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Contributions of the planned obsolescence theme for the learning of electrochemistry

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RESUMO

This work aimed to investigate contributions from a thematic workshop on the theme “planned obsolescence”, aiming to minimize conceptual difficulties in learning concepts related to electrochemistry. Based on an activity in the form of a thematic workshop taught by students majoring in Chemistry Teaching, for 13 students of a technical course in electrical engineering of a private school in 2022. The thematic workshop was based it on the perspective of the Three Pedagogical Moments (3PM). Throughout the workshop, participants answered some questions based on the experimental activities that were developed. The students' answers were analyzed based on content analysis, and it was possible to notice the emergence of three categories, which indicated possible contributions from the use of the theme: “planned obsolescence”, contamination by metals, and chemical reactions. While carrying out the activity, it was possible to infer that the ideas expressed by the students present contributions from the theme to learning, showing the potential of a contextualized experimental activity based on a thematic approach.

KEYWORDS: experimentation; environmental context; science teaching.

Contribuições da temática obsolescência programada para a aprendizagem de eletroquímica

RESUMO

O presente trabalho visou investigar contribuições de uma oficina temática com o tema "obsolescência programada", com o objetivo de minimizar as dificuldades conceituais na aprendizagem de conceitos relativos à eletroquímica. A partir de uma atividade em forma de oficina temática, aplicada por professores em formação, acadêmicos do curso de Licenciatura em Química, para 13 alunos do curso técnico em eletrotécnica, de uma escola da rede privada de ensino no ano de 2022. Para a elaboração da oficina temática, nos fundamentamos na perspectiva dos Três Momentos Pedagógicos (3MP). No decorrer da oficina os participantes responderam algumas questões baseadas nas atividades experimentais que foram desenvolvidas. As respostas dos estudantes foram analisadas com base na análise de conteúdo, sendo possível reconhecer a emergência de três categorias, que indicaram possíveis contribuições do uso da temática: "obsolescência programada", contaminação por metais e reações químicas. Com o desenvolvimento da atividade pôde-se inferir que as ideias expressadas pelos estudantes demonstram contribuições da temática para o aprendizado, demonstrando a potencialidade de uma atividade experimental contextualizada baseada em uma abordagem temática.

PALAVRAS-CHAVE: experimentação; contexto ambiental; ensino de ciências.

ISSUES RELATED TO TEACHING AND LEARNING ELECTROCHEMISTRY

Over the years, technology has become increasingly present in our daily lives and, nowadays, it is almost impossible to go a single day without resorting to using some electronic device, be it a refrigerator or even a cell phone. Technological innovations have come up so quickly that electronic devices are soon considered outdated, even if they meet demands and function properly.

Being widely discussed by authors such as Bauman (2011), Rossini and Naspolini (2017) as well as in the documentary "The Light Bulb Conspiracy" (Dannoritzer, 2010), the shorter durability of electronic devices is due to the programming of their lifespan by their manufacturers, aiming at them becoming obsolete and their consequent replacement, and the generation of profits through the high consumption rate. This unrestrained consumption has several social, economic and environmental impacts, whether due to the incorrect disposal of electronics or the extraction of natural resources for the production of devices, as brought by Araujo, Olivieri and Fernandes (2014) and by Maughan (2015).

Based on what has been mentioned, it is important that discussions of such aspects occur during our citizens' schooling, since school is a suitable space for this. Thinking about teaching chemistry, the study of electrochemistry, in addition to explaining the most varied chemical systems in our context, is essential for discussing issues regarding consumption and the social, economic and environmental impacts generated. It can also enable a discussion about the importance of creating and maintaining laws and bodies that carry out inspection, regulate and protect the environment.

