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EXPERIMENTAL CLASSES IN THE TEACHING OF CHEMISTRY

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ABSTRACT
The teaching of Chemistry in the context of Basic Education has been the subject of frequent discussion among teachers and researchers, especially with regard to the lack of motivation of students to learn the contents of the discipline, considered by the vast majority of students as abstract and difficult to understand. In this scenario, many studies show that experimental classes can play a crucial role in improving the teaching and learning process of this subject. Thus, the objective of this research was to investigate how teachers and students evaluate the experimental class in the face of the learning of these contents. We developed this investigation based on an internet survey of articles related to the theme. After previously analyzing several works, five of them were selected. Then, we carefully read each one of them and, based on some reflections in the light of the thought of several scholars, we prepared the final report of the research. The articles describe activities developed by teachers, and which were applied with Chemistry students, both from elementary schools and from licentiate schools. They present, as their main focus, the realization of experiments that enable students to observe chemical phenomena, raising questions and reflections. In two of them, the relationship of the experiments with the theme Science, Technology, Society and Environment is highlighted, which considerably stimulates the participation of students. In each article, the authors highlight the contributions that conducting an experiment can bring to improve the teaching of Chemistry in Basic School. The methodology used by the authors to evaluate these contributions ranges from the application of questionnaires before and after the experiment, to debates and discussions promoted throughout the development of the activity. According to the authors, in addition to arousing students' interest in chemical content, improving learning, the experimental approach makes the subjects of the discipline more concrete and less complicated, which contributes to a more conscious and participatory citizenship education. Concluding the results and discussions, we present our testimony, as a high school and undergraduate student in Chemistry, about the experience with chemical experimentation as a pedagogical strategy. In order for the teaching of Chemistry to acquire a more practical character, it is urgent to invest in adequate infrastructure, quality materials and equipment, as well as teacher training aimed at preparing professionals capable of developing experimental activities.

Keywords: Chemistry Teaching. Experimental classes. Basic education.

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INTRODUCTION

Chemistry is the science that studies the properties and transformations of matter present in our daily lives. This finding, in itself, should be the greatest motivation for students to want to learn the subjects covered in this discipline. However, many students consider the contents covered in the teaching of Chemistry in Basic School to be quite complex and abstract, which ends up generating a lack of interest in learning them. In a contradictory context, experimental classes can become excellent tools capable of facilitating students' understanding when they study the subjects of this discipline.

Some teachers have shown that, through the development of practical experiments, it is possible to allow students to apply the theoretical concepts studied, observing in a real way, the phenomena related to chemical knowledge. In addition, these activities are capable of contributing to the development of some skills in students, such as, for example, critical thinking, which is essential for citizenship education. In this sense, the teacher plays a fundamental role, since he would be largely responsible for the planning and execution of these classes. For this, it is important that the teacher acquires a solid training, capable of allowing him to adopt experimental classes as an integral part of his pedagogical practice.

Taking into account the above, the objective of this work is to present the result of the analysis of five scientific articles, which show the importance of experimental classes for a more meaningful teaching of Chemistry. More specifically, we seek to investigate how teachers and students evaluate the application of the practical class for a better learning of the chemical contents.

To this end, we conducted a survey in electronic journals that publish works related to the theme. From a reading of the abstracts of the articles found, we selected five published by the Química Nova na Escola Journal. The reason for this choice is based on the objectivity, organization and improvement of the writings, on the clarity of the methodological outline and, mainly, on the evidence of the success achieved with the application of the pedagogical activity planned by the authors.

Two reasons led us to develop this theme. The first refers to our conviction in the ability of practical classes to arouse a greater interest of the student in learning Chemistry. The other is related to personal issues. As high school students and undergraduate students in Chemistry, we were able to perceive a voluminous load of concepts and theories of this discipline, which is essentially experimental, coexisting with an insignificant (or almost non-existent) practical and/or experimental part.

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TEACHING AND LEARNING CHEMISTRY: SOME PARTICULARITIES

For Atkins (2018), Chemistry is the science that studies matter and the transformations it undergoes. This means that the entire material world is inserted in the scope of Chemistry. This scope ranges from the chemical composition of celestial bodies to food, from the constitution of biological tissues to the materials used in technological production, among other various aspects related to our daily lives. Therefore, no material exists independently of Chemistry, and the entire Universe can be understood from this science.

For Oliveira and Barbosa (2019), Chemistry is a science that is dedicated to the study of chemical transformations, being able to explain the most common phenomena through simple reactions. However, for the vast majority of Basic Education students, it is considered a complex and difficult discipline to understand, due to its formulas, equations, principles and concepts. For this reason, students often express criticism and dissatisfaction with the teaching of this school subject.

From the point of view of Clementina (2011), the study of Chemistry, as well as that of other areas of knowledge, plays a fundamental role in the development of the capacity for logical reasoning, observation, clear writing, experimentation and the search for explanations about what is seen and read. This allows us to understand and reflect on the facts of everyday life, as well as to critically analyze reality, which is essential for the exercise of citizenship. Silva et al. (2023) discuss the same thought:

> The appropriation of the knowledge of Chemistry is also of fundamental importance for the exercise of citizenship and training for the world of work. The appropriation of this knowledge by students is a necessary condition for the resolution of practical problems posed by reality, as well as for a conscious performance as a citizen, whether in professional practice or as a citizen who can contribute to the public debate on certain problems based on scientifically based knowledge (SILVA *et al.*, 2023, p. 94).

From these considerations, we observe that, although the authors recognize the importance of Chemistry in various aspects of daily life, students often perceive it as a complex discipline and their learning based on memorization, which will not be useful for their future work. However, the guiding documents of the Brazilian educational process, such as items III and IV of Article 35 of the LDB (BRASIL, 2019), say that one of the purposes of basic education in High School is,

> III – the improvement of the student as a human person, including ethical training and the development of intellectual autonomy and critical thinking;

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> IV - the understanding of the scientific-technological foundations of the production processes, relating theory to practice, in the teaching of each discipline (BRASIL, 2019. p. 25).

According to the PCNEMs, the teaching of Chemistry should allow students not only to understand chemical processes, but also to be able to build knowledge that makes it possible to evaluate the information received with fundamentals and autonomy. This is essential for them to be able to judge, based on scientific knowledge, the social, cultural, environmental, political and economic implications of technological applications related to chemical science. In this way, students will be prepared, as individuals and citizens, to make informed decisions (BRASIL, 2000a).

In this sense, Machado and Mortimer (2007, p. 24, *apud* SANTOS; FERREIRA, 2018, p. 498) highlight:

> [...] Chemistry class is much more than a time during which the teacher will dedicate himself to teaching Chemistry and the students to learn some concepts and develop some skills. It is a space for the construction of chemical thought and for the (re)elaboration of worldviews, and in this sense, it is a space for the constitution of subjects who assume perspectives, visions and positions in this world (MACHADO; MORTIMER, 2007, p. 24, *apud* SANTOS; FERREIRA, 2018, p. 498).

THE TEACHING OF CHEMISTRY IN THE COUNTRY

According to the National Common Curricular Base (BNCC) (BRASIL, 2017), the historical approach to Chemistry is considered of great relevance for the formation of students in High School. Through this approach, students have the opportunity to understand the evolution of chemical concepts over time, contextualizing them and understanding their importance to society.

> It is important that this training makes it possible to know how Chemistry has been consolidating itself as a science, with its methods, models and theories. This allows the understanding of the dynamics of knowledge generation, with its advances, disputes and mistakes, and the influence of social contexts in this process of human construction. [...] The teaching of Chemistry, with these assumptions, involves the sociocultural contextualization of knowledge [...]. It also involves the socio-historical contextualization [...] (BRASIL, 2017, p. 221).

