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THE TEACHING OF ENVIRONMENTAL CHEMISTRY USING INVESTIGATIVE EXPERIMENTATION ON THE THEME OF WATER POLLUTION IN WELLS

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ABSTRACT
Given the difficulty of interacting theory with reality, it is important that the student understands Environmental Chemistry according to what is around him, so that there is meaningful learning. This article presents a teaching proposal through investigative experimentation with the objective of favoring learning in Environmental Chemistry on the

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theme of water pollution. The research was carried out at IFCE/Caucaia-CE, in the period of Feb. -Mai. 2024, with students in the 1st and 2nd year of high school. The methodology continued with the following meetings: diagnosis of prior knowledge; conceptualization of the theme; field activity and sample analysis; and perception of learning. The results obtained showed the construction of a low-cost and reusable well water collection kit. In addition, the analysis of previous knowledge using qualitative statistics (IRaMuTeQ Software) showed that the students have some knowledge on the subject. The evaluation of the perception of learning and experimentation showed that the technical and theoretical training given to students motivates and facilitates meaningful learning on the subject when related to the student's reality. In this context, applied experimentation in order to favor meaningful learning in the teaching of Environmental Chemistry is a great alternative and a great ally to make the teaching and learning of high school students from public/technical schools more attractive, effective and meaningful.

Keywords: Environmental Chemistry, Water Pollution, Water from Wells, Experimentation, Meaningful Learning.

INTRODUCTION

The teaching of Environmental Chemistry favors the critical sense and understanding of the concepts of Chemistry because it is associated with the reality and interests of the student (OLIVEIRA *et al.* 2016). However, the content must be articulated from contextualized themes to give meaning and significance to them, through the main mediator between it and learning, which is the teacher (NASCIMENTO & SEIXAS, 2020; MARQUES *et al.* 2020). In accordance with the contextualization of the content with the reality of the learner, we have the National Curriculum Parameters (PCN) that suggest for high school the development of skills to research, search and analyze information, as opposed to simple memorization exercises. It is also necessary to select content related to subjects or problems according to the student's reality so that meaningful learning occurs (BRASIL, 2000). In addition, another existing legal aspect is the promotion of environmental education at all levels of education through the Federal Constitution of 1988 in Brazil, as a guarantee of an ecologically balanced environment (BRASIL, 1988).

The theme "environment" was suggested for the integration of contents from different disciplines, including the teaching of Environmental Chemistry (BRASIL, 1997). In this context, according to Santos & Rodrigues (2018), the themes "water" and "water pollution" meet the understanding of social reality and allow us to address various contents pertaining to environmental chemistry, as it is known that this discipline covers the study of several themes such as land, water, living environments and air (atmosphere), and thus it is possible to correlate water pollution with properties, concepts and other observations that water brings to teaching (MANAHAN, 2013).

The laws that govern education in Brazil have been undergoing changes that impact the teaching work, further increasing their efforts, in order to carry out educational practices that promote research, providing an investigative learning environment through experiments that correlate with the content (DINIZ *et al.* 2021; MARRA & ALMEIDA, 2023; NASCIMENTO & SEIXAS, 2020). From this perspective, investigative experimentation stands out as a promising and appropriate methodology for the teaching of Environmental Chemistry, as it has the character of scientific investigation with the help of the teacher, through debates of real problems, which will produce scientific knowledge so that students participate and carry out small researches. This new knowledge will interact with the students' reality and the student's relevant previous knowledge, resulting in meaningful learning (MOREIRA, 2012).

Thus, in view of the presentation of an Environmental Chemistry teaching so that the contextualization of the content with the students' reality occurs, this article presents a proposal for a methodology with the objective of favoring a significant learning in the teaching of Environmental Chemistry on the theme of water pollution in wells through investigative experimentation.

THEORETICAL FRAMEWORK

ENVIRONMENTAL CHEMISTRY IN TEACHING

Environmental chemistry deals with the reactions and sources of chemical substances present in the atmosphere, water and soil (BAIRD, 2011), and according to the Environmental Chemistry Division (AMB) of the Brazilian Chemical Society (SBQ), it also studies the chemical processes that occur in nature, natural or anthropic, which affect human health and the planet. This aims to teach what anthropogenic pollution is, raise awareness of its effects and make the student know and understand in an integrated way the chemical processes that occur in the environment around him (CANELA, 2017; FERREIRA, *et al.* 2021).

Currently, there is a great concern with understanding environmental chemistry with the aim of improving the quality of life on the planet (CARVALHO, *et al*. 2023), either to understand the origins of environmental damage, or to develop strategies to minimize impacts (SILVA, *et al*. 2020) through this discipline. Thus, in the face of numerous transformations, the teaching of environmental chemistry has been changing. However, one of the reasons that may lead students not to be interested in this content, because they do not have an affinity with chemistry, may be the use of traditional teaching methodologies (GONSALEZ & SOARES, 2023), which makes it difficult to understand the subject.

In view of this, we know that learning brings its particularities throughout the history of humanity, and educators in the teaching of environmental chemistry must remake themselves in the act of teaching, developing the students' reasoning with solid proposals using subjects related to the environment so that they can interconnect theory with the student's daily life, personal life and experience. which will allow prominence in social life and meaning to the content, (NUNES; ROSEMARY, 2015; BRAZIL, 2000; MORES, *et al.* 2016; LOPES *et al*. 2020). Therefore, knowledge of environmental chemistry should be a target for transformation in teaching (MAINIER & MAINIER, 2024).

Furthermore, according to Law No. 9,795/1999 emphasizes that environmental education is an essential component of national education, and should be present at all levels and modalities of the educational process, and be developed with the objective of building a global awareness related to the environment to obtain values of protection and improvement for the environment (BRASIL, 1997). In view of this, environmental chemistry relates chemistry to environmental education, seeking to reveal how reactions occur so that we can have critical thoughts about our attitudes in the environment (DIAS; RIOS, 2018).

