical themes. Although easy access to information is a characteristic nowadays, providing reflections, critical analysis and developing ethical values in students based on chemical concepts is a task of the school and the teachers. As a mixed methodological aspect, four classes from the third grade of high school were selected as a sample, named A, B, C and D. Classes A and B were separated from classes C and D and a questionnaire was applied to compare results and propose discussions. The supremacy of the experimental activity was observed when compared to the theoretical one. The resignification of concepts and the mobilization of skills and competences during an investigative experimentation confirms its importance as a methodology to generate learning.
Keywords: teaching chemistry, theoretical class, experimentation.

INTRODUCTION

Chemistry is intertwined with our daily lives and its absence would have deprived civilization of scientific and technological advances, hence its importance over time. In this sense Silva and Bandeira state,

> Chemistry is at the base of economic and technological development. From the steel industry to the information technology industry, from the arts to civil construction, from agriculture to the aerospace industry, there is no area or sector that does not use any input that is not of chemical origin in its processes or products. (Silva and Bandeira, 2006).

The constant presence of chemistry in the lives of individuals justifies the need for it to be presented to students as a science that makes it possible to expand the frontiers of knowledge and allow its interaction with the environment. The need arises, then, for the teaching of chemistry to be committed to citizenship. In this sense, Santos and Schnetzler (1997, p. 47) mention that "it is necessary for citizens to know how to use substances in their daily lives, as well as to critically position themselves in relation to the environmental effects of the use of chemistry".

A more committed education, which contributes to the understanding of knowledge, which enables students to make decisions and improves the quality of life is a necessary reflection in chemistry classes. Scientific literacy as knowledge, which allows men and women to read the world in which they live, becomes a major challenge. Chassot (2016, p. 14) emphasizes:

> I repeat that I am not unaware of the existence of a specific statute for the chemical language, but I allow myself to emphasize, once again, the need to translate this language many times to facilitate the understanding of scientific illiterates that we need to literate[..] There is something which is still paradoxical, on the threshold of the 21st century: more and more we can consider Science divided into applied and that which has not yet been applied; but the intervals are getting smaller and smaller in which the transformation from pure to applied Science takes place. The reasons for the reduction of this gap are complex, involving issues of a social and epistemic nature. When a curriculum aimed at the integral formation of the citizen or citizen is postulated, this refers to a citizen or a full citizen capable of understanding the rapid transformations of the modern world.

The school needs to introduce students to social chemical themes, through concepts that allow them to make reflections and critical analysis, so that they become responsible citizens. This way, the development of ethical values is a premise for responsible and sustainable education. Considering that the current moment is characterized by the speed in obtaining information, it is up to the teacher, whenever possible, to select and use them, as a way of bringing students closer to their reality and favoring the redefinition of concepts.

The construction of knowledge is based on significant learning. According to Ausubel apud Moreira (2006, p. 14), the theory of meaningful learning "is a process by which new information is related, in a substantive (non-literal) and non-arbitrary way, to a relevant aspect of the individual's cognitive structure".

Among the many topics covered in chemistry classes, one of them is basic and extremely relevant: batteries. This is because students constantly use electrical and electronic equipment, which need them as a source of energy, which is not a guarantee that they know how they are made, how they work and how to dispose of them correctly after use. So, if bringing students closer to their reality is essential, presenting this device, which converts chemical reaction into energy, is valuable. Therefore, comparing the form of presentation, using a theoretical class or an experimental class in the teaching of chemistry, with regard to understanding the functioning of a battery and its implications, was the core of this research.

Although many students consider chemistry to be very abstract, it is essential, whenever possible, to bring the chemical concepts worked in the classroom to the students' experience. Does the way a concept is presented to students infer the learning outcome? What makes learning easier: a theoretical class or an experimental class on a certain subject? Seeking to answer these questions, the present study was carried out, which will be explained in the methodological aspects and discussions.

METHODOLOGICAL ASPECTS

As for the approach, this research is mixed, qualitative, applied in nature, bibliographic and exploratory; and quantitative, through the application of a questionnaire with multiple choice questions.

According to Villaverde et al. (2021, p. 34), "research with a quali-quantitative approach presents a sense of intercomplementarity between the numerical data provided by the quantitative research and the analyzes and reflections obtained through a quantitative research". While quantitative research is based on deductive reasoning, rules of logic and measurable attributes of human experience, in turn, qualitative research emphasizes dynamic and individual aspects of human experience, according to the context of those who experience the phenomenon. (p. 36)

The exploratory nature allows future investigations, based on criteria, techniques and other methodological assumptions, which may be adopted considering the research object (Schwalm, 2021).

Thus, four classes of the third grade of high school were chosen, two of which were researched after an expository class on galvanic batteries, and the other two after its assembly in the school's laboratory. Comparing and analyzing the results regarding the understanding of the subject, unit, potentials, disposal, assembly and validity of the laboratory classes were objectives of the study in Question.