However, the process of institutionalization of structured science teaching in Brazil was long, difficult and demanded a considerable period of time, being established only from the nineteenth century onwards. Until the early 1800s, Brazilian scientific and technological progress was directly related to the level of development of science teaching in the country (RHEINBOLT, 1953 apud LIMA, 2013).

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Chemistry began to be practiced in Brazil during the colonial period. However, throughout this time, several factors prevented Brazil from achieving significant scientific advancement. Among these factors, the political, cultural and economic dependence of the colony on Portugal stood out and, especially, the lack of interest on the part of the Portuguese in relation to the technological and economic advances that occurred in Europe in the seventeenth and eighteenth centuries. 1953 *apud* LIMA, 2012).

The first elementary schools in Brazil were built in Salvador, Bahia. Due to the interest of the Portuguese crown in forming a literate and mainly Catholic population, the arrival of more Jesuits gradually resulted in the construction of more schools throughout Brazil, thus increasing the number of adherents of Catholicism. Over the years, Portugal stopped advancing in the educational and scientific area, falling behind other European countries. This setback occurred due to the illusion of self-sufficiency generated by the riches coming from the lands recently colonized and exploited by the Portuguese crown. Around 1759, there were only a few schools scattered throughout Brazil, which obviously did not meet the demand of the population. In this same period, the Jesuits were expelled from the kingdom of Portugal, including its colonies, resulting in a great loss for education in Brazil (OLIVEIRA, 2017).

With the Pombaline reform promoted in 1771 and the introduction of the teaching of experimental sciences, many Brazilians, with the aim of pursuing a scientific or medical career, chose to study at the University of Coimbra. However, the Law and Letters courses were still the most popular among those seeking a higher education. This resulted in a significant shortage of qualified professionals in Brazil, in addition to not providing a favorable environment for the development of regular scientific careers, as was already happening in Europe. At that time, the teaching of Chemistry was still in its early stages, being predominantly theoretical and book-based, often associated with mineralogical studies. Chemistry was considered a secondary area of Physical Science (OLIVEIRA; CARVALHO, 2006).

Markedly, the beginning of Chemistry in Brazil occurred with the creation of the Scientific Academy of Rio de Janeiro, in 1772, on the initiative of the Viceroy Marquis of Lavradio (FILGUEIRAS, 1988). The academy encompassed several sections dedicated to different areas of scientific knowledge, including a specific space for chemistry, which was unusual at the time, as it was generally considered only a branch of physics. The space dedicated to Chemistry had a limited but significant number of works such as the book by the Portuguese Manoel Joaquim Henrique de Paiva, who was the first to bring the term Chemistry in its title, 'Elements of Chimica and Pharmacy'. However, the Scientific Academy of Rio de Janeiro had a brief existence, as discussions about scientific works and knowledge became scarce, due to the lack of scientific materials and scientists, since many of them were in Europe (OLIVEIRA, 2017; FILGUEIRAS, 1991).

It is interesting to mention the contribution of Vicente Coelho de Seabra Silva Telles in the field of Chemistry, with several writings and publications of works, including notably the book 'Elementos de Química', which was the first book written in Portuguese to abandon the theory of phlogiston[3]. This work presented content that covered everything from alchemy to the nomenclature of chemical substances, in addition to exploring the influence of heat on chemical reactions. However, it is important to emphasize that, despite his contributions, Vicente Coelho de Seabra Silva Telles did not receive recognition, fame or glory during his lifetime (OLIVEIRA; CARVALHO, 2006; FILGUEIRAS, 1991).

In the nineteenth century, there was a significant advance in scientific studies, with the dissemination of science around the world. An important milestone in this period was the invasion of the French into Portugal, which led D. João VI and his court to flee to Brazil and establish the seat of the empire in Brazilian lands. From this context, several documents were issued to start structuring scientific activities in the country. One of the first steps in this direction was the creation of some educational institutions throughout the country (OLIVEIRA; CARVALHO, 2006).

D. João VI implemented a series of important measures during his reign in Brazil. One of these measures was the opening of Brazilian ports to friendly nations, which had a significant impact by ending the country's isolation from the non-Portuguese world. In addition, D. João VI established the School of Anatomy and Surgery of Bahia in February 1808, during his stay in Salvador after his arrival from Portugal. Shortly thereafter, in April of the same year, a similar school was founded in Rio de Janeiro, known as the Anatomical, Surgical and Medical School. Other relevant changes included the creation of the Royal Garden (later called the Botanical Garden), which aimed to acclimatize exotic plants of economic interest, and the foundation of the Royal Printing (later renamed the

[3] Conceived by the German chemist and physician Georg Ernst Stahl in 1659-1660, this theory assumed that all types of flammable matter had a fundamental and ethereal substance, called phlogiston, which was released during combustion or absorbed in calcination (DE LUCA; WALZ, 2020)

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National Press), which ended the old ban on the printing of books in Brazil (FILGUEIRAS, 2015).

Despite the scientific advances that occurred at the time, teaching in schools still followed a traditional approach, in which teachers played the role of speakers and students were mere listeners. Faced with this situation, it became necessary to promote a reform in the Brazilian educational system. But it was only in 1837, with the creation of the Colégio Dom Pedro II, located in Rio de Janeiro, that the country sought a significant restructuring of its education system, since this school aimed to serve as a model for the others in Brazil. Inspired by the molds of French basic education institutions, Colégio Dom Pedro II included the discipline of science in its curriculum. However, the teaching of this discipline was still very abstract for the students, as the didactic approach was not related to their daily lives. The discipline of science only began to gain importance and to be sought after when its content was included in the entrance exams for higher education courses at the time. This fact aroused the interest and research of students in the area of science, contributing to the dissemination of the importance of scientific research (OLIVEIRA, 2017).

As Silva, Santos and Afonso (2006) discuss, even with D. Pedro II's interest in chemical knowledge, the first Brazilian school, with the specific objective of training professionals in the chemical industry, was only created in the republican period, at the beginning of the twentieth century, in 1918, the Institute of Chemistry of Rio de Janeiro. In the same year, the Polytechnic School of São Paulo implemented the Chemistry course. Progressively, from these institutions, scientific research in the country was developed. With the creation, in 1920, of the Agricultural Industrial Chemistry course, linked to the School of Agriculture and Veterinary Medicine, the National School of Chemistry in Rio de Janeiro was created, finally established in 1933.

According to Lima (2013), currently in Brazil there is a wide offer of Chemistry courses, both at the high school and higher levels (licentiate, bachelor's degree, industrial chemistry, chemical engineering and others). Practically all universities, whether state or federal, as well as federal institutes of education, offer undergraduate courses in Chemistry and related areas. In addition, many of these institutions already have graduate programs in Chemistry, in which Chemistry Teaching is one of the areas of concentration for both master's and doctoral degrees.

In the context of this short historical overview, it is worth highlighting what Cebulski and Matsumoto (2010) state:

> The History of Chemistry has a great importance within Science; it is through it that we can reflect on the progress that man has made over the centuries, acquiring experience, investigating and discovering facts that have made the way of life of successive generations could be improved (CEBULSKI; MATSUMOTO, 2010, p. 3).

MAIN CHARACTERISTICS OF THE TEACHING OF CHEMISTRY

Tfouni (1987 *apud* LIMA, 2012) argues that, in the teaching of the contents of the discipline of Chemistry, it is common for an exclusively verbalist approach to occur, in which the transmission of information is done in a superficial way. In this context, learning is seen only as a process of accumulating knowledge, without a deeper understanding.