In this sense, not only the normative education documents, such as the Brazilian National Common Core Curriculum(BNCC) (Brazil, 2018), but also some authors such as Morin (2005), Santos (2007) and Bazzo (2014), recommend the development of knowledge and skills related to concepts and reflections of a socio-scientific nature, which can be supported by the teaching and learning of principles related to electrochemistry. According to the BNCC, regarding the field of Natural Sciences and their Technologies, at the end of High School, students should know how to:

> Analyze natural phenomena and technological processes, based on the interactions and relationships between matter and energy, to propose individual and collective actions that improve production processes, minimize socio-environmental impacts and improve living conditions at local, regional and global levels. Investigate problem situations and evaluate applications of scientific and technological knowledge and their implications in the world, using procedures and languages specific to Natural Sciences, to propose solutions that consider local, regional and/or global demands, and communicate their findings and conclusions to varied audiences, in different contexts and through different media and information and communication technologies (ICTs) (Brazil, 2018, p.553).

In chemistry teaching, such knowledge and skills can be achieved through contextualized teaching, which discusses scientific concepts through socio-environmental themes, which can promote the development of attitudes, values, and social awareness. They can also enable changes in attitudes towards individual and collective problems, foster the establishment of relationships between Science, Technology and Society (STS) and, consequently, provide better training (Santos & Schnetzler, 1996; Coelho & Lima, 2020).

In relation to the conceptual knowledge and themes developed in the field of Natural Sciences and their Technologies, the BNCC concludes that:

> they make up a foundation that allows students to investigate, analyze and discuss problem situations that come from different sociocultural contexts, in addition to understanding and interpreting laws, theories and models, applying them to solving individual, social and environmental problems. This way, students can rework their own knowledge related to these themes, as well as recognize the potential and limitations of Natural Sciences and their technologies (Brasil, 2018, p. 548).

Therefore, many teachers and researchers have tried to develop contextualized lessons that address relevant and meaningful topics for students, aiming to form critical and reflective citizens.

However, it is rare for socio-environmental issues to be the focus in chemistry teaching, with a predominance of scientific content (Santos et al., 2018). Besides not bringing meaning to the study of this science, this predominance also causes a series of conceptual difficulties in the teaching of electrochemistry, such as: lack of understanding of chemical language, greater familiarity with questions that consider quantitative aspects (related to calculations) than qualitative aspects (interpretation of concepts), problems regarding electric current, electrical conductivity in solutions, representation of oxidation-reduction reactions and reduction potential (Lima & Marcondes, 2005; Caramel & Pacca, 2011).

In this context, experimentation in chemistry teaching is extremely important, as it constitutes a pedagogical resource that can help in the construction of scientific concepts and in understanding the world. Still, most of the time, when carried out by students in the laboratory, these activities are based on closed scripts, which must be followed strictly by the students (Ferreira et al., 2010). This type of activity does not promote reasoning and questioning in students, but rather an impoverished perception of science (Gil-Perez et al., 1999).

Thus, Silva (2016) argues that practical activities should not be restricted to experimental procedures, but provide students with moments of discussion, interpretation and explanation of these situations, so that they can build connections with their experiences.

Therefore, authors such as Ferreira, Hartwig and Oliveira (2010); and Barbosa and Pires (2016) argue that experimental activity with an investigative approach should be encouraged, where learning occurs through the active involvement of the student in the construction of knowledge (Silva & Marcondes, 2007). Like this, thematic workshops can be used to carry out investigative experimentation, since their main characteristic is the approach to socially relevant issues through generating themes or problem situations (Silva & Marcondes, 2007).

In view of this, the approach to the theme “Planned Obsolescence” through investigative experimentation can be relevant not only to promote the meaning of concepts and minimize difficulties, but also to achieve the skills for teaching electrochemistry. This is due to its focus on a ICTS perspective that, in addition to establishing a connection between the three aspects, promotes the development of attitudes, values, social awareness, critical thinking and decision-making, enabling changes in attitudes regarding individual and collective problems, also promoting scientific and technological literacy (Freire, 1996; Lima & Marcondes, 2005; Oliveira, 2010).

Thus, a thematic workshop was designed and implemented, with the theme "Planned Obsolescence". With the purpose of minimizing difficulties in learning electrochemistry. For this purpose, the responses of the research participants to the activities proposed throughout the workshop were analyzed.