The study was carried out in 2019. According to the sample already mentioned, four classes of the third grade of high school were used in a private school in Caxias do Sul/RS (called classes A, B, C and D), and a questionnaire with 16 closed questions was applied, involving the subject batteries and some correlations thereof.

The group of students researched was composed of students of one of the authors of the research, and letters were assigned to identify each one: A, B, C and D.

Currently, most electronic equipment uses batteries as energy sources. It follows from this the choice of the base subject to be used, in order to allow comparisons between the expository theoretical class and the investigative laboratory class.

Classes A and B were proposed to build a galvanic battery in the school's laboratory, using copper and zinc electrodes. For this, all the necessary material was left on the bench, so that each group could use it as needed. A sheet with instructions was handed out, as shown in Table 1 below, and the teacher gave instructions on the experiment. The students had autonomy in the assembly of the groups, and the teacher was only with the role of mediator and observer of the experimentation, making provocative interferences when perceiving discussions in the groups about the practice. Students were encouraged to debate among themselves and between groups when they observed something different in the functioning of the stack or in its failure.

To measure the voltage generated by the batteries, voltmeters were made available to the students, and it was suggested that they carry out different tests, using LED lamps, clocks and motors. They were also asked to use the resource of associating the batteries between the groups if they observed the non-functioning of any of the objects, in addition to testing the voltage generated. Discussions were encouraged between the groups, based on the results obtained and notes on possible causes, according to the observations. After carrying out the experiment, classes A and B answered a questionnaire containing some questions about the proposed theme.

Classes C and D stayed in the classroom, where, in an expository way, they received information from the teacher about the material, assembly and operation of a galvanic battery with copper and zinc electrodes. Oxidation and reduction potentials were explained, a table with values was presented and, theoretically, the entire functioning of a galvanic cell was explained, writing the poles, the semi-equations, the global equation, etc.

After the lecture, the same questionnaire applied to classes A and B was applied to classes C and D, as a way of comparing the results.

RESULTS AND DISCUSSIONS

As a result, a sample of 98 students was obtained, aged between 16 and 19 years old (one 16-year-old student, 53 17-year-old students, 43 18-year-old students and one 19-year-old student), 48 male and 50 female.

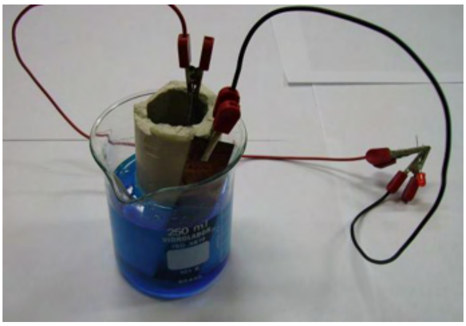
The questionnaires were answered by 98 students, 51 of them (sum of classes A and B) answered after assembling the stack in the laboratory and 47 (sum of classes C and D) after the lecture on the subject. The questions that were part of the questionnaire were analyzed, drawing a comparison between the answers of classes A and B, who carried out the experiment, and classes C and D, who only saw the subject in a theoretical way; according to the questions and analyzes reproduced below.

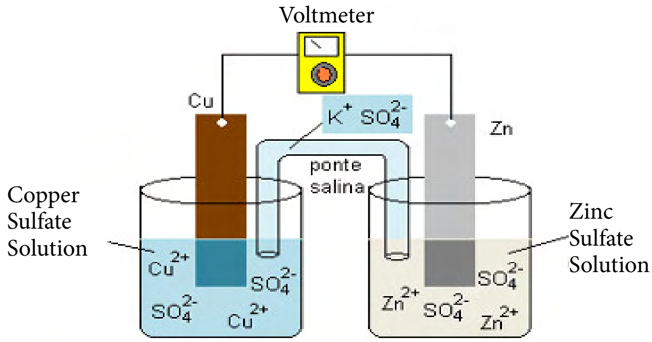
It was observed that 73% of the students were able to conceptualize galvanic battery after the experiment, and this percentage is reduced by 22% when compared to the lecture (graph 1). Likewise, the percentages also differed in terms of not being able to conceptualize galvanic battery. With experimentation, 25% of the students stated that they do not know

DANIELL'S STACK

The first device that harnessed the energy of redox reactions to generate electricity was the Alessandro Volta battery. It was made in 1800 and was formed by discs of different metals, such as zinc and copper, interspersed and connected by a conductive wire, in addition to a disc moistened in brine.

In 1836, English chemist John Frederic Daniell (1790-1845) perfected Volta's pile, making it less risky. This new pile came to be known as the Daniell pile. Daniell's cell consisted of two electrochemical semi-cells or semi-cells. The first was formed by a zinc plate dipped in a solution of zinc sulfate (ZnSO4) in a beaker, and the other was formed by a copper plate dipped in a solution of copper II sulfate (CuSO4) in another beaker. These two plates were interconnected by a conductive copper wire. In addition, the two solutions were connected by a tube that contained an electrolyte solution, i.e., a salt bridge.