EXPERIMENTATION AND MEANINGFUL LEARNING

It is important that students build their own knowledge through experimentation and autonomy. According to Taha *et al* (2016), there are some types of experiments that help in this construction, which are: the illustrative, *gig*, problematizing and investigative. The latter, which is of interest to us, has the character of scientific investigation, promoting debates through real problems that enable investigation (LEITE, 2018). And although there is the premise that the teaching of chemistry has not been providing good learning with what is worked on, it is of great importance to understand the contents through the student's daily life (GONZAGA, *et al.* 2020) through investigative experimentation. But it is necessary for the student to be motivated to learn the new concepts, as this requirement is a great influence on the effectiveness of meaningful learning (AUSUBEL, 2003), as this learning is an active process that obeys the relationship between the acquisition of new knowledge that is significant for the learner, with that previously acquired by the learner, in a non-arbitrary and non-literal way, reformulated according to the student's language (AUSUBEL, 2003). Thus, it is important to first diagnose what the student already knows, and then use potentially significant didactic resources (ALISON; LEITE, 2016). And it is in this context of meaningful learning that experimentation must be eminent, making the subjects leave the position of spectators and become developers of the action (SILVEIRA *Et. Al.* 2021), because when experimentation is well planned, content theory becomes more enjoyable, increasing the learner's participation, and contributing to meaningful learning in relation to the topic addressed (ALISON; LEITE, 2016).

EXPERIMENTATION IN THE TEACHING OF ENVIRONMENTAL CHEMISTRY

According to specific competence three of the National Common Curricular Base (BNCC) at the high school level, it is expected that students can appropriate procedures and practices such as sharpening curiosity about the world, building hypotheses, investigating problem situations, experimenting with more improved data collection and analysis, through some skills such as: employ measurement instruments and interpret experimental data or results to evaluate and justify conclusions in coping with problem situations from a scientific perspective; and interpret data in the form of graphs or tables in order to build the selection of reliable sources of information (BRASIL, 2018).

But in the face of a complex teaching system in the classroom, due to the student's personal experiences, it is necessary to create conditions to develop an active role in Chemistry classes in order to encourage research and develop the student's reasoning capacity. And knowing that the discipline of chemistry "walks" together with experimentation, investigative experimental activities are a very useful didactic resource, despite being little used, but they help teaching and help teachers in this process, providing improvements in their classes through traditional teaching (OLIVEIRA *et al*, 2016; FERREIRA *et al.* 2021; SILVA *et al.* 2018; SILVA *et al.* 2021; BARBOSA, *et al.* 2016; BALDAQUIM, *et al.* 2018). Since the 60s, the explanation of the scientific method has been mastered in the teaching of chemistry, as well as applying it with the objective of carrying out experimentation in the classroom, because in investigative experimentation the teacher, along with problem, questioning and dialoguing situations, leaves the position of reproduction of knowledge and starts to have other attitudes as a mediator, advisor, conductor to reflection, and also raises hypotheses discussing results obtained to reach certain conclusions (NEVES *et al.* 2019; PEIXOTO, 2016). And these discussions that contextualize the concepts can arouse more interest SILVA, 2019). And the importance of performing this activity to generate reflection in the student becomes evident, leading him to hypotheses to, finally, understand the phenomena (BALDAQUIM, *et al*. 2018) in the teaching of environmental chemistry. In addition, the teacher also proposes an exercise and leads the student to research, performing experimental activities, which provide this scientific development that explores intellectual capacity and builds a critical view of certain facts as well as sharpens curiosity (SANTOS, *et al.* 2016; CARVALHO, 2013; ALISON *et al.* 2016; ROCK *et al.* 2019). In this context, investigative experimentation can be carried out in the classroom in the face of a problem-situation where students, when dialoguing, will raise hypotheses for solutions (DA SILVA; DA SILVA, 2019). And in the teaching of environmental chemistry, this method becomes relevant, because through it the student explores his creativity, critical sense and improves his teaching and learning process (GONÇALVES; GOI, 2019).

WATER, POLLUTION AND LEGISLATION

Water is present in many forms, and covers 70% of the planet's surface, mostly in liquid form. All organisms need this water resource to survive, emphasizing the importance of this in presenting adequate physical and chemical conditions for its use (BRAGA, *et al.* 2005). Groundwater has less restriction of use in natura compared to surface water, as the soil layers serve as natural filters eliminating contaminants (HERRÁIZ, 2009). However, for human supply purposes, the water needs to go through a disinfection process, as recommended by the Ministry of Health (MS) Ordinance No. 2.914/2011, which establishes the standards of potability and also defines the tolerable levels of certain impurities, and CONAMA Resolution No. 368 of April 3, 2008, which deals with the use of groundwater (HAGER, 2007).

Water pollution is linked to the concentration of pollutants (waste) in water that can cause damage to human health and deterioration of materials. This pollution is the alteration of its physical, chemical and biological characteristics by any actions in the environment, in an anthropogenic way, which can come from two types of sources, the punctual or the diffuse. The first occurs when pollutants are introduced by individualized releases, and the second occurs along the margin of bodies of water without a specific release point (BRAGA, *et al*. 2005). In addition, organic waste, which are materials susceptible to bacterial degradation, are part of water pollution, due to the environmental consequences that, due to the increase in intense bacterial activity in the receiving waters, reduce oxygen levels incompatible with life, and there is also the possibility of the existence of pathogenic agents being transmitted to humans (CARAPETO, 1999). In addition, another type of water pollution is non-biodegradable water pollution with characteristics of processes so slow that the addition of this type of pollutants is considered permanent. This category includes halogenated hydrocarbons, industrial chemicals and toxic metals, which can cause the presence of Total Dissolved Solids (TDS), chemicals and high water turbidity (CARAPETO, 1999). It is worth mentioning that toxic metals such as Zinc (Zn), Copper (Cu), Manganese (Mn) and Iron (Fe), for example, can bring symptoms such as nausea, vomiting, hemolytic anemia, pneumonitis, neuropsychic disease, cancer and hypertension in humans. And such pollutants come from industries, steam production, and textiles (NBR 9897; SAINTS *et al*. 2018; KLAASSEN & WATKINS III, 2012; GOMES *et al*. 2018).