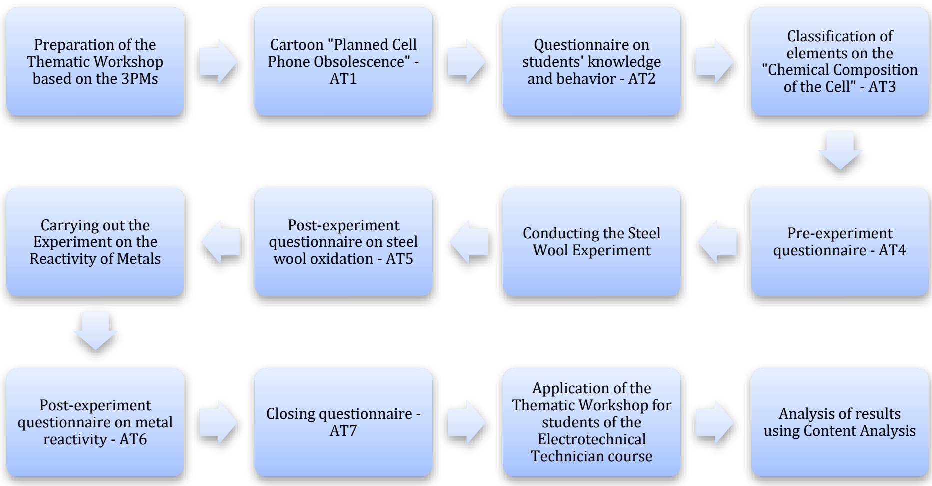
PROCESS OF PREPARING AND IMPLEMENTING THE ACTIVITIES DEVELOPED

This thematic workshop was developed within the scope of the Research in Chemistry Teaching discipline of the Chemistry Degree course at the State University of Maringá (UEM), and implemented with 13 students of the technical course in Electrotechnics at a private school, in 2022.

Preparing the thematic workshop, the Three Pedagogical Moments (3PMs) perspective, which was proposed by Delizoicov et al. (2002) was used as a basis. It consists of Initial Problematization, Knowledge Organization and Knowledge Application. The process of elaboration, implementation and analysis of the research results is structured in Figure 1.

Picture 1

Developing, implementing and analyzing the results of the research.



Source: Own authorship (2023)

The First Pedagogical Moment refers to the Initial Problematization, where according to the authors, the problem situation to be investigated is presented, so that it associates the content to be studied, in this case electrochemistry, with the students' experiences (Delizoicov et al., 2002). Thus, initially, Figure 2 "Planned Cell Phone Obsolescence" (Santos, 2019) was presented, which is related to the theme of electronic waste, and students were asked to write down all their observations and interpretations of the image.

Picture 2

Cartoon "Cell phone Planned Obsolescence"

Text: "It won't take long for this cell phone to get here."

Source: Extracted from Santos (2019).

Afterwards, a questionnaire with alternative questions related to the theme was given, to which the students responded based on their knowledge and behaviors, and they could choose more than one alternative. Finally, a problematizing question was presented (Table 1), adapted from the text "Have you changed your cell phone today?" (Barbosa, 2021), which was widely discussed.

Table 1

Guiding problem-solving question.