Luca (2001) and Merçon (2003) corroborate the idea that there is a distancing of the contents of the Chemistry discipline, taught in High School, from the reality and daily life of the student. Once the curriculum is content-based, knowledge becomes essentially academic and, consequently, students lack motivation to study this science. This lack of interest is mainly due to the teaching methodology traditionally used, which is based on the memorization of concepts and rules of nomenclature, in addition to the application of formulas in problem solving, which, in most cases, serves a single purpose: to prepare the student for competitive examinations and entrance exams.

Another characteristic of the teaching of Chemistry, as well as of the other Exact Sciences, is the use of a mathematical language associated with macro and microscopic phenomena. The mastery of this language is fundamental for the development of competencies and skills related to the establishment of logical-empirical, logical-formal, hypothetical-logical and proportional reasoning relationships (BRASIL, 2000b). However, the lack of clarity in communication and the excessive use of technical terms can make it difficult for students to understand, especially those who are having contact with the contents of the course for the first time,

> Many types of classification are emphasized, such as types of reactions, acids, solutions, which do not represent significant learning. Chemical language, a tool, is often transformed into the ultimate goal of knowledge. Chemical knowledge is reduced to mathematical formulas and the application of "rules", which must be exhaustively trained, assuming mechanization and not the understanding of a problem-situation. At other times, current teaching privileges theoretical aspects, at levels of abstraction inadequate to those of students (BRASIL, 2000b. p. 32).

Nunes and Adorni (2010 *apud* VEIGA; QUENENHENN; CARGNIN, 2012) emphasize that students are unable to establish connections between the content studied in the Chemistry discipline and their daily life, resulting in a lack of interest in the topics covered in it. This situation suggests that the teaching of Chemistry is being conducted in a decontextualized way and not linked to the other disciplines to which it relates, that is, without interdisciplinarity.

Silva *et al.* (2023) also agree that the contents of Chemistry are often not assimilated due to the lack of contextualization of the subjects covered in the discipline and the absence of an interdisciplinary approach that should be overcome by teachers. Although there are guidelines in school discourses, in the Pedagogical Projects of Courses (PPC), in the National Curriculum Parameters (PCN) and in the BNCC, there are still many difficulties that prevent the implementation of these practices, which could make the learning of Chemistry more effective (Goulart *et al*., 2025).

In addition to these characteristics that stand out in the teaching of Chemistry, Lima (2012) draws attention to the lack of an approach that evidences the context of the history of Chemistry in the evolution of human society, becoming a preponderant factor that contributes to increase the problem faced in the student's teaching and learning process. Also according to this scholar, for the teaching of Chemistry to become really effective, it is necessary that it be problematizing, challenging and stimulating, with the main purpose of leading the student to build his own scientific knowledge. We can no longer accept a teaching of Chemistry that only admits the presentation of pre-established concepts, questions with programmed and immutable answers. It is essential that the Teaching of Chemistry can promote an approach capable of encouraging reflection, research and the active participation of students in the learning process.

2.3 MAIN DIFFICULTIES IN THE TEACHING OF CHEMISTRY

Costa, Passerino and Zaro (2012) corroborate the thought that the microscopic and often abstract nature, intrinsic characteristics of much chemical knowledge, usually causes difficulties among students in learning the various chemical laws, principles and concepts. In addition, there is the fact that chemical language is essentially symbolic, which presupposes the need for a great capacity for abstraction and generalization.

Based on the results of the analysis of survey data, Santos *et al*. (2013) state that more than fifty percent of students attribute a greater difficulty in learning Chemistry contents to the lack of a 'mathematical basis', necessary for the understanding of many chemical phenomena. A probable justification for the high rate of this category of students is the emphasis, usually given by teachers, to the role of mathematics in the teaching of

Chemistry, that is, with an excessive algebraic treatment predominating, completely neglecting the implication of the results in the chemical process studied, applying mathematics.

As Silva (2011) points out, based on results obtained in a field research, the teaching of Chemistry has been declining due to several factors, such as, for example, "[...] a) deficiency in teacher training; b) low salaries of teachers; c) methodology in an outdated classroom; d) reduction in the training of chemistry graduates; e) few experimental classes; f) students' lack of interest" (p. 7).

Luca (2001) says that in this context the fundamental role of the teacher endures, and that some teachers face devaluation, lack of motivation and, to a certain extent, unpreparedness to teach Chemistry in Basic School. Often, they do not have sufficient training and autonomy to develop their own teaching program, limiting themselves to reproducing programs considered traditional. In addition, there are those who only repeat simplistic pedagogical techniques, which require little knowledge of the area.

Also according to Pozo and Crespo (2009), the difficulties in learning Chemistry faced by students, in large part, occur due to the school practices used in the solutions of questions and problems, which are centered on routine or delimited tasks, with little scientific significance.

The teaching of Chemistry is also deficient, according to Silva (2011), as a result of the training of Chemistry teachers in Higher Education Institutions (HEIs),

> a) with exceptions, most chemistry teachers in HEIs have a bachelor's degree and few have a degree; b) the predominant methodology is still the traditional class; c) didactic chemistry laboratories of the HEIs are becoming obsolete; d) lack of interest of graduates in the teaching profession (SILVA, 2011. p. 8).

The need for knowledge in other disciplines in the area of Exact Sciences, such as Mathematics and Physics, is also an impasse. The lack of qualified professionals, the use of an inadequate methodology and/or the absence of materials for carrying out practical classes in laboratories will have repercussions on higher education students. This is because, without a solid foundation in these disciplines, students will certainly develop limitations when entering universities (BELO; MILK; MEOTTI, 2019).

For Andrade and Costa (2016), there are several obstacles that make it difficult to carry out practical classes:

> The lack of a laboratory is one of the most cited factors among the studies that seek

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> to verify the obstacles to the realization of practical classes. However, many schools have these spaces, but they are not used. [...]. In addition, it is worth noting that many natural sciences teachers have a deficient initial training, approaching practical laboratory classes in a simplistic way and without didactic preparation to deal with basic education (ANDRADE; COSTA, 2016, p. 209).

In their conclusions, these same authors also highlight:

> [...] The existence of a laboratory alone does not guarantee the realization of practical classes, as there are several obstacles that make it impossible to carry them out, such as the deficiency in initial training, the excessive load of classes, the large number of students per class, lack of materials and maintenance of laboratories, lack of professional recognition, lack of support from the management/coordination, indiscipline, among others (ANDRADE; COSTA, 2016, p. 213).

Thus, most of the time, the practical stage of teaching Chemistry is neglected, either due to lack of teacher training, lack of student discipline or lack of an adequate environment for conducting experiments. In addition, schools do not have sufficient financial resources to carry out external activities, which would make learning the subject more engaging and closer to the students' reality (SANTOS; GONÇALVES, 2017).

THEORETICAL CLASSES AND EXPERIMENTAL CLASSES

According to Kovaliczn (1999 *apud* BUENO; KOVALICNZ, 2012), the teaching of Science requires a constant relationship between theory and practice, between scientific knowledge and common sense. This connection is extremely important, since the Natural Sciences (Chemistry, Physics, Biology) are considered essentially experimental, based on scientific evidence and based on theoretical assumptions. Thus, conducting experiments is disseminated as a fundamental didactic strategy for the teaching and learning of these disciplines. However, this practice should not be seen only as a utilitarian activity, but rather as a transformative practice, adapted to the students' reality and with well-defined objectives, aiming at the effectiveness of praxis.

For Gil *et al.* (1999, *apud* GIANI, 2010), when talking about theory and practice, there is a dichotomy between both and, in order to provide students with a closer view of scientific work, it is essential that the aspects theory, practice and problems are worked on as in scientific activity, inseparable. Otherwise, this can become a real obstacle to scientific knowledge.