In view of this, for some time the concern regarding the entry of pollutants into the aquatic environment has been growing, as they cause damage to both human beings and the environment (DIAS; NAYAK, 2016), making it of fundamental importance to monitor water quality, to control potability levels within the safe range acceptable by legislation to result in a healthy quality of life for the population (FERRAZ, *and. ly.* 2018).

It is also known that physicochemical characteristics are very important for understanding the anthropogenic influence on water bodies (ARCOS & CUNHA, 2021), and with this, physicochemical parameters, in addition to representing water quality, comprise the dynamics of toxic metals in water, identifying information through Electrical Conductivity (EC), for example (SILVA *et al*. 2017; BAGGIO *et al.* 2016), which identifies the concentration of salts in the water (ALENCAR *et al.* 2019). It is worth noting that the classification of water bodies and their environmental guidelines follow the Resolution of the National Council for the Environment - CONAMA No. 357/2005, which presents the maximum limits of toxic metals for the potability of water in class I and II, and which considers that human health should not be affected by the deterioration of water quality. Ordinance GM/MS No. 888/2021, which establishes the potability standard with allowed values for the parameters of water quality for human consumption, and the World Health Organization (WHO) (Table 1).

Table 1 - Physicochemical parameters of water according to government agencies

	CONAMA 357/2005 (Class I/Class II)	PORTARIA GM/MS No. 888/2021	WORL HEALTH ORGANIZATION (WHO)	
Cu (mg/L)	0,009	-	-	
Zn (mg/L)	0,18	-	-	
Fe (mg/L)	0,3	-	-	
Mn (mg/L)	0,1	-	-	
Na (mg/L)	-	200	-	
K (mg/L)	-	-	Indefinite	
Color (uH)	-	15	-	
CE* (µS)	Indefinite	-	-	
Dureza total (mg/L)	-	300	-	
pH	-	6,0 – 9,0	-	
Turbidity (uT)	-	5	-	
SDT** (mg/L)	-	500	-	

*CE – Electrical conductivity; ** SDT – Total Dissolved Solids; (-) unreferenced
Fonte: CONAMA 357/2005; Portaria GM/MS nº 888/2021; Worl Health Organization (WHO)

CONAMA Resolution No. 357/2005 does not establish EC levels. However, it is known that levels above 100 µS indicate negative changes in the environment (BAGGIO, et al. 2016; CETESB, 2017), as well as the World Health Organization, which did not refer to a maximum concentration limit of Potassium (K) in water because this substance is very beneficial to humans even in high concentrations.

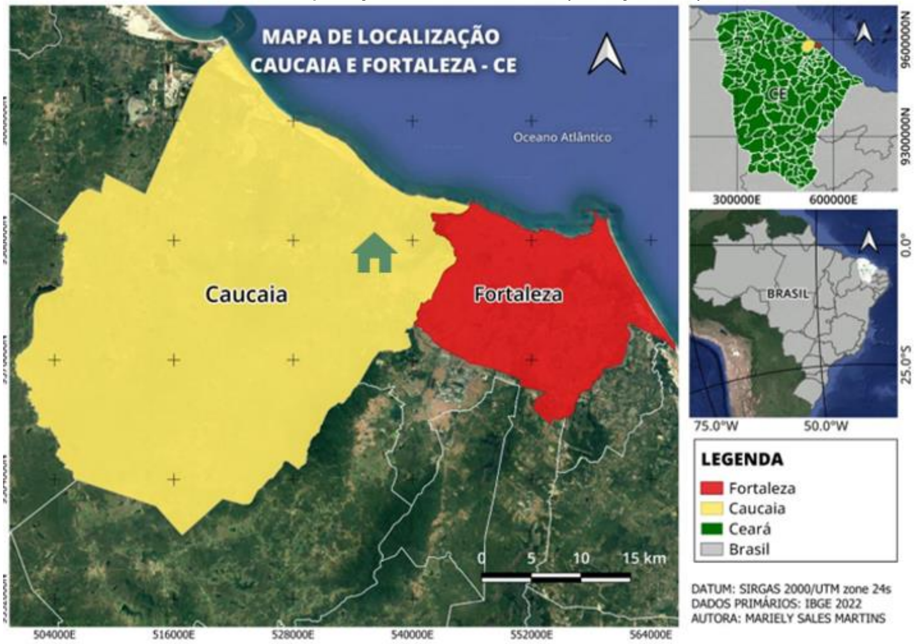
METHODOLOGY

METHODOLOGICAL PROCEDURE

This work was carried out at the Federal Institute of Education, Science and Technology of Ceará (IFCE), *Campus* Caucaia, located at Rua Francisco da Rocha-Pabussu, municipality of Caucaia (Figure 1), in the first half of 2024, between the months of

February and May. According to IPECE (2017, 2021), Caucaia is a municipality located in the North of Ceará, with latitude 3º 44' 10" and longitude 38º 39' 11". Its absolute area is 1,228.5 km² and it is at an altitude of 29.9 m. Its distance as the crow flies from the capital is 20 km. The city's climate varies between tropical hot, semi-arid, mild, tropical, hot, sub-humid, and tropical hot humid. The temperature varies between 26°C and 28°C and the rainfall index is around 1243.2 mm, with a rainy season from January to May.