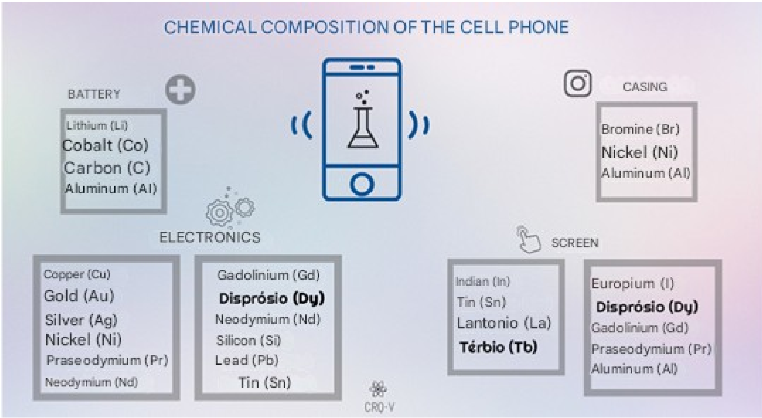
PROBLEM SITUATION: According to a survey conducted by the Brazilian Institute of Geography and Statistics (IBGE), approximately 81% of the Brazilian population aged 10 or over owned a cell phone for personal use in 2019 (EDUCA IBGE, 2020). On average, approximately two billion smartphone users worldwide change their device after 11 months of use (Santino, 2017). Have you changed your cell phone today? What consequences can this consumption have for us and our planet?

Source: Adapted from Barbosa (2021).

The Second Pedagogical Moment deals with the Organization of Knowledge, where activities are proposed regarding the theme and problematization, which enable the construction and organization of scientific knowledge by students, under the guidance of the teacher (Delizoicov et al., 2002). In this sense, Figure 3 "Chemical Composition of the Cell Phone" (CRQ-V, 2017) was first presented, where the study of the chemical components described on it was carried out, focusing on the issue of heavy metals.

Picture 3

"Chemical Cell Phone composition



Source: Extracted from CRQ-V (2017).

Afterwards, a pre-experiment questionnaire was given, from which it was possible to discuss the students' initial conceptions about metal contamination. Soon after, an experiment was carried out with steel wool in water, bleach and hydrochloric acid, from which the students answered a post-experiment questionnaire and through which it was possible to discuss issues related to the concept of oxidation-reduction.

Next, another experiment was carried out, in which gold, zinc, lead and copper were immersed in hydrochloric acid. After this, the students answered a second post-experiment questionnaire, which allowed for discussion about the reactivity of the metals. Thus, the chemical equation proposed by the students and the correct chemical equation were used to conduct discussions about the oxidation number (NOX), as well as other chemical concepts related to oxidation-reduction.

Finally, the third and final Pedagogical Moment began, which refers to the Application of Knowledge and, according to the authors, this is where the knowledge built throughout the activity is addressed, to analyze and reinterpret the initial problem, as well as other situations that are not related to it, but that can be explained based on such knowledge (Delizoicov et al., 2002).

Thus, a closing questionnaire with alternative questions was made available via Google forms, which addresses the participants' perceptions after the workshop. In Table 2 we present a summary of the activities applied, with their respective objectives, strategies and socio-scientific concepts addressed.

Table 2

Summary of activities developed.

Code	Activity	Objectives	Strategies	Socioscientific Concepts
AT1	Charge “Planned Cell Phone Obsolescence”.	Discuss the impacts of irregular disposal of electronics and consumerism.	Slides, cartoon, printed activities.	Consumerism; Electronics disposal; Technological advances; Environmental pollution; “Planned obsolescence”.
AT2	Questionnaire about knowledge and behaviors related to the topic.	Promote reflection on student behavior and lead to problematization.	Printed activity	Consumerism; Electronics disposal; Technological advances; Environmental pollution; “Planned obsolescence”
AT3	Classification of the elements of the image “Chemical Composition of the Cell Phone”.	Discuss the composition of cell phones, heavy metals and their effects.	Slides, CRQ-V image, periodic table, printed activity.	Chemical composition of cell phones; Heavy metals
AT4	Pre-experiment questionnaire.	Discuss initial concepts about metal contamination.	Printed activity	Environmental pollution; Heavy metal contamination.
AT5	Post-steel wool experiment questionnaire.	Discuss issues related to the concept of oxidation-reduction.	Printed activity.	Chemical transformations; Oxidation-reduction reactions; Oxidation number (NOX).
AT6	Post-experiment questionnaire on metal reactivity.	Discuss issues related to the concept of standard reduction/oxidation potentials.	Printed activity.	Chemical transformations; Oxidation-reduction reactions; Oxidation number (NOX); Standard reduction potentials.
AT7	Closing questionnaire.	Understand students' perceptions after the workshop.	Google Forms.	Consumerism; Electronics disposal; Technological advances; Environmental pollution; “Planned obsolescence”.