Silva *et al*. (2017 *apud* FELIPE; ALMEIDA; CARVALHO, 2022) highlight that the use of experiments during classes can be an effective strategy to assist in the learning process

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of Chemistry content. In this sense, the teacher can incorporate the experiments as part of the activities developed in the classroom, allowing students to have the opportunity to experience in practice the theoretical concepts presented in the textbook.

With this same line of thought, Cruz (2007) emphasizes the importance of working theory and practice together,

> It can be deduced that theoretical learning, combined with practice, is immeasurable. It is the path that leads to discovery and the pleasure of creating. Today, in schools, we find students eager for challenges, but, most of the time, they lack the incentive to transform them into the scientists of tomorrow. In the past, people had to hide, seek resources in the simple things of life and made their homes the laboratory for experiments. Now, it is necessary to give opportunities and stimulate young students so that they can take longer flights. There is the appropriate place in the school. It is enough to train the technical personnel, so that they are able to leverage the progress of the students (CRUZ, 2007, p. 17).

WHY EXPERIMENTAL CHEMISTRY CLASSES

The origin of practical activities in schools took place more than a hundred years ago, influenced by the experimental practices that were developed in universities. These activities aim to improve the learning of scientific content that, theoretically, is learned by students through expository classes. However, its development in the classroom, as a pedagogical strategy, has always presented difficulties (ARAÚJO, 2019).

Conducting experiments in the teaching of the contents of the Science disciplines represents an excellent didactic tool, as it allows the student to concretely experience the content studied and establish a relationship between theory and practice. The establishment of this relationship helps students to understand the topics covered and their applications in everyday life. By experiencing experiments and observing the results, students have the opportunity to visualize chemical concepts in action, which facilitates the assimilation and fixation of knowledge. In addition, experimental classes arouse the interest and curiosity of students, making the learning process more dynamic and meaningful (FONSECA; SOARES, 2016).

According to Farias, Basaglia and Zimmermann (2008), the use of experimental classes is an effective strategy to overcome students' difficulties in understanding the contents of Chemistry. Gonçalves and Goi (2021) ratify that the use of experimentation in the classes of the disciplines of Natural Sciences constitutes a methodological approach capable of engaging students and stimulating the development of critical thinking, allowing the observation of phenomena, data collection and formulation of hypotheses, thus contributing to the promotion of learning. Cruz (2007) highlights that the use of the didactic laboratory in the educational environment is extremely important, and brings significant benefits to teachers who use experimental activities in their classes,

> The didactic laboratory helps in interdisciplinarity and transdisciplinarity, since it allows the development of various fields, testing and proving various concepts, favoring the student's capacity for abstraction. In addition, it helps in the resolution of everyday problem situations, allows the construction of knowledge and reflection on various aspects, leading him to make interrelationships. This enables them to develop the skills, attitudes and values that provide greater knowledge and prominence in the sociocultural scenario (CRUZ, 2007, p. 24).

If an experimental class is organized in such a way as to place the student in front of a problem situation, and is directed towards its resolution, it can contribute to the development of the student's logical reasoning about the situation, leading him to present arguments in an attempt to analyze the data and present a plausible conclusion. In addition, if the student has the opportunity to follow and interpret the stages of the investigation, he will possibly be able to elaborate hypotheses, test them and discuss them, learning about the phenomena studied and the concepts that explain them, achieving the objectives of an experimental class, which favors the development of cognitive and logical reasoning skills (ARAÚJO, 2019).

DIFFICULTIES IN CONDUCTING LABORATORY CLASSES

For Suart and Marcondes (2009), experimentation is important to facilitate the learning of concepts seen in the classroom, but it is still much criticized, since

> Experimental activities, both in high school and in many universities, are still often treated in an uncritical and unproblematic way. Little opportunity is given to students in the process of data collection, analysis, and hypothesis development. The teacher is the holder of knowledge and science is treated in an empirical and algorithmic way. The student is the passive agent of the class and it is up to him to follow a protocol proposed by the teacher for the experimental activity, prepare a report and try his best to get closer to the expected results (SUART; MARCONDES, 2009, p. 51).

Barbosa, Sete and Guedes (2018) agree with the statement that it raises the performance of experimental activities to the level of being able to arouse greater interest from students and provide more positive results. According to an article published in the newspaper O Globo in September 2013, only 11% of Brazilian schools have science laboratories. This number represents approximately 20,424 of the 192,676 schools in

Brazil, whether public or private. This statistic is considered low for science teaching in the country.

> The deficit of these laboratories impairs both the development of classes and the student's knowledge, as the lack of practical classes makes the student not make an effort to learn, and chemistry is considered to be a subject of difficult understanding (BARBOSA; SEVEN; GUEDES, 2018. p. 3).

From Calixto's (2015) point of view, one of the problems in carrying out experimental activities is due to the fact that the experimentation, implemented in Basic Education schools, is only demonstrative and observational classes, with the objective of proving theories previously worked on in the classroom.

Santos and Menezes (2020) emphasize the simplistic and unrepresentative view of the pedagogical potential that is given to the role of experimentation, the theory/practice dichotomy, the lack of equipment and adequate materials for its realization, as well as the existing gap in teacher training and the lack of interest of students in participating in the proposed actions. For Coltri and Rubio (2013), the main difficulty in conducting experimental classes lies in the lack of access to a laboratory with all the necessary conditions to carry out an excellent experimental class. However, for the authors, this does not prevent the teacher from developing or pursuing other, simpler experiments, adapting them to the content being taught.

Axt (1991 *apud* GIANI, 2010), in agreement with the authors above, mentions two factors that corroborate the difficulty of conducting experimental classes: the lack of equipment and the impossibility of making repairs or replacements and the limitation of qualified teachers for this. As Santos (2015, p. 33) states, "The non-use of experimental activities ends up happening because teachers do not have the training, knowledge and competence to use and develop them".

Andrade and Costa (2016) confirm the previous idea, highlighting that,

> [...] in addition to the lack of infrastructure, the main reasons for not holding practical classes in the teaching of Science "are the curricular time, the insecurity in teaching these classes and the lack of control over a large number of students within a challenging space such as the laboratory" (ANDRADE; COSTA, 2016, p. 209).

Knowing the importance of developing experimentation in teaching laboratories, Silva and Zanon (2000, p. 182 *apud* BUENO; KOVALICZN, 2012) mention

> Teachers usually report that experimental teaching is important to improve teaching-learning, but they always emphasize the lack of materials, a high number of

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> students per class and a very small workload in relation to the extensive content that is required in the school (BUENO; KOVALICZN, 2012, p. 5).

METHODOLOGY

This paper presents the results of a research, developed under a qualitative approach (CAMPOS *et al.*, 2023), which sought to know how teachers and students, from different levels of education, conceive the role of experimental classes for the development of a more satisfactory teaching of Chemistry.

The text constructed here is, therefore, the result of reflections made from visits to scientific articles that deal, above all, with the theme related to the importance of conducting experimental classes in the teaching of Chemistry in Basic School. To search for these articles on the internet, keywords such as 'experimentation' and 'chemistry teaching' were used. To collect data on each article and to delimit the choice, an analysis of the abstract and title was carried out, followed by detailed readings of the selected texts.

The most appropriate articles for carrying out this work, that is, those that were most closely related to the theme, were found in the Revista Química Nova na Escola (QNesc). This journal is dedicated, almost exclusively, to the publication of articles related to Chemical Education, presenting several sections and modalities, such as classroom reports and experimentation in the teaching of chemistry, in which the articles studied here were found.

Five articles published between 2016 and 2018 were selected for analysis. The most noteworthy aspect in these articles is the students' opinion about the application of practices in Chemistry classes, as well as the authors' position on the subject. Thus, as one of the methods of excluding the article from the scope of the research, was the distancing from the established theme.