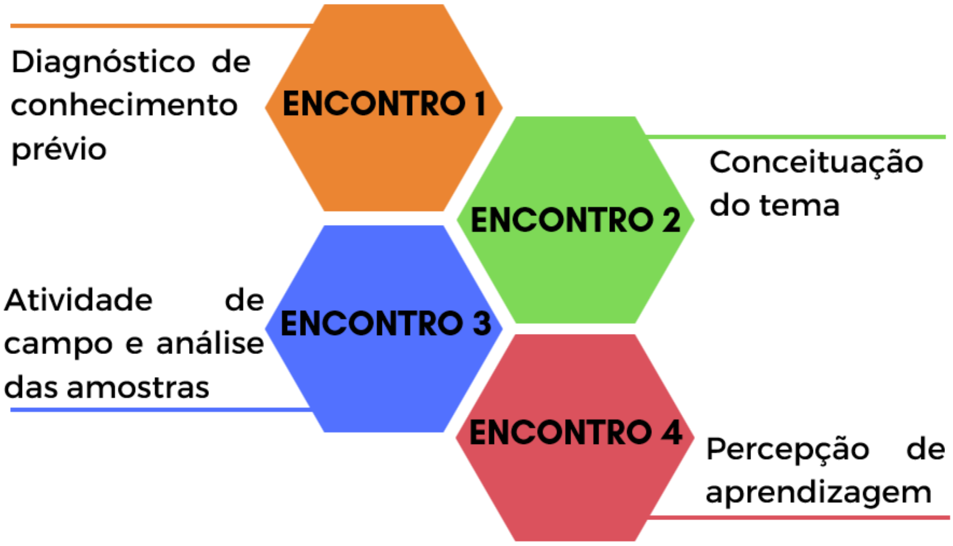
Figure 1 – Location of the Municipality of Caucaia-CE (study area) in relation to the capital.



Source: Prepared by the authors through Qgis (2024).

The project was applied in the Integrated Technical Course in Chemistry, in the classes of the 1st semester, of the discipline of environmental management, and 3rd semester, of the discipline of Analytical Chemistry, equivalent to the 1st and 2nd grade of high school. These classes were formed by 40 and 38 students, respectively, aged between 15 and 18 years old. However, the selection of participants was based on the presence and use of wells at home and we had 11 students in one class and 12 in another, respectively. The school was selected due to its location and the presence of a laboratory equipped for the analyses.The participation of the students in this research was conditioned to the signature of their guardians and the volunteer students to the Informed Consent Form addressed to parents (TALE) and the Informed Consent Form (ICF). Subsequently, the present study was submitted to and approved by the Research Ethics Committee (CEP) and approved in accordance with the opinion of CEP No. 6.599.663. For the development of the research, the following didactic sequence was carried out (Figure 2):

Figure 2 - Didactic sequence executed in the project.



Source: Authors (2024)

Prior Diagnosis x Conceptualization of the theme

In this stage, a diagnostic instrument was used to assess the students' previous knowledge (Chart 1**).** The questionnaire of previous perceptions of toxic metal pollution in well water was applied through *Google forms*, as this type of approach facilitates both the student's access and the researcher's obtaining and processing of data (VIEIRA *et al.*, 2010; DA COSTA ANDRES *et al.*, 2020). The *link* to the form was sent through a social network, *whatsapp*, (https://docs.google.com/forms/d/1pr94lumRROWeXE2ewNpIkEo31d87DGVuFKQwbDDJ-0A/edit) and access was only allowed through the-student's institutional email. The questions were answered in a single moment, and the student had to justify or not his answers.

Chart 1 - Diagnosis of prior knowledge.

PREVIOUS DIAGNOSIS
1. What is water pollution?
2. What can contribute to water pollution
3. What are the consequences of water pollution?
4. Does water pollution impact human health and the environment? Justify.
5. What types of pollutants can contaminate water?
6. What actions can be taken to reduce pollution in the water?

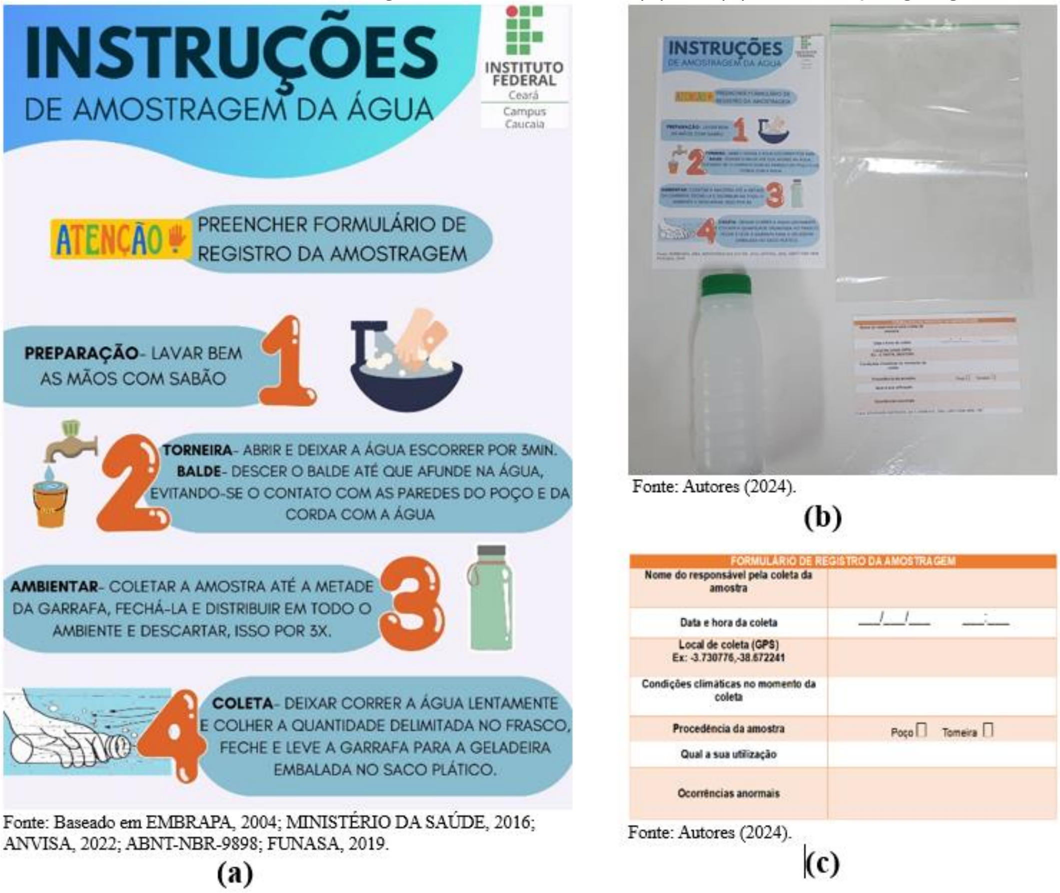
Source: Authors (2024)

The analysis of the responses to the previous diagnosis occurred qualitatively through the Analysis of the Similarity of the responses with the aid of the Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires (IRaMuTeQ version 4.3.1). After the previous evaluation of knowledge, theoretical classes were held, where the aspects of the toxic metal pollution in well water were contextualized, defined and explained with practical examples, in order to make learning meaningful with the inclusion of new concepts and also guide students to the next stages of the project.