REDUCTION POTENTIAL	Cu^{2+} = + 0,34 V	Zn^{2+} = - 0,76 V
Reduction half-reaction		
Who oxidizes and who reduces?		
Half-reaction in the half-cell		
Identification of battery poles		
Observation of the plates		
Observation of [ions] in the solution		
Ion flux across the salt bridge		
Electric current flow		
stack ddp		
Overall stack equation		
Official representation of the pile		
Notes	**Quizz** a) When reversing the poles, did the clock work? Why? b) Why were 2 batteries used in series? c) What was observed when turning the clock on only one battery? Explain what you observed. d) Why must blades be sanded?	

Table 1. – Instructions for building a galvanic battery

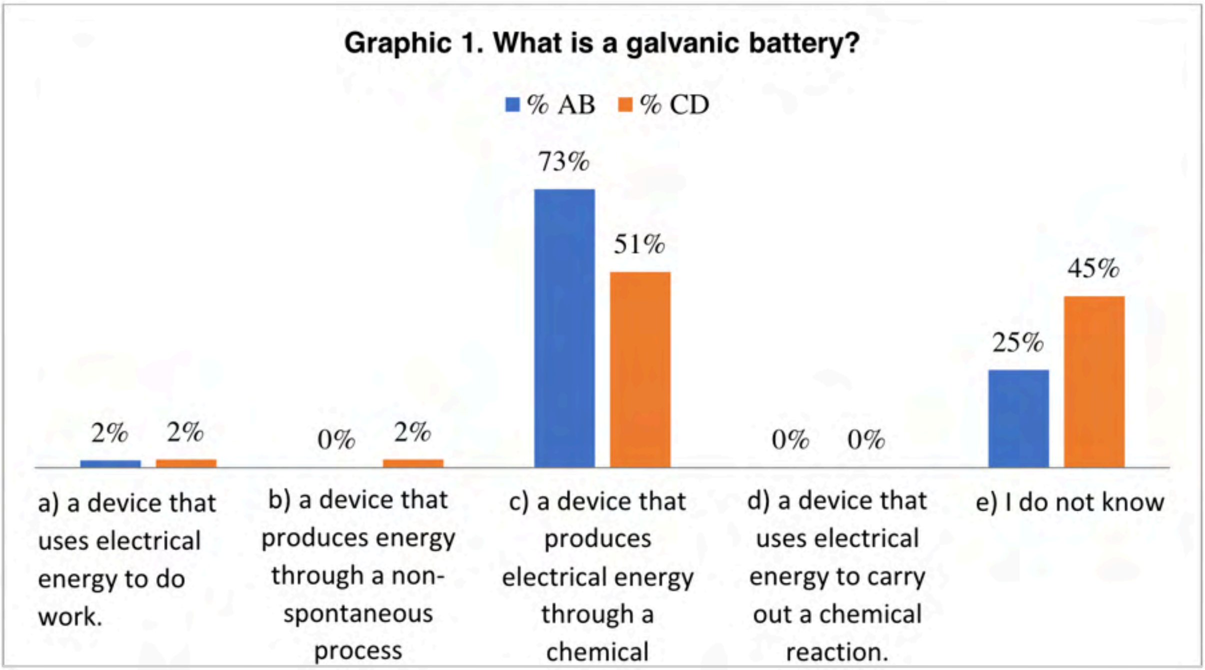


Figure 1. – Question 1.