It is worth mentioning that this journal is a national reference for publications in the field of Chemistry Education, and is linked to the Brazilian Society of Chemistry (SBQ), the most important entity that brings together Brazilian chemists.

The publications selected for the discussions presented in this work are listed in Chart 1. In our opinion, these writings report successful experiences of teaching Chemistry through experimentation, as all of them were able to detect a significant improvement in the learning of the students who participated in them.

After the analysis and reading of the articles, a report was prepared in which the main contributions of these works to the theme explored are included, which would justify

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their choice to achieve the objective proposed in this monograph. In addition, the author exposes a short text in which she describes her experience as a student, and her relationship with practical Chemistry classes throughout her training.

Table 1 – Year, title and authors of the articles used to prepare this monographic work

YEAR OF PUBLICATION	ARTICLE TITLE	AUTHORS
2016	Water treatment with biodegradable coagulant: a proposal for an experimental activity.	ANDRADE, Danilo Oliveira do Nascimento de; BRANCO, Natália Bruzamarello Caon; GONÇALVES, Fábio Peres.
2017	Electrochemical cells, daily life and students' conceptions	BARRETO, Bárbara S. J.; BATISTA, Carlos H.; CRUZ, Maria Clara P.
2017	Paper chromatography: reflection on an experimental activity to discuss the concept of polarity	OLIVEIRA, Gislei A. de; SILVA, Fernando C.
2017	The corn of typical June foods: a didactic sequence for sociocultural contextualization in the teaching of Chemistry.	RODRIGUES, Jéssyca B. S.; SANTOS, Patrícia M. M.; LIMA, Rozeane S.; SALDANHA, Teresa C. B.; WEBER, Karen C.
2018	Colorants: a Science, Technology and Society (STS) approach using advanced oxidative processes.	FERREIRA, Wendel M.; ROCHA, Leticia B. da; SANTOS, Lenaldo D. dos; SANTOS, Bárbara L. S. R.; PITANHA, Ângelo F.

Source: prepared by the authors.

The intention of this study is to contribute to an in-depth reflection on the importance of experimental classes in the teaching of Chemistry, highlighting mainly the ability to overcome some difficulties that they can provide.

RESULTS AND DISCUSSIONS

Below we present the final report of the analysis of the five articles used for the development of our investigation. The systematic of the activities reported in these articles, in general, can be systematized in three phases: probing (application of a questionnaire to the participating students, to assess their previous knowledge), experimentation (practical part itself, to enable the participants to observe chemical phenomena) and evaluation (identification of changes that occurred in the students' initial conceptions).

Each article was described in a very succinct way, including the final considerations of its authors. To conclude each description, we make some comments about our conception of what was dealt with in each article.

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First article

The first article, published in 2016, is entitled 'Water treatment with biodegradable coagulant: a proposal for an experimental activity'. Its authors are Danilo Oliveira do Nascimento de Andrade, Natália Bruzamarello Caon Branco and Fábio Peres Gonçalves.

The objective of this work was to present an experimental proposal that can be used in the teaching and learning process of Chemistry related to environmental issues. To achieve this goal, the authors used a simulation of one of the stages of the water treatment process that normally occurs in a WTP (Water Treatment Plant), replacing conventional coagulants with one of a biodegradable nature. This proposal was developed with undergraduate students in Chemistry, who highlighted the importance of this experimental activity to promote discussions on Science, Technology, Society and Environment (CTSA), articulating theory and practice based on scientific knowledge.

In the text of the article, the authors present a table containing the script of the entire activity carried out, including questions for discussions made before and after the experimental part. After the experiment, consisting of simulations of the water treatment stages that occur in a WTP, a debate was promoted, whose objective was to seek answers to the problematizing questions presented in the table.

The authors started the activity based on the students' previous knowledge, aroused through a discussion about the advantages and disadvantages of using Aluminum Sulfate [$Al2(SO4)_3$] in the water treatment process, discussing the importance of using this compound to obtain quality drinking water. In order to favor the conduct of the debate and awaken the critical thinking of the students, a text of a report was made available that discussed the use of aluminum sulfate in the process of obtaining drinking water for residential supply in Florianópolis-SC, conducted at the water treatment plant.

The news addresses the damage that $Al2(SO4)_3$ can cause to consumers, with greater emphasis on the fact that it contributes to the development of degenerative diseases (dementia and Alzheimer's disease, for example). The experiment promoted by the authors used tannic acid[4], instead of aluminum sulfate as a coagulant.

Subsequently, the authors made available the script of the experimental part, indicating the use of glassware and laboratory reagents, and also proposing the use of alternative materials. They began the experimental procedures by preparing a sample of

[4] An acid belonging to the class of tannins and whose formula is C76H52O46 (BRANDÃO *et al.*, 2008).

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muddy water (tap water + earth), to which a solution of tannic acid and sodium hydroxide (NaOH) was added to promote the coagulation, flocculation, and decantation steps. After that, a filtration was carried out to obtain the sample of treated water, with which analyses were carried out to identify the presence of tannin, using ferric chloride (FeCl3). The non-appearance of blue color in the sample indicated the absence of tannic acid, which was retained in the filter paper along with the sand.

Other analytical tests were conducted to determine some parameters in the initial (untreated) and final (after treated) water sample. The class ended with discussions about some questions related to the practice carried out.

In order to assess the relevance of the experimental proposal for the students, the authors used a kind of questionnaire containing 10 statements, in which the 18 participating undergraduates could mark one of the options: Strongly Agree (FC), Agree (C), Undecided (I), Disagree (D) and Strongly Disagree (DF). The authors divided the statements into categories, from which they evaluated the potential of this activity for: the acquisition of knowledge related to CTSA interactions; favoring the understanding of concepts, procedures and attitudes of students in decision-making; and the active participation of students in activities of this nature.

Regarding the first category, the authors found that the percentage of agreement (C and CF) was predominant, that is, a high number of undergraduates showed agreement that the experimental activity carried out has the potential to favor the appropriation of knowledge related to CTSA interactions. A similar percentage was observed for the answers related to the second category (i.e., the students agreed that the experimental activity can also favor the learning of conceptual, procedural and attitudinal knowledge), and for the answers to the third category, in which they assumed that the experimental activity can actively encourage student participation. The percentage of I, D and FD were lower in the second and third categories.

From the analyses and discussions carried out in the article, the authors came to the conclusion that the experimental proposal, using tannic acid as a coagulant in the water treatment process, proved to be adequate for the teaching of Chemistry, presenting a great potential to be worked on in the CTSA approaches. The greatest emphasis is on the possibility of forming critical citizens to understand how these interactions are processed and their implications for human life. However, the authors emphasize that the evaluation of the licentiate students in relation to the experimental proposal should be considered with due moderation, not in an unrestricted way. In this sense, the authors observe that this activity can contribute to broader training processes, which seek to enrich students' knowledge.

From the reading and analysis of this article, it was possible to consider that the use of experimental activities, aimed at favoring the teaching and learning process of Chemistry, are capable of contributing to the development of skills and the construction of knowledge. The experiment presented in the analyzed work, from our point of view, is consistent with the authors' proposal, as it was able to promote a more meaningful and engaging learning, since it appropriates a theme related to the students' daily lives, such as drinking water, obtained from the water treatment process.

Works of this nature reinforce the thought that experimental activities, as Silva (2016) points out, are indispensable in the teaching of Chemistry, since they facilitate the understanding of the relationships between theory and practice, as well as the relationship that the student makes between what he knows and the new ideas he learns. What's more, the use of a biodegradable coagulant, such as tannic acid, not only reduces the negative environmental impact, but also influences students in the search for sustainable solutions to issues related to water and the environment. The fact that the percentages of I, D and FD were much lower in the second and third categories may confirm that the chemistry teaching process developed from experiments can mean better student learning.