Description of the Experimental activity

The student volunteers who had wells and agreed to participate in the project received technical guidance on collection and a kit (Figure 3b) containing a water collection manual (guidance), a sampling registration form and a sterilized 500 mL polyethylene bottle (Figures 3a and 3c).

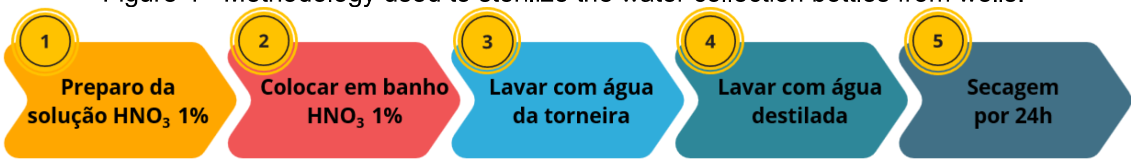
Figure 3 - Instruction Manual for collecting water from the well (a), kit (b) and sampling registration form (c).



Source: Authors (2024).

The polyethylene bottles used in this project were sterilized according to the flowchart in Figure 4 (APHA, 2017). After this procedure, the students collected the well water and then the samples were taken to the laboratory according to the guidelines given. Then, the samples were filtered, pH measured (Figure 5) and acidified with HNO_3 1% to pH 2 and refrigerated at 4º C until metal analysis.

Figure 4 - Methodology used to sterilize the water collection bottles from wells.



Source: Authors (2024).

The physicochemical parameters (conductivity, pH, total hardness and metals) were analyzed in triplicate for each well water sample, as described by APHA, (2017) (Table 2). A blank was prepared for each analysis following the same methodology.

Table 2 - Parameters and analytical methods used for well water analysis

PARAMETERS	ANALYTICAL METHODS	REFERENCE*	Instruments
Dureza total (mg CaCO3/L)	2340 C EDTA Tritimetric Method	APHA, 2017	-
Sódio (mgNa+/L)	3500 Na B Flame emission photometric	APHA, 2017	Tecnow7000
Potássio (mgK+/L)	3500 K B Flame photometric Method	APHA, 2017	Tecnow7000
Metais (mgFe/L)	3111 B Direct Air-Acetylene Flame Method	APHA, 2017	*Thermo Scientific*
ph	4500 H+ B Electrometric Method	APHA, 2017	MS Tecnopon
Conductivity	2510 B Laboratory Method	APHA, 2017	MS Tecnopon,

Source: Authors (2024).

Then, the free software QGIS version 3.28.2 was used with the help of the Google Earth plugin for georeferencing and elaboration of location maps of the collection points and Excel for data treatment.

Figure 5 – Filtration and measurement of water pH

Source: Authors (2024).

Assessment of learning and didactic resources

The results of the research were presented to the students and discussed in class, correlating each point of the research with maps, tables and graphs. Next, a questionnaire was applied to evaluate the perceptions of learning and the experimental resource as a teaching proposal through a questionnaire (Chart 2).

Chart 2 - Evaluative questionnaire of the experimental resource as a teaching tool.

Questionnaire on the perception of learning of the experimental resource as a teaching proposal		
I fully disagree	✏	Answer each statement according to the degree of agreement, according to the scale on the side.
Disagree	✏✏	
I don't agree, nor do I disagree	✏✏✏	
Agree	✏✏✏✏	
I strongly agree	✏✏✏✏✏	

	✏	✏✏	✏✏✏	✏✏✏✏	✏✏✏✏✏
1) The experiment contributed to my learning in water pollution					
2) The experiment was efficient for my learning compared to lecture-only classes					
3) I was able to relate what I learned to my reality					
4) My attention to the theme was stimulated					
5) This approach leveraged the knowledge I already had					
6) My active participation influenced the learning of the discipline					
7) This type of approach left something to be desired					

Any comments will be very welcome and helpful to the project: Thank you very much for your important collaboration! ____ ____ ____ ____ ____ ____ ____ ____

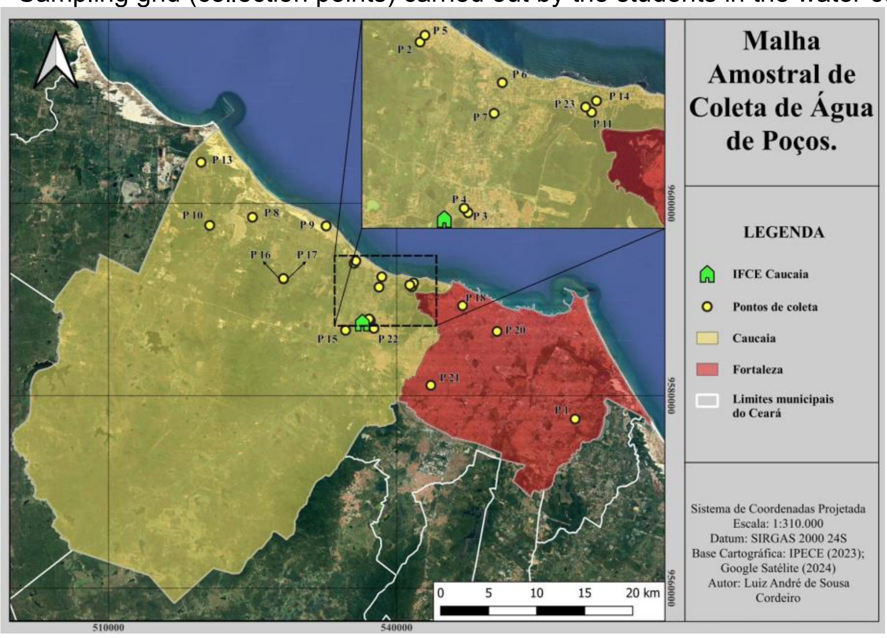
Source: Based in PETRI, *et. al*. 2017; ROCHA, *et. al*. 2015; ARINI, *et. al*. 2021.