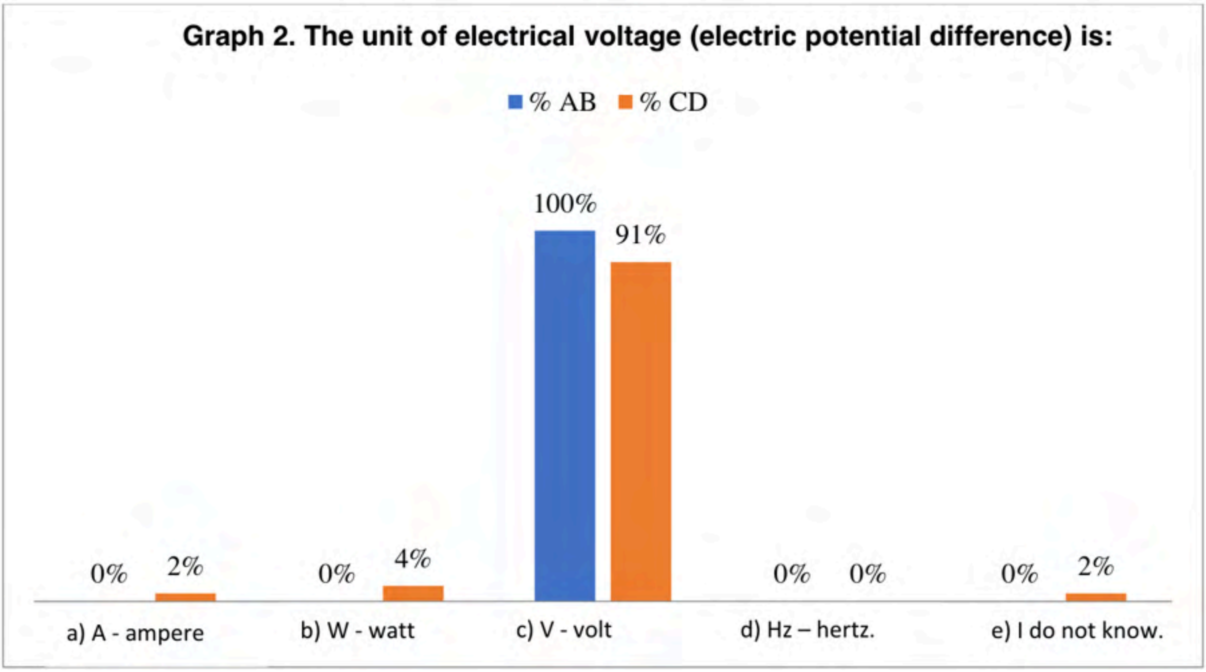


Figure 2. – Question 2.

how to conceptualize, however, this value rises to 45% in the case of the theoretical class, which showed that the construction of the concept is favored by the process that occurs in an experimental class, and corroborated the idea that experimentation contributed to the construction of concepts.

Using experiments as a starting point to develop understanding of concepts is a way of getting students to participate in their learning process, leaving a passive posture and starting to act on their object of study, relating the object to events. and looking for the causes of this relationship, therefore looking for a causal explanation for the result of their actions and/ or interactions. (Trivelato e Silva, 2016, p. 74).

When comparing the experimental and theoretical classes, it was noticed, with regard to the tension unit, that the practical class allowed all students to identify the correct unit. According to graph 2, in the lecture, 91% of the students knew how to recognize the correct unit, 6% used the wrong unit and 2% could not say. All the students who recognized the tension unit in the experimental class confirmed its importance in understanding the subject. It was also possible to consider that, in the experimental class, they handled a voltmeter and had discussions about the measured values, which perhaps facilitated understanding. In the theoretical class, only the instrument used to measure the potential difference was mentioned. The importance of carrying out practical activities was confirmed, with the active participation of students in their execution, which allowed for the discussion of ideas and the construction of investigative hypotheses.

> [...] experiments will make no sense to them if it is not through their written reconstruction, thanks to which both the process and the resulting "world view" will make sense. Thus, discussing with others about the experiments, writing about them in a reflective way and building the appropriate signs (tables, graphs, symbols, words) reaching a consensus on their meaning will be the "method" that leads to the construction of school scientific knowledge. (Izquierdo, Sanmartí and Espinet, 1999, p. 50).

It was observed, in graph 3, that the students who carried out the experiment in the laboratory and made the measurements (class A and C), in their entirety, stated that the value is equal, greater or that it was not possible to say because it depends on the conditions in that the experiment was performed. Although it cannot be said, because the questions in the questionnaire were closed, this may reflect what happened in the practical class. The fact that 49% of the students say that it depends on the conditions at the time of experimentation may result from the fact that they experienced equal and greater measures than the theory indicated. It was interesting to confirm that none of the students who participated in the experimental class mentioned not knowing the subject. On the other hand, students from classes C and D, who participated in the lecture, stated, in an expressive percentage of 32%, not knowing the subject. The remaining 68% divided their opinions between equal, greater, lesser and depending on the conditions.

According to the results obtained in classes A and B, who performed the experiment and were free to test, they had the possibility to reflect, compare, discuss, ponder, that is, they participated in the process; in addition to having carried out exchanges between the groups.

> A group of researchers from the Physics Teaching Research Laboratory (Lapef) at the USP School of Education presented works aimed at Elementary and High Schools, in which the experiment is always used as a starting point. The researchers report that, for an experimental activity to be considered an investigation, the student's action must not be limited to the work of