Source: Own authorship (2023).

Based on the applied activities (Table 2), the students' responses were analyzed, in which the possible relationships and understandings regarding "planned obsolescence" and scientific concepts were explained. We understand that by analyzing these concepts, we would be able to understand whether the theme actually contributed to a better understanding of the chemical concepts addressed. In view of this, for data analysis, the concepts explained were grouped in the seven applied activities according to their similarities. Content Analysis (Bardin, 2016) was used as a data analysis methodology, where it is important to highlight that after the unitarization process, some responses generated more than one context unit, and thus could be included in more than one category. Through this process, the emergence of three categories was recognized, presented in Tables 3, 4 and 5, which are directly related to the theme and the concepts addressed.

CONTRIBUTIONS OF THE THEME IN LEARNING ELECTROCHEMISTRY

Something noteworthy in recent decades concerns the growth of the electronics industry, especially in the electronic devices sector. According to Canalys (Jones, 1998), a technology market analysis company, in the fourth quarter of 2020 alone, had an increase of approximately 25% in the shipment of desktops, notebook computers and workstations to retail stores, when compared to the same period in 2019, which was mainly due to the increase in demand caused by the COVID-19 pandemic.

According to data from the Continuous National Household Sample Survey (PNAD CONTÍNUA - IBGE), in 2021, 96.3% of private households owned a mobile phone (cell phone), while in 2019 the percentage was 94.4% (IBGE, 2022). This increase in demand for electronics and their consumption had consequences regarding the increase in the generation of electronic waste, since old devices were exchanged for new, more beautiful and updated ones, thus meeting the needs of consumers. However, there is a question about the durability of these electronics. Given this, for Rossini and Naspolini (2017, p.54), the "planned obsolescence"

> is a strategy in which, from the moment a product is developed, the industry schedules and plans for the early end of its useful life, whether due to the wear and tear of its parts or technological evolution that makes it mandatory to purchase an updated model. The product is produced to last less. The product lifespan is purposely reduced by the industry in order to stimulate consumption and move the industrial market.

Therefore, it becomes necessary and important to discuss the issue of "planned obsolescence" within the educational process, not only to understand the concepts that students have on the subject, but also to understand how its use can help in understanding the concepts of electrochemistry.

So, Tables 3, 4 and 5 present some examples of units of meaning, which represent excerpts from the students' responses to the activities carried out during the workshop. We observed terms and ideas that referred to socio-scientific concepts, and that are related to "planned obsolescence", with the contamination by metals, as well as chemical reactions.

In the category "Planned Obsolescence" (Table 3), we observed a total of 25 units of meaning, which were grouped into four subcategories: consumerism (9 occurrences), technological advances (5 occurrences), planning the useful life of electronic devices (3 occurrences) and incorrect disposal (8 occurrences). The units of meaning were found in the responses to activity 1, for which students had to examine the cartoon "Planned Obsolescence of Cell Phones" and describe everything they observed, interpreted and understood about it.