RESULTS AND DISCUSSION

ANALYSIS AND REFLECTION OF THE SAMPLE GRID AND WELL CHARACTERISTICS

The results of the location of the collection points (wells) carried out by the students are shown in Figure 6. In this study, the students were able to verify that the distribution of the sampling points was between Caucaia (19 points) and Fortaleza (4 points). At this point, we presented the importance of carrying out a spatial distribution of the collection points that would cover the largest possible area of the sampling site in order to have a faithful representation/approximation of the different water quality profiles as a function of location. Through the map it was verified that most of the wells collected were located near the coast. The challenges of doing research on water pollution were also highlighted, because through the map they were able to understand the dimension of planning, preparation of equipment, displacement, and the importance of engaging the population as a way to expand discussions and compare points with different characteristics. In the discussions, it was also pointed out by the students within the map how points P13 and P10 stood out, due to the distance from the others, as they are located in the limits of the Municipalities of Caucaia and São Gonçalo.

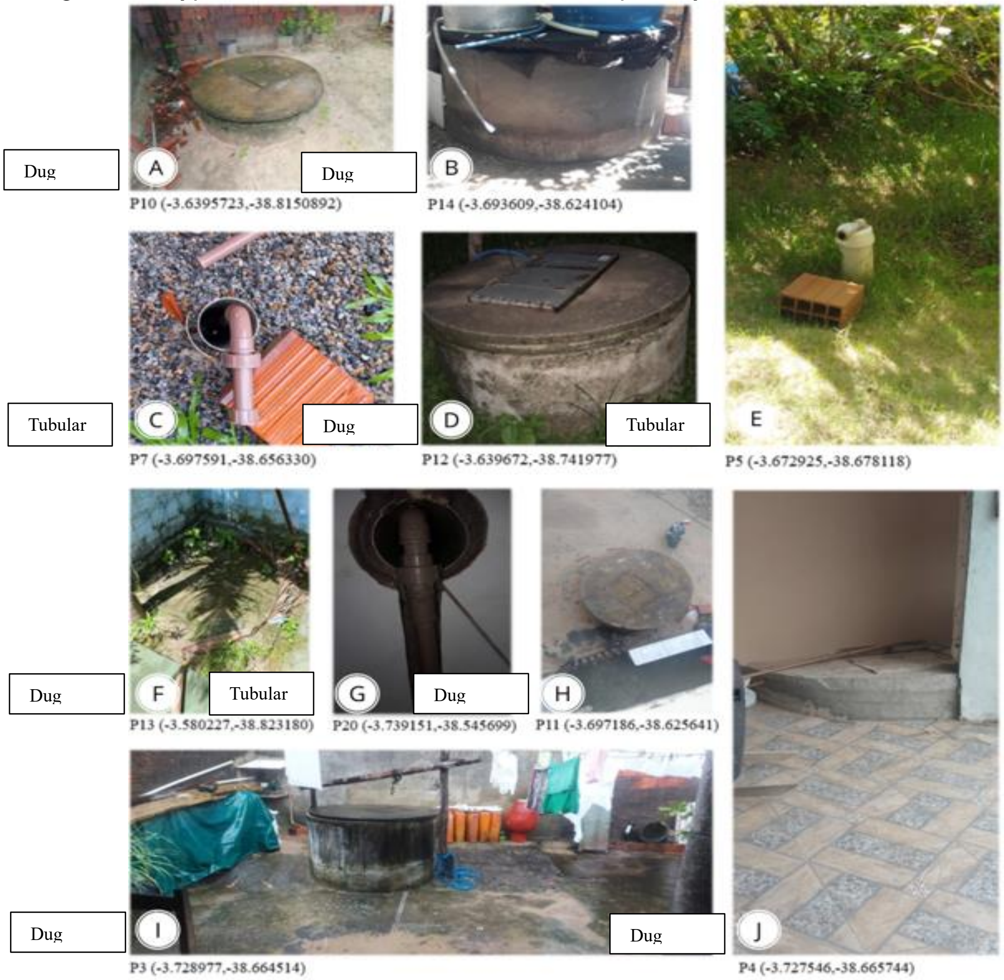
Figure 6 - Sampling grid (collection points) carried out by the students in the water collection.



Source: Prepared by the authors through Qgis (2024).

The analysis and reflection of the collection results also helped us to discuss the definition of what a water well is and its types. The literature reports that a well is a generally vertical, man-made system that acts on the subsurface, used for the capture, recharge or observation of groundwater through artificial or natural mechanisms". These can be divided into two groups (excavated and tubular) which, in turn, have subdivisions according to the mode of construction, diameter, coating and hydraulic pressures (RECURSOS HIDROS, 2015). Our results showed that most of the wells studied are of the excavated type (cacimba , cacimbão) and a minority tubular (phreatic and non-gushing artesian) (Figure 7a - 7j). $\emptyset = 0{,}5m$ $\emptyset = 1{,}0m$

Figure 7 – Types and characteristics of wells sampled by the students for water collection.