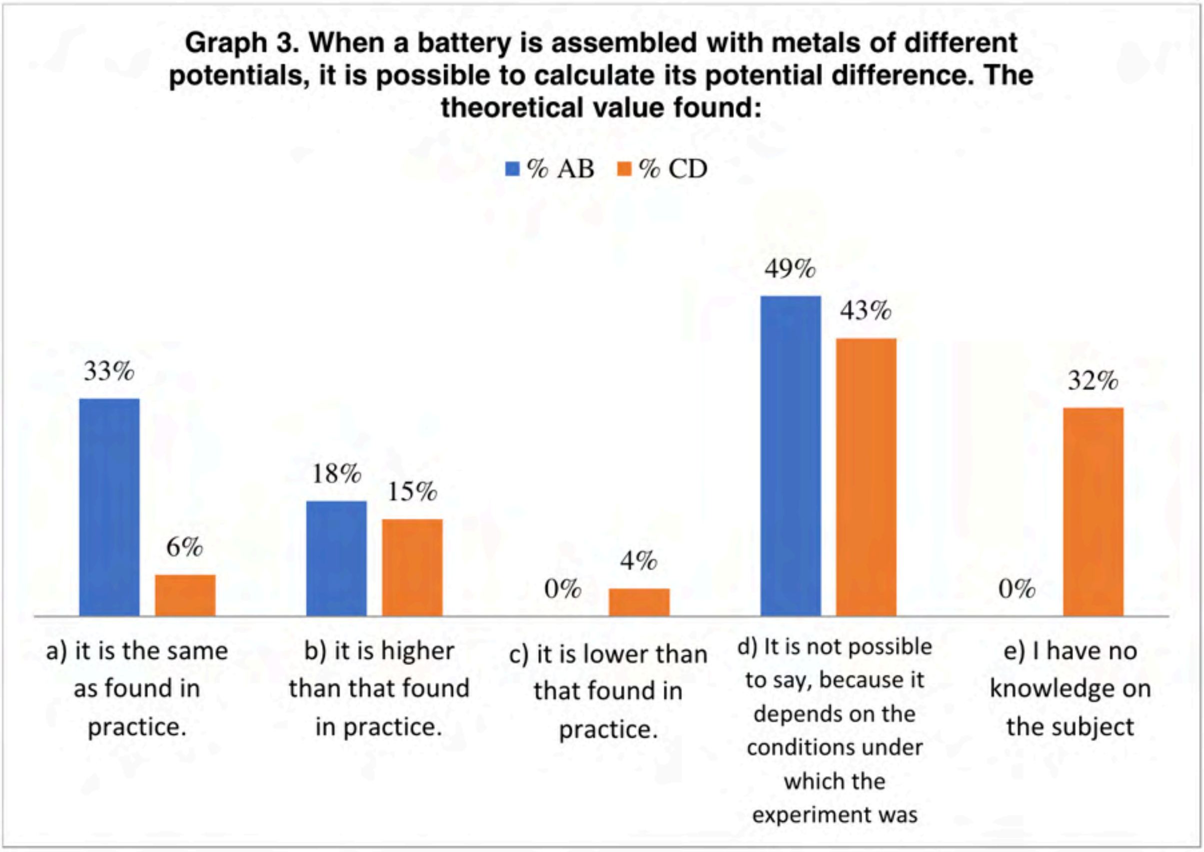


Figure 3. – Question 3.

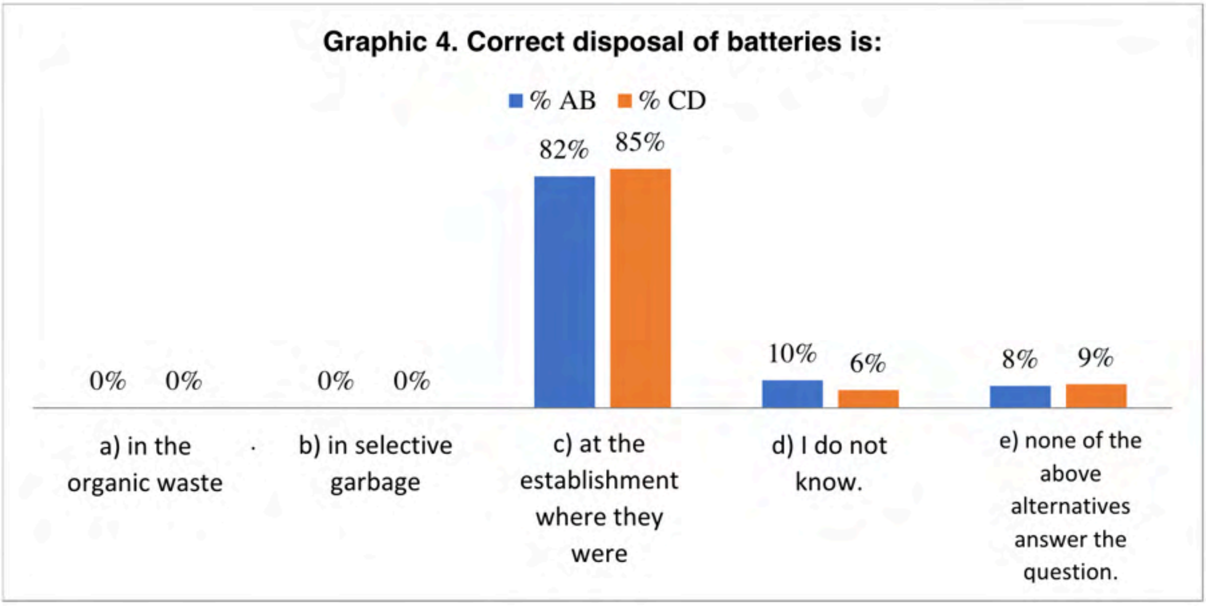


Figure 4. – Question 4.

> observation and manipulation, but must contain characteristics of scientific work, that is, reflections, reports, discussions, considerations, among others. (Trivelato e Silva, 2016, p. 74).

As shown in Graph 4, the Question became relevant to be analyzed together with the next one (Graph 5). Analyzing only this question, it was observed that most students, regardless of having taken an experimental or theoretical class, know that the disposal must take place in the establishment where the batteries were purchased, demonstrating that, in some way, they had knowledge about the subject, in line with Brazilian legislation. He hesitated to make any statement, as the questions in the questionnaire were closed, about the fact that 17% (sum of the students in the practical and experimental classes) mentioned that the correct disposal would not be in organic waste, neither in the selective nor in the establishment. where they bought it, leaving the question of where it would be correct for these students.