Second article

Published in 2017 with the title 'Electrochemical Cells, daily life and conceptions of students', this article is authored by Bárbara dos Santos Juca Barreto, Carlos Henrique Batista and Maria Clara Pinto Cruz.

The objective of this work was to present a chemical experiment that would enable students to understand some concepts related to electrochemistry, awakening in them the ability to distinguish the types of processes that occur in an electrochemical cell and to differentiate spontaneous from non-spontaneous chemical reactions. To this end, the authors developed experiments related to chemical deposition and electrodeposition, which refer to phenomena related to the daily lives of students. The experimental practice was carried out after an explanation of the content in the classroom.

The authors emphasized that the most important points in these experiments were the phenomenological observations, that is, the description of the deposition and

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electrodeposition experiments, and a simple qualitative analysis of what was observed was also made.

The first part of the experiment consisted of chemical deposition. The students prepared a silver ion solution, in which a copper bar was dipped. The phenomenon observed was the spontaneous chemical deposition of silver on the surface of the bar, which occurred within a few minutes. The second experiment was electrochemical deposition, which consisted of a demonstration by the authors, that is, the students could not manipulate the materials used. An electrolytic cell with two electrodes and a 12-volt electrical discharge energy source was used. Solutions were prepared from the dissolution of sodium cyanide (NaCN) and silver chloride (AgCl). In this experiment, the students were able to observe that the deposition of metallic silver on a brass ring only occurred because of the electric current generated from the electron source, a phenomenon that consists of a non-spontaneous chemical reaction.

After the part of the experiments, a discussion was then held comparing the processes of chemical deposition and electrodeposition. To conclude, examples of phenomena that occur in the daily life of students similar to those observed were highlighted, in order to facilitate the students' understanding of the subject studied.

In the process of evaluating the class carried out, initially the authors made an analysis of the profile of the participating students, using questions about their age, gender, school they studied and which sources they used to study Chemistry. In addition, through an investigative questionnaire, it was possible to conduct an individual interview on the subject. After the practice, the authors evaluated the opinion of the participating students based on their testimonies, and asked them to represent the electrochemical cells through drawings. This enabled the authors to analyze the impact that experimentation had on the process of understanding the concepts in question.

Based on the analyses made by the authors of this work, it was possible to verify that the participating students were within the appropriate age/year criterion to deal with these concepts. They were also able to observe the presence of a more representative female audience. Also in the analysis of the students' profile, it was observed that the vast majority of them attended all of Elementary School in a Public School. These students reported that their knowledge was acquired during Chemistry classes, with their teacher, and that they did not use the internet for their studies. In the interview carried out through the investigative questionnaire, regarding their chemical knowledge related to the content of the experiment, it was possible to observe that the students were able to previously discuss the subject, but using common sense knowledge, which does not present a scientific language.

In the second moment of the final considerations of the work, the authors highlight that the results obtained in the conduct of the spontaneous reaction were not satisfactory. This was due to structural physical factors of the interior of the room, such as the incidence of a high intensity of light, which caused the rapid darkening of the silver deposited on the copper bar.

In the second part of the experiment, the results were much better, and it was possible to provide, through the final physical aspect of the brass ring, the discovery made by the students through the observation of the chemical phenomenon that occurred. The majority of students evaluated the class as excellent, and a minority percentage considered the class good. They emphasized the need to continue working the teaching of Chemistry with experimentation, as it facilitates both the explanation and the learning of concepts related to electrochemistry.

By analyzing the drawings of the electrochemical cells made by the students, the authors concluded that the level of understanding of the subject differs among students. The illustrations of some of the students represent a better interpretation of these devices, when compared to drawings of other students who did not interpret them in the same way. For the authors, these drawings make it possible to identify the students' level of understanding in class and, based on this, the teacher can draw up a plan to carry out a more objective intervention. Finally, the authors report that the main objective of the work was achieved, since the students were able to differentiate the types of electrochemical cells after applying the practice, which was confirmed by the illustrated representations.

Through what has been exposed in this article, we can assess that it is possible to highlight some difficulties regarding the understanding of the contents of Chemistry, especially those more related to other areas of knowledge, such as Physics. However, they can be overcome, or at least minimized, when explored through experimentation, in which the content abandons the purely theoretical aspect to take on a much more 'experience' and, therefore, more interesting aspect.

Another element that we highlight in this work refers to the different forms of learning and the varied levels of understanding, which was evidenced by the drawings. Some can immediately achieve a more accurate interpretation of the concepts, while others may face

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some challenges in their understanding, but which, assisted by the teacher, can perfectly overcome the difficulties that arise. To conclude, in light of what is exposed by the article, we emphasize that experimentation is fundamental for us to work on electrochemical concepts. However, it is necessary for the teacher to remain attentive to the different learning modes of his students, in order to enable everyone to benefit from these enriching experiences and to reach the minimum appropriate level of learning.

Third article

With the title 'Chromatography on paper: reflection on an experimental activity to discuss the concept of polarity', the third article was published in 2017, with Gislei Aparecido de Oliveira and Fernando César Silva as authors.

The objective of the work presented in this article was to study the concept of polarity, with students of the first year of high school, through the realization of an experimental practice using paper chromatography. Using the process of separating pigments from peppers through this chromatographic technique, the authors wanted to better understand the learning process of these students, enabling the search for interventionist actions capable of improving learning.

Initially, the authors applied a questionnaire asking the students about the phenomena that would occur in their daily lives, and that are used in the processes of separation of mixtures, such as, for example, the absorption of urine in the diaper and the removal of pan fat with water alone. After the application of this questionnaire, the experimental part was started, which is not described in this article. However, the authors point out that the experiment carried out was a reformulation of a practice already described in the literature.

Visiting the internet, it was possible to locate the document that describes this practice, presented in the article 'Analysis of pepper pigments by paper chromatography', by the authors Núbia Moura Ribeiro and Carolina Rodeiro Nunes, also published in the journal Química Nova na Escola (RIBEIRO; NUNES, 2008). Briefly, the experiment is developed from obtaining the extracts of colored peppers, after they have been chopped, weighed and mixed with acetone and hexane or thinner. These mixtures are macerated and then filtered to obtain the final extracts. The final solutions are then applied on chromatographic paper, to analyze the main pigments contained in the peppers.

To evaluate the results obtained with the development of this experiment, the

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authors applied another questionnaire after the end of the practical part, in addition to using observations made during the development of the experiment. The entire activity lasted 100 minutes. The experiment was conducted after the application of the initial questionnaire, whose questions were used as a starting point for the discussion of the concept of polarity and the development of the practical part. With this, the authors were able to stimulate students in the search for explanations for the process of extracting pigments from peppers, and sought to understand how the learning process of these students occurs. The final questionnaire was based on the implications of polarity in the separation of pigments with the use of paper chromatography. The answers were categorized and classified as: correct answers, partially correct answers, incorrect answers, and do not know or did not answer.

In the opinion of the authors, the results showed that more than half of the students are able to recognize the presence of Chemistry in phenomena that occur in everyday life. This was perceived through the answer given to the question that asked to identify the processes that are used, in their daily lives, to separate the components of mixtures. However, to the second question, which asked about the absorption of urine in the diaper, it was possible to identify a large number of incorrect answers. For the authors, this demonstrates that students have great difficulty in identifying the properties of the different materials that make up the diaper.