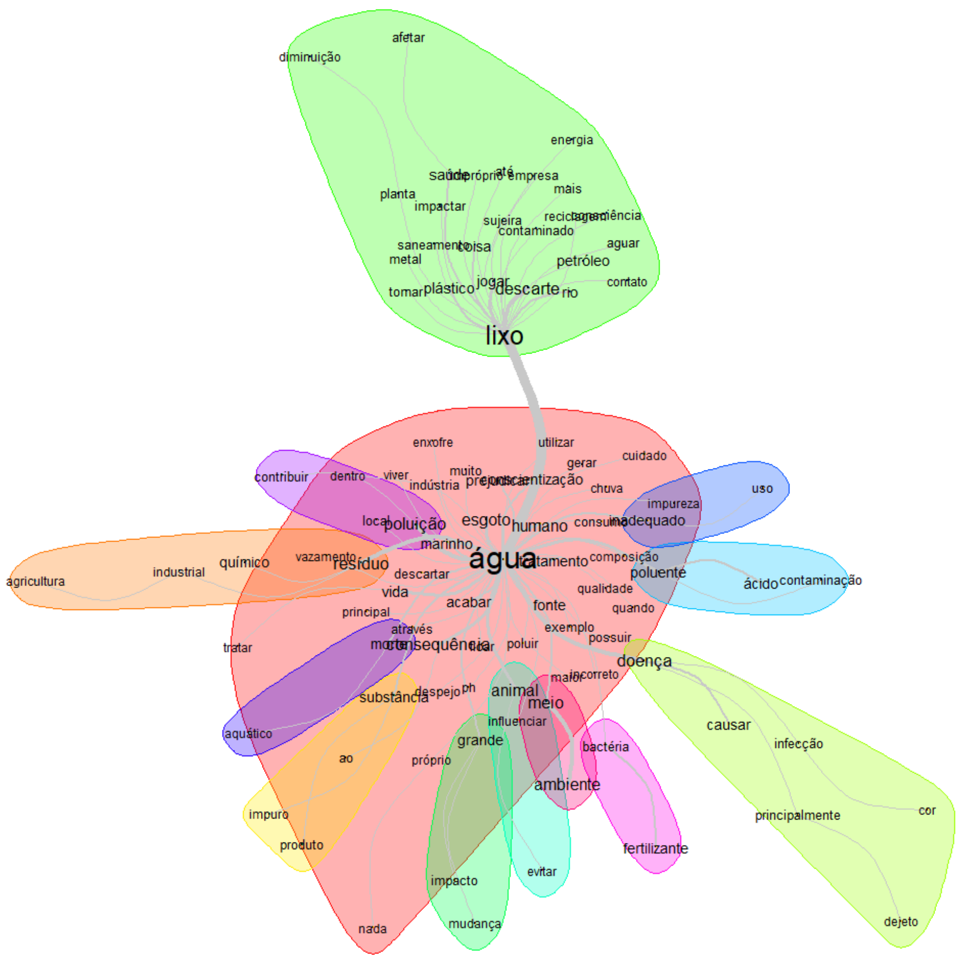
Source: Authors (2024).

ANALYSIS OF THE PERCEPTION OF PRIOR KNOWLEDGE

The results of the prior knowledge diagnosis were carried out through lexicographic textual analysis with the support of the IRaMuTe 4.3.1 software. For this analysis, 23 textual *corpus formed* by the answers to the questionnaires presented in subsection 3.1.1 (Figure 8) were tabulated. It is verified that the tree of similarity graph of this textual corpus is presented in thirteen nuclei (halos), with the pink halo being the main root with a predominance of the word 'water', followed by 'garbage', 'pollution', 'waste', 'consequence', 'substance', 'large', animal', 'environment', 'fertilizer', 'disease', 'pollutant' and 'inadequate'. In addition, one can observe the relevance of the relationships and connections between the central term 'water' with the term 'garbage' above and the terms 'pollution', 'waste', 'consequence' and 'substance' on the left side, 'large', 'animal', 'environment' and 'fertilizer' below and 'disease', 'pollutant' and 'unsuitable' on the right side.

This composition of nuclei may indicate that the published answers are in 4 general lines of prior knowledge: scientific, declarative, basic and intuitive, that is, that students have a satisfactory and diversified prior knowledge of the subject (SANTOS and ROYER, 2018).

Figure 8 – Similarity Tree Graph of the answers to the previous knowledge questionnaires.



Source: Authors (2024).

STRUCTURING OF KNOWLEDGE

It is known that for the significant construction of knowledge through an investigative experimentation, it is necessary for the student to understand the theme mediated by the teacher, in addition to the realization of the experimental part (FARIAS *et al.* 2024). In other words, for students to build their knowledge, it is necessary for the mediator to use inquiries and questioning through a problem-situation, leading them to small researches, and consequently to the autonomy of this construction. Therefore, after the results of the analysis of the perception of previous knowledge, the theme (Figure 9a) and a training

(Figure 9b) on how to proceed in the practice of water collection using the polyethylene bottle and experimental were presented.

Figure 9 - Presentation of the theme (a) and formation of the collection practice (b).

(a) **(b)**

Source: Authors (2024).

ANALYSIS OF METAL LEVELS AND PHYSICOCHEMICAL PARAMETERS OF WATER

The reflection of the results obtained for the levels of metals and Physicochemical analyses are presented in Table 3. In this one, we were able to verify the absence of all metals (Cu; Zn; Fe; Mn) in all well samples analyzed, except for wells P7 (Fe 2.3312mg/L and Mn 0.0271mg/L) and P12 (Fe 0.0421 mg/L). The amplitude of the results for the analyses of Na (8.9854 mg/L-125.66mg/L) and K (0.9496mg/L- 48.2801mg/L) showed evidence of high salinity caused by the Na ion^{+}, which can cause soil salinization (VOGEL & BELTRAME, 2022). The results of electrical conductivity (EC) showed that the values vary from 1.71mS/cm2 – 2.61mS/cm2, indicating a high amount of ions (cations and anions) in solution. These results corroborate the high values found for Na+, K+, Ca+2 and Mg+2. The results of the total hardness analyses (Ca+2 and Mg+2) showed variations from 29.47 to 368.46 mg/L. According to the literature, total hardness is caused by multivalent cations, the main ones being calcium (Ca+2) and magnesium (Mg+2). However, there are other secondary causes, which are iron (Fe+2), manganese (Mn+2), copper (Cu+2) and zinc (Zn+2) (SANTANA *et al.* 2016; MENDONÇA & FLORES, 2017). Although the Ministry of Health ORDINANCE No. 888/2021 limits the concentration of water hardness to 300 mg/L of CaCO3, it is possible to obtain a classification of levels of this substance. According to SCHORR 2022, a hardness less than 50mg/L is considered soft water; between 50 and 150 mg/L, water with moderate hardness; between 150 and 300 mg/L, hard water; and greater than 300 mg/L, very hard water. Thus, according to the results obtained, the only sample that is classified as very hard water is well P9, while wells P2, P11, P14 and P20 are classified as hard water.