The relevance of the sequential Question to the number 4 was observed (graph 4). Considering that more than 80% of the students, both those who participated in the experimental and theoretical classes, stated that the correct disposal must be in the place where the batteries were purchased, it was noticed that the action does not match the knowledge. This is because 31% of the students who participated in the practical class and 43% of the students who participated in the theoretical class make the correct disposal. This revealed the need to reflect at school on the correct disposal of batteries. The information must be translated into action, and the environmental theme must be a constant in the classes. As a space for reflection and transformation of society, the school needs to provide students with experiences in which they can develop as active participants and transforming agents of society.

Attention must also be paid to the correct disposal of batteries, which is necessary to know and apply the current legislation, with the school being the appropriate place for such learning.

Graph 6 showed that, among students in classes A and B, who took the experimental class, 82% believe that assembling a battery in the chemistry laboratory allows for a better understanding of the subject, in addition to arousing their curiosity. Combining this result with the sum of the percentage of students who stated that experimentation allows for a better understanding of the subject, dissociated from the fact of arousing curiosity, it would be possible to reach a percentage of 96%, demonstrating the importance of building the stack in the laboratory for learning, regardless of of the curiosity involved. According to Silva and Bandeira (2016, p. 12 apud. Giordan, 1999):

> [...] Experimentation has the ability to arouse students' interest and it is common to hear from teachers that it promotes an increase in learning capacity, as the construction of scientific knowledge/formation of thought depends on an experimental approach and occurs mostly in the development of investigative activities.

Only 4% of students who participated in the experimental class believe that it does not help in understanding the subject, although 2% still say that the class in the laboratory aroused their curiosity.

It is important to mention that, among students who only had the lecture (classes C and D), 85% believe that assembling a pile in the chemistry laboratory allows for a better understanding of the subject, in addition to arousing their curiosity. Although the difference is minimal, it proved to be superior to the students who participated in the experimentation, which perhaps reflects the expectation about the construction of a galvanic battery. Combining this result with

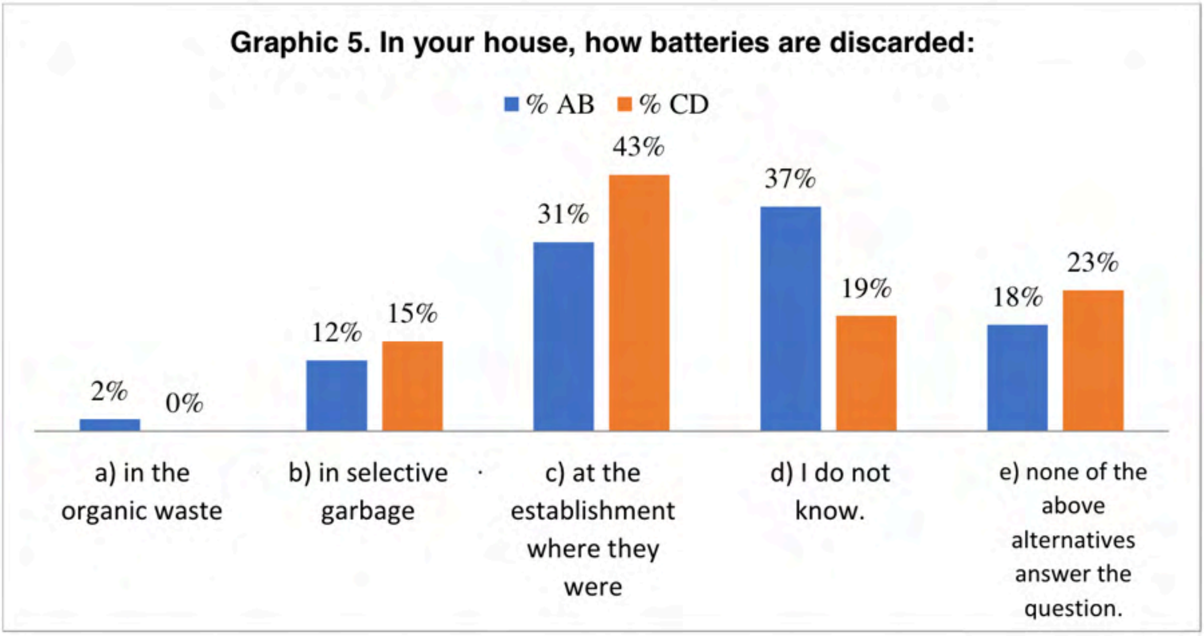


Figure 5. – Question 5.