In the question about the use of water only to wash bowls, the authors expected the students to answer that the water did not remove the fat, however about 57% of the students answered incorrectly, believing that the steel wool was the main responsible for the removal of the fat. From these conjectures, the authors concluded that the students did not have basic knowledge about polarity, however, with the application of the practice, they were able to evolve in relation to the learning of this concept.

Still, according to the authors "We understand that the concepts discussed are difficult to teach, but we observe that experimentation can be an effective strategy to study this concept, contributing to later relationships with the context of these students" (OLIVEIRA; SILVA, 2017).

In view of the results presented in the article discussed, we can see that these students, in addition to presenting a certain lack of previous knowledge about the content explored, did not use their critical sense satisfactorily. Difficulties of this nature may be linked to the scarcity of information that is irremediably capable of contributing to the non-

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recognition of the association between scientific knowledge and the chemical phenomena that are involved in everyday life. For these and other reasons, students often consider Chemistry a difficult subject to understand and, therefore, it becomes uninteresting, which causes its dispersion during classes.

On the other hand, we can consider that these difficulties are intensified when the student does not have the skills related to the use of scientific language, as emphasized by the PCNEM (BRASIL, 2000b):

> It should be considered that Chemistry uses its own language for the representation of reality and chemical transformations, through symbols, formulas, conventions and codes. Thus, it is necessary for the student to develop adequate skills to recognize and know how to use such language, being able to understand and use, from the information, the symbolic representation of chemical transformations. The indiscriminate memorization of symbols, formulas and names of substances does not contribute to the development of desirable skills and abilities in high school (BRASIL, 2000b, p. 34).

Fourth article

The fourth article is entitled 'The corn of typical June foods: a didactic sequence for sociocultural contextualization in the teaching of Chemistry'. Its authors are Jéssyca Brena Soares Rodrigues, Patrícia Maria de Moura Santos, Rozeane Santos de Lima, Teresa Cristina Bezerra Saldanha and Karen Cacilda Weber.

The authors' motivation for the development of this work came from the concern to integrate school knowledge with the cultural experience of students, associating the environmental, social, scientific and technological dimensions with the contextualization of Chemistry through the theme 'June festival'. Focusing on the characteristics and aspects of corn, used as raw material in some foods typical of these cultural manifestations, this activity was developed by the authors and developed with students in the second year of high school.

The authors planned and elaborated the experiment based on the studies and ideas of Paulo Freire. However, the model used was based on the sequence of Pedagogical Moments, proposed by Delizoicov, Angotti and Pernambuco (2002). Thus, the authors divided the activity into three moments: the initial problematization, the organization of knowledge and the application of knowledge.

In the first moment, the authors investigated the students' knowledge about the theme explored in the activity. To do this, they resorted to the reference matrix of the National High School Exam (ENEM), to correlate the Chemistry contents to the proposed

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contextualized theme. During the first class of the development of this stage, the cultural and social importance of this festive period was then discussed and, later, the reading of the cordel entitled 'Confessions of a girl who loves June food!', which emphasizes the foods prepared with corn, and which are typical of the popular festivals characteristic of the month of June.

In the next class, they continued the problematization with the individual reading of another text, entitled 'The importance of corn in people's lives'. After the reading, debates were promoted in the groups of students present in the class, so that, at the end, it was possible to observe the development of a socialization of the activity, with the participation of the whole class. At a later time, the students were again organized into groups to elaborate questions related to the theme studied.

At the time of the organization of knowledge, after the initial problematization, the themes were selected for discussion in the following classes. Finally, in the last stage, which consisted of the application of knowledge, the concepts studied were used to solve the problems pointed out in the first moment.

The process of evaluating the results obtained by the development of this activity consisted of analyzing the students' answers to some questions. Thus, the authors applied an initial questionnaire in the problematization stage, to analyze the students' previous conceptions in relation to the theme explored, in addition to another that aimed to generate a final evaluation based on a discussion about the content of the answers.

Based on the answers obtained, the authors stated that some students associated everyday chemistry only with industrialized chemicals. However, the vast majority correlated Chemistry to food, cooking processes, digestion and the reactions that occur in the human body. In a second moment, when the presence of Chemistry in the June festivities was discussed, the authors found that almost 70% of the students were able to associate it only with fireworks and bonfires. A minority of students mentioned the association of Chemistry with typical foods, which was the object of study of the analyzed work. At the time when the discussion was set up in the class, some doubts of the students were clarified in relation to the characteristics of the corn contained in the texts read.

At a later time, based on the answers given by the students, the authors evaluated the class as beneficial. At the last moment, when the knowledge was applied, the teachers made available another questionnaire with subjective questions, similar to those produced by the students during the discussions, so that they could answer it and return it to them.

After evaluating these responses, the authors were able to conclude that it was possible to evidence an advance in the process of understanding the chemical content related to the theme explored.

According to the authors, the crucial point for the success of the study was the moment of the initial problematization, which fulfilled its function, since it managed to arouse the curiosity of the students, strengthening the debate. In addition, this proposal adopted by the authors used concepts of an interdisciplinary nature, which contributed significantly to the involvement of students, since everyday themes strengthen the teaching and learning process in school.

From the activity briefly reported here, it was possible to observe that it is essential to develop activities in the classroom that work on Chemistry content in a contextualized and, above all, regionalized way, which can 'make sense for the student' to learn them.

In this sense, it is worth highlighting what is stated by the PCNEM (BRASIL, 2000b, p. 39), as one of the skills to be developed by the teaching of Chemistry, is to make the student capable of "Recognizing the role of Chemistry in the productive, industrial and rural system. Recognize the relationships between the scientific and technological development of Chemistry and socio-political-cultural aspects", through the sociocultural contextualization of the contents explored in the study of this science.

Fifth article

The fifth article selected for the elaboration of this monographic work is entitled 'Colorants: an approach focusing on the CTSA relationship using advanced oxidative processes. Published in 2018, its authors are Wendel Menezes Ferreira, Leticia Bispo da Rocha, Lenaldo Dias dos Santos, Bárbara Luisa Soares dos Reis Santos and Ângelo Francklin Pitanha.

This work aimed to expose an experimental didactic intervention carried out by the authors addressing the theme of dyes. The main purpose was to discuss the role of oxidative processes and to analyze how this approach is associated with the CTSA theme. The experiment explored advanced oxidative processes, seeking to identify their contributions to students' understanding of the process of using dyes, discussing their implications in different aspects of society and technology. To do this, the authors used an experiment using the Fenton process (oxidation of organic matter in wastewater using

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Fe2+ ions and hydrogen peroxide) and photo-Fenton (same reaction, however, irradiated by a light source), developed with third-year high school students.

When planning and elaborating the activity developed, the authors were based on the premise of the possibility of better learning through concrete evidence of the chemical phenomenon:

> Experimentation should be treated as a process, not a product. Therefore, during the insertion of this type of activity, it is necessary to integrate into practice (the observations of possible evidence of the experiments) discussions, analysis and interpretations of data and results, which should be directed to the conceptual and cognitive development of the students, in order to allow them to be able to evidence phenomena and, from there, (re)construct their ideas (FERREIRA *et al*., 2018, p. 250).

The activity developed consisted of several moments. The first, lasting 50 minutes, consisted of an exposition of the proposal to the students, followed by the application of the initial questionnaire, containing questions that involved the STSA context, with the purpose of analyzing the students' conceptions on the subject. In the second, the students read and discussed the text entitled 'With purple water in sewage, textile factory is interdicted in Paulista/PE', and watched videos addressing problems caused by dyes and water scarcity in the world. To close this moment, the students prepared an inventory containing names of types of industrial products that they would have used during the week, and that could have dyes.