Table 3 - Results of the analysis of toxic metals and Physico-Chemical of the water of the wells.

Wells	Collection period	Average rainfall (mm)	Conductivity (mS)	pH	Fe (mg/L)	Mn (mg/L)	Zn (mg/L)	With (mg/L)	K (mg/L)	On (mg/L)	Dureza total (mg/L)
P1	25/03/2024	0.0	2.02	6	< LD	< LD	< LD	< LD	0,9496	8,985	29,47
P2	25/03/2024	0.0	1.92	6	< LD	< LD	< LD	< LD	13,37	67,89	184,2
P3	25/03/2024	0.0	2.28	6	< LD	< LD	< LD	< LD	10,41	58,51	99,48
P4	25/03/2024	0.0	2.33	5	< LD	< LD	< LD	< LD	15,82	65,92	106,8
P5	25/03/2024	0.0	2.03	5	< LD	< LD	< LD	< LD	8,810	57,15	121,5
P6	25/03/2024	0.0	2.34	5	< LD	< LD	< LD	< LD	9,989	66,04	103,1
P7	25/03/2024	0.0	1.93	6	2,33	< LD	< LD	< LD	7,510	39,36	95,80
P8	25/03/2024	0.0	1.93	5	< LD	< LD	< LD	< LD	3,519	10,83	36,84
P9	24/03/2024	22.0	1.64	6	< LD	< LD	< LD	< LD	9,778	59,12	368,4
P10	24/03/2024	22.0	1.78	6	< LD	< LD	< LD	< LD	12,46	44,55	128,9
P11	25/03/2024	0.0	2.24	6	< LD	< LD	< LD	< LD	9,475	42,20	151,0
P12	25/03/2024	0.0	2.08	5	0,042	< LD	< LD	< LD	8,508	30,4751	88,43
P13	25/03/2024	0.0	2.15	5	< LD	< LD	< LD	< LD	11,19	41,71	81,06
P14	27/03/2024	21.4	2.61	5	< LD	< LD	< LD	< LD	13,98	73,57	228,4
P15	25/03/2024	0.0	2.46	5	< LD	< LD	< LD	< LD	7,268	42,45	136,3
P16	26/03/2024	26.0	2.52	5	< LD	< LD	< LD	< LD	48,28	125,64	88,43
P17	26/03/2024	26.0	2.33	5	< LD	< LD	< LD	< LD	19,78	117,02	55,27
P18	26/03/2024	26.0	2.09	5	< LD	< LD	< LD	< LD	20,87	76,78	147,3
P20	26/03/2024	26.0	2.31	6	< LD	< LD	< LD	< LD	22,44	75,06	224,7
P21	01/04/2024	0.0	2.25	6	< LD	< LD	< LD	< LD	4,759	20,71	77,37
P22	31/03/2024	12.0	2.38	6	< LD	< LD	< LD	< LD	20,08	57,76	121,5
P23	27/03/2024	21.4	2.13	6	< LD	< LD	< LD	< LD	10,08	53,81	110,5
P24	02/04/2024	0.0	1.71	6	< LD	< LD	< LD	< LD	7,087	54,68	51,58

< LD = less than the detection limit of the method/Source: Authors (2024)

LEARNING ASSESSMENT AND DIDACTIC RESOURCE

After all the stages of the didactic sequence, a diagnosis of the students' perception of learning and of the experimental activity was carried out, as shown in Graph 1. The results showed that 94.10% of the students see that the practical activity contributed/improved the teaching of concepts in water pollution. Many attested that this methodology is much more practical, rich and easy, when compared to the traditional methodology (questions 2/88.20% and 5/82.30%), where the teacher uses the whiteboard to explain the content. On the other hand, between 6 – 32.30% answered the questions with some indifference, while 3% of these were unable to relate what they learned to their reality. In the light of these results, Moreira (2012) highlights that there are specific conditions for meaningful learning, such as: planning, organization, significant instrumental resource and the student's predisposition to learn the content.

Graph 1 - Results of the assessment of learning perception and investigative activity.

Source: Authors (2024).

FINAL CONSIDERATIONS

The present work showed that applied experimentation in order to favor meaningful learning in the teaching of Environmental Chemistry is a great alternative and a great ally to make the teaching and learning of high school students from public/technical schools more attractive and effective. The work pointed out the efficiency of experimentation as a teaching methodology, because when well organized and planned, it can be simple to apply and with excellent results. In addition to emphasizing the importance of placing students at the center of the teaching process, the data collected and presented served as a reference for the dialogue on the pollution of water from wells in the classroom, and these values are only an indication of the concentrations of pollutants existing in each sampled location. This project also reinforces the importance of interdisciplinarity and multidisciplinarity, in such a way that Environmental Chemistry should not be seen as an isolated science, but that it promotes the teaching and learning process of students in a significant way, in order to promote the possibility of human, critical and reflective formation of the student. And finally, it is possible to realize that there is still a reasonable way to go for experimental classes to be implemented in schools, since factors such as infrastructure, time, teacher, pedagogical project, social and environmental factors, corroborate to hinder the implementation of this methodology.

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