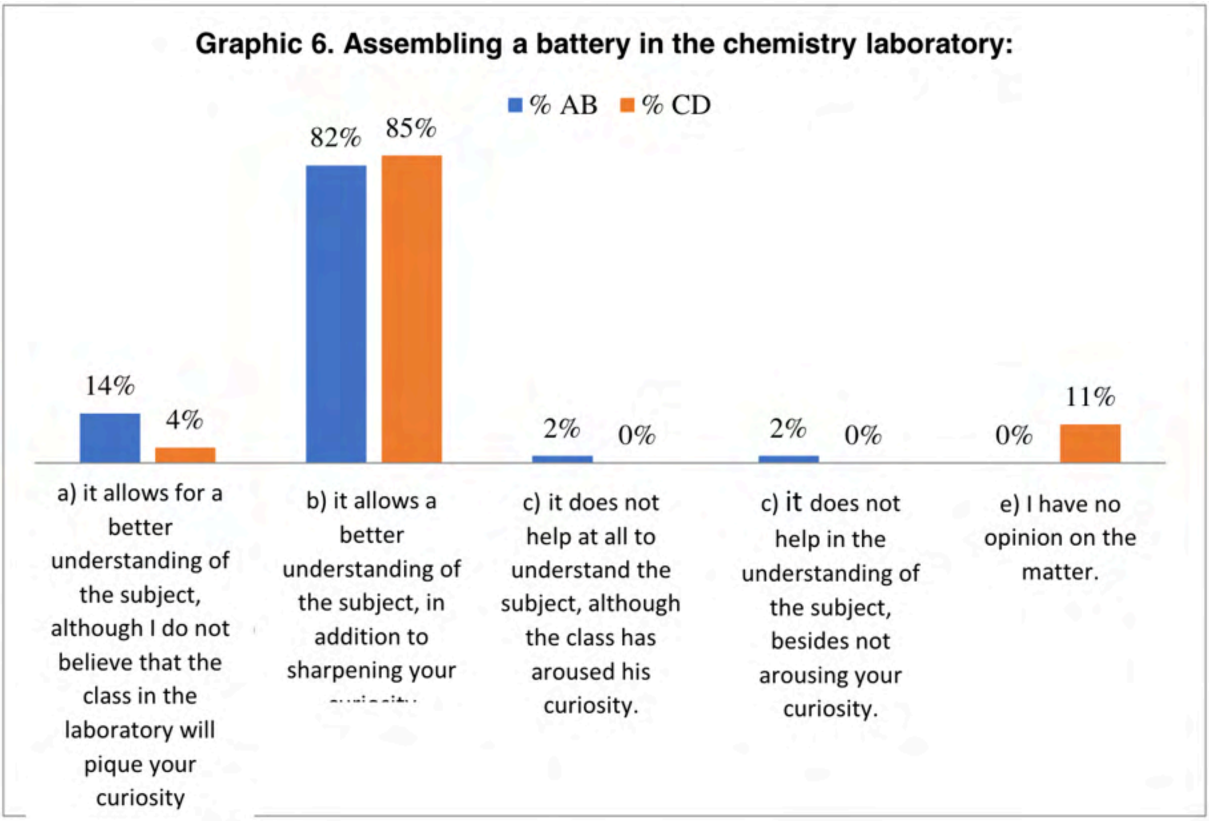


Figure 6. – Question 6.

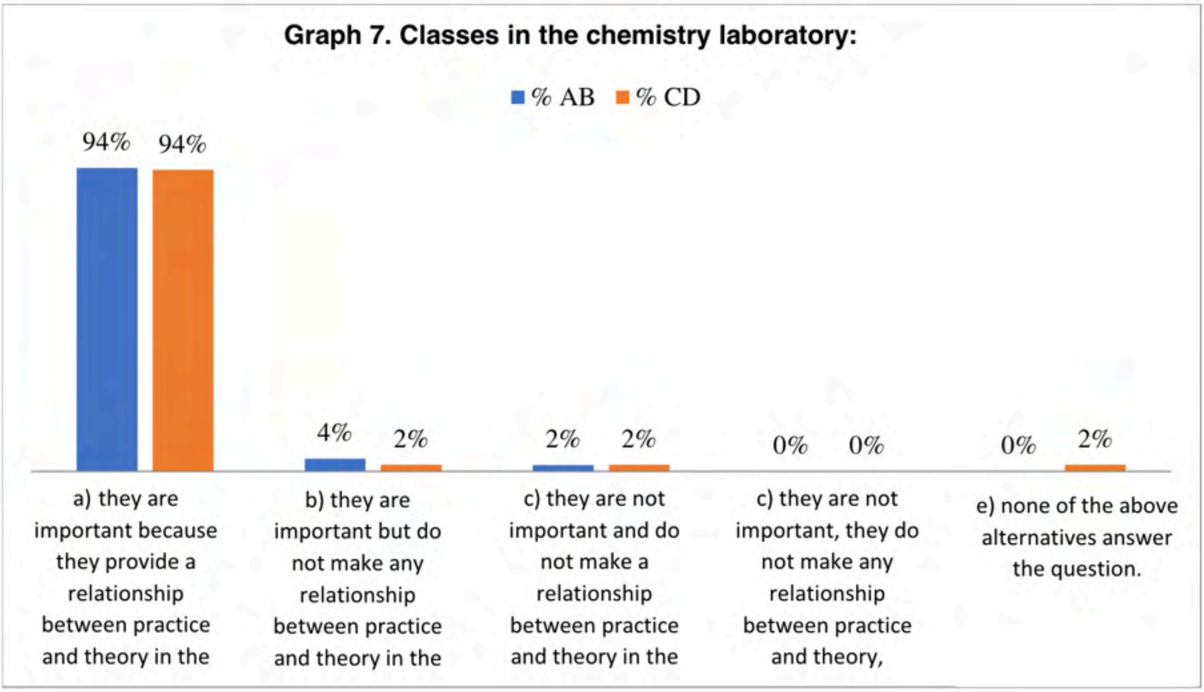


Figure 7. – Question 7.