In the third moment, the practical part was carried out, called demonstrative-investigative by the authors. The activity developed in this part basically consisted of two experiments that were adapted by the authors to be carried out in the classroom and with materials that were easy to acquire. The first experiment was based on the degradation of methylene blue by Fenton. The practice consisted of adding a solution of methylene blue, vinegar to a disposable cup to adjust the pH, a ferrous sulfate tablet and creamy hydrogen peroxide, under constant agitation. The second experiment consisted of the degradation of tartrazine yellow by photo-Fenton. Also under constant agitation, a tartrazine yellow solution, vinegar (to fulfill the same function as before), iron sulfate II and creamy hydrogen peroxide were added to a disposable cup. This mixture was placed in a box with an ultraviolet (UV) light source. The source was turned on and the box closed. After 30 minutes, the box was opened and the results were observed.

In the fourth moment, an expository-dialogued class was held, ending with an evaluation of the activity developed. This evaluation consisted of an essay-argumentative

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text produced by the students.

According to the authors, based on the responses to the initial questionnaire, the results of the study indicated that most students had a limited understanding of the social and environmental implications of the use of dyes. In this sense, the teachers confessed that they expected more. However, when comparing the answers to the questionnaire with the production of the final texts, they observed a significant improvement in the conceptions of these students, recognizing that the use of dyes can impact health and the environment. For them, students "[...] broadened their social views considerably, arguing and criticizing, in a solid way, the use of dyes in today's society" (FERREIRA *et al.*, 2018, p. 255).

The authors also showed significant improvements in students' understanding of scientific and technological aspects, especially in relation to chemical concepts, helping them to appropriate the chemical language. This contributed greatly to the mobilization of critical thinking about the theme.

Based on the discussions presented in the article, the approach based on experimentation with implications in the STSA relationship, in our point of view, offers a very valuable perspective for the development of the teaching of Chemistry in the classroom. In this sense, we highlight a statement contained in the text of the PCNEM (BRASIL, 2006, p. 63):

> The STS approach can contribute to the construction of competencies, such as: critical attitudes towards social events involving scientific and technological knowledge, and decision-making on topics related to science and technology, [...], in an analytical and critical way (BRASIL, 2006, p. 63).

4.2 AUTHOR'S TESTIMONY

I remember the Chemistry classes during high school, however, there was a shortage of practical classes. The institution where I studied had a high-quality laboratory, since it was a technical-vocational school. However, even with a well-structured laboratory, practical classes were rare.

The first contact with this space of the school took place when the Chemistry teacher made a presentation of the laboratory, as well as the glassware, equipment and its standards. However, the classes were always numerous, which made it difficult to carry out practices within this environment. In addition, the lack of adequate Personal Protective

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Equipment (PPE) made it unfeasible to carry out practical classes, allowing me and my colleagues to only observe the experiments that were performed by the teacher.

I remember only one practice that took place outside the laboratory, in which the professor performed two demonstrations involving the combustion process. In the first it 'breathed fire' and in the second it produced the 'serpent of the pharaoh'. Another practice was directed to the class to carry it out at home, in groups. It was about homogeneous and heterogeneous mixtures. Each group should create a polyphasic representative system. Unfortunately, there are few memories and, in fact, there were few practices in the Chemistry laboratory during high school.

When I entered higher education, I remember a practice in the discipline of General Chemistry on the flame test, used to identify some ions present in salts. The professor taught an expository class and, later, we went to the laboratory, where we had the opportunity to handle some equipment and glassware.

Another practice occurred only in the discipline of Methodology and Practice of Research, whose main focus was to learn how to prepare reports. In this discipline, my class carried out the practice of titling in pairs or trios, in order to obtain data for the construction of the report, not having as the main point the understanding of that practice. After that, practices were reduced and, due to the COVID-19 pandemic, it became unfeasible to use the laboratory space. The only way to contact experiments, during the remote teaching period, was through YouTube videos, showing practices related to the discipline of Analytical Chemistry. On the return to face-to-face classes, it was possible to carry out some practices related to the identification of cation groups in the discipline of Analytical Chemistry II.

Another fundamental aspect in my training was the privilege of being a PRAE scholarship holder and being allocated at the LQ (Chemistry Laboratory) of FAEC. This provided me with a unique learning about carrying out experiments, especially in relation to the acquisition of knowledge about glassware and reagents, as I actively participated in the preparation of solutions, weighing and maceration of materials for practical classes in the laboratory.

I also participated in PIBID, but in the period of social distancing, during which I had to adapt to the remote format. Other programs and activities were also carried out in this modality. It was a great challenge to have to deal with the lack of access to the school environment and the laboratory, as these spaces are essential for carrying out more effective pedagogical practices. However, even in the face of these limitations, during PIBID, I sought alternatives to continue providing school students with experiences related to content. I carried out practices adapted to the home environment and used audiovisual resources to make the classes more dynamic, such as gas toboggan experiences and potassium permanganate oxidation-reduction processes. Although it was only demonstrations, I tried to work as much knowledge as possible with the students, even in the face of the difficulties that arose.

As a Resident of the PRP-Chemistry Subproject in my last year of training, I also had the opportunity to experience and have a more direct and lasting contact with the laboratory at the school where I followed the classes. With the implementation of the new High School, which included the creation of elective courses and tracks, I was able to follow, throughout a module, the elective of 'Laboratory Practice in Chemistry'. I was able to observe the way the teacher carried out the experiments, and I taught some classes, developing some experiments with the students. Many of them commented during the experimental class that this would have been the best elective, which confirms the literature when it mentions that, in fact, these classes arouse in students a greater interest in the contents of the discipline.

FINAL CONSIDERATIONS

The study of the articles selected for this work enabled a better understanding of the benefits of the applicability of experimental activities, since all of them explained the importance of using practical classes to understand chemical concepts, which makes them fundamental for the success of the teaching and learning process of this discipline. In addition to arousing students' interest in chemical content, the experimental approach makes learning more concrete and effective, contributing to forming citizens capable of consciously intervening in the social, political and cultural issues that surround them.

A teaching based only on theoretical classes is not able to make the teaching of Chemistry meaningful, since this discipline has an essentially experimental character, that is, it is necessary that its contents be taught observing the way chemical knowledge is scientifically constructed. In this way, it is probably possible to train teachers who no longer privilege a totally traditional teaching of Chemistry, contributing to their students being able to understand the concepts in a more concrete and effective way.

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In this sense, the authors of the articles analyzed here emphasize the importance of experimental classes, but list factors that also make this type of activity unfeasible. These obstacles can be overcome, but this requires a better (re)organization of a series of factors, such as the course load, the large number of students per class, the time of each class, the student's motivation and, above all, adequate and continuous teacher training.

The last of the factors listed in the previous paragraph is crucial for the success of the teacher, as it will allow him greater security in the process of planning, elaborating and developing more dynamic, participatory and contextualized classes, which could be observed from the pedagogical experiences lived by the authors of the articles studied.

Thus, it is essential that we recognize the role of schools and teachers in the development of a much larger number of experimental classes. However, even more urgent is the need to raise awareness among society, the competent authorities, school leaders and, especially, teachers, in order to implement changes in the school curriculum, in order to encourage the realization of more experimental classes in Basic School.

In order for the teaching of Chemistry, and other essentially experimental sciences such as Physics and Biology, to acquire a more practical character, it is also urgent to invest in adequate infrastructure, in the acquisition of materials and in the purchase and maintenance of laboratory equipment. However, there is an imperative need for teacher training aimed at preparing professionals capable of developing experimental activities.

Finally, we hope that the results and discussions promoted in this work can encourage the adoption of more experimental practices in schools, in order to provide students with a more complete, meaningful education that gives meaning to 'studying Chemistry'.

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