Table 3

"Planned Obsolescence" Category

Units of meaning	Subcategories	Categories
"What I understood from this cartoon is that we are always changing cell phones and electronics […]. That is why the man in the cartoon said that the cell phone would not be long in coming, because they would soon buy that cell phone and exchange it for a newer one" — A2 "We consume more than we use, we buy devices and new things, often out of pure consumerism or luxury, which makes us discard things that are in good condition, but because they do not keep up with the 'trend' we do not like them" — A7 "[…] The idea shows the reader how consumerism encouraged as a way of life by capitalism places society in an idle cycle of discarding perfectly functional products/devices, simply because they have been considered 'outdated' both from an aesthetic point of view and in terms of their ability to meet all the user's needs by the consumer mentality. […]" — A13	Consumerism (9)	Planned Obsolescence (25)
"[…] we can see the consequences of technological evolution, which were not foreseen by scientists" — A1 "This 'new cell phone' represents not only the cell phone, but also all technologies and, as everything that is new, are forgotten, they will always create something better to surpass our 'new cell phone', so we should not worry so much about having the 'best' and the 'newest'" — A8 "The character's line 'it won't be long before this cell phone gets here' confirms the thesis that the so-called 'new cell phone' will soon be replaced and discarded. Since it will be replaced by a newer version, which will soon be released" — A9	Technological advances (5)	
"The accumulation of electronic waste under an airplane promoting a new device demonstrates the concept of planned obsolescence, in which electronics companies create components that are pre-defined to fail after a certain amount of time as a way of forcing the consumer to buy a newer device" — A5 "[…] this is because the devices are programmed	Programming electronic devices lifespan (3)	

Units of meaning	Subcategories	Categories
not to last very long, so that the electronics market remains thriving […]" — A12 "From the analysis of the cartoon, one can see the effect of planned obsolescence, as indicated by the title itself. […] From the point of view fundamentally linked to its basic operating structure, the example of its electrochemical energy sources, which continue to obey the same rule with each new launch, one can conclude as to the ability of capital psychology to establish an ideal period of service in its market, until they become obsolete again" — A13		
"When analyzing the image, we can see an exorbitant amount of discarded electronics […], taking into account that the discarded electronics look like a landfill […]" — A1 "[…] people discard their electronics in the wrong places due to the lack of places to dispose of electronics correctly" — A6 "Notice the pollution caused by incorrect disposal of electronics. […]" — A10	Incorrect disposal (8)	

Source: Own authorship (2023).

We understand that 9 of the students expressed ideas that the cartoon is directly linked to consumerism, either because *"we are always changing cell phones and electronics"*, because *"we consume more than we use"*, or because it is "*encouraged as a way of life by capitalism*". In this line of reasoning, Bauman (2008) argues that consumerism does not depend solely on need, but that it is largely linked to the need to discard and replace, which is pure consumerism or luxury, as mentioned by the students. Also in this sense, when asked, in activity 7, if unbridled consumption happens because people want to feel more up-to-date with new technologies, all students answered yes, which indicates this relationship between consumption and individual desire.

Other 5 students expressed ideas that the causes of obsolescence are related to technological production. In this sense, obsolescence can be interpreted as being inevitable, as a result of scientific/technological developments, since new products will continue to be produced that people will need to consume. In view of this, the students mentioned that "*we can see the consequences of technological developments*" or the fact that the device "*will be replaced by a newer version*", since "*they will always create something better to surpass our 'new cell phone'*". Despite this, in activity 2, when asked if they change their device when a new cell phone model is released, the students said no, but justified it only due to a lack of financial means.

Still on the subject of the production of new technologies, we asked, in the final activity, whether students think that it always aims to improve the well-being of the population. The majority, 11 students, said no, while 2 said yes. Regarding this, Gurgel and Mariano (2008) and Rosa and Strieder (2018) state that science and technology should be understood as complex processes, which are influenced by economic, social, political and cultural factors, and influence values, habits and beliefs. However, teachers in the area of natural sciences, whether they are active or in training, present milder ideas about science and technology (Gurgel & Mariano, 2008; Miranda & Freitas, 2008), and these can be reflected in teaching and, consequently, in students' conceptions.

In addition to consumerism and technological advances, three students mentioned the programming of the electronic devices lifespan as a cause of obsolescence, either because "*the devices are programmed not to last*", or because "*electronics companies create components that are predefined to fail after a certain amount of time*", or because it "*demonstrates the concept of planned obsolescence*". From this perspective, Leonard (2011) states that products are "programmed to be thrown away", which is in line with what students expressed in one of the questions in activity 7, who state that obsolescence is designed so that products have a shorter lifespan.