the sum of the percentage of students who claim that experimentation allows for a better understanding of the subject, dissociated from the fact of arousing curiosity, a percentage of 89% was obtained, which is in line with this probable possibility of setting up a galvanic cell in the laboratory. It was observed that the 11% of the remaining students of the students who had lectures made it clear that they do not have a formed opinion on the subject.

In graph 7, it was noticed, with regard to the classes in the chemistry laboratory, that both the students who built the battery in the laboratory (classes A and B) and those who only had a lecture on the subject (classes C and D) stated that they believe in its importance, both with a percentage of 94%. It is important to report that, in the case of students who participated in the experimental activity, 4% consider this modality important, although they believe there is no relationship between theory and practice in the construction of concepts. Therefore, it was possible to affirm that 98% consider the classes in the laboratory important. Regarding the students who only had the theoretical class (classes C and D), 2% of the students consider them important, although they believe there is no relationship between theory and practice in the construction of concepts. In this case, 96% of the students who did not have the class in the chemistry lab to build the battery endorsed its importance. It is important to emphasize, in relation to the practical class in the laboratory, that the experimentation was investigative, as it had the active participation of the students. In this sense, Lewin and Lomascólo (1998) state,

The situation of formulating hypotheses, preparing experiments, carrying them out, collecting data, analyzing results, that is, viewing laboratory work as 'research projects', strongly favors students' motivation, making them acquire attitudes such as curiosity, desire to experiment, to get used to doubting certain information, to confront results, to obtain profound conceptual, methodological and attitudinal changes. (Lewin and Lomascólo, 1998, p. 148).

FINAL CONSIDERATIONS

The curricular component of Chemistry, by working with models and many abstractions, often distances itself from the students. However, when it is presented to students as an experimental science that allows to amplify the frontiers of knowledge, allowing interactions with the environment, it favors an approximation with the reality of the students. Therefore, this study sought to compare a theoretical class and a practical class of a galvanic battery and its implications for third grade high school students.

The accomplishment of the research allowed to perceive the supremacy of the experimental class when compared to the theoretical class. The fact that 71% of the students who performed the experiment were able to conceptualize galvanic battery and 45% could not say after having had the lecture was indicative. In the same way, none of the students who participated in the experimental class, with regard to questions 2 and 3, claimed to be unaware of the subject; among those who participated in the lecture, the percentages were, respectively, 2% and 32%.

It was also observed that, of those surveyed who performed the experiment, 73% were able to assertively conceptualize galvanic battery; 100% use the correct unit for the electrical potential difference; 96% believe in the importance of assembling a stack in the laboratory, regardless of whether it piques curiosity or not; and 94% consider laboratory classes important. These values were higher than those obtained by students in classes that had lectures, except for the question about the importance of laboratory classes, which had the same percentage value.

It was possible to affirm, then, that the experimental class made possible the interaction between colleagues, the raising of hypotheses, discussions about the different observations and measurements, proving its importance as a methodology to generate learning, because many were the skills and competences developed in this process. In this sense, Guimarães (2009) states that, "experimentation can be an efficient strategy for the creation of real problems that allow the contextualization and stimulation of investigation questions".

It is also important to note that most students, both those in the theoretical and practical classes, mentioned knowing where the correct disposal of batteries must be carried out, however, their actions do not match the knowledge presented. This is because, in question number 5 of graph 5, where students are asked about disposal in their homes, an expressive number of them (over 50% in both theoretical and experimental classes) divide their answers between: selective, organic, not know and others that are not where they bought it.

It becomes essential, then, that the school is a space for reflection, and that it provides opportunities for students to experience so that they develop as active participants and transforming agents of society. It is believed in the importance of environmental education being addressed in chemistry classes at school, in addition to the presentation of some topics related to Brazilian legislation in this sense.

The importance of student protagonism during investigative experimentation, with the teacher only as a mediator, highlights the commitment of those involved in the teaching-learning process. However, it is important to emphasize that, although the students who had only the expository class did not reach the percentages of the experimental class, the importance of theoretical complementation after experimentation is recognized.

Considering that this study is exploratory, it does not end here, but it can be a starting point for other analyses. It is considered that the investigative practice, through the assembly of a galvanic battery in the chemistry laboratory, allowed the students to approach their daily lives, corroborated the teaching-learning process and enabled access and involvement with scientific culture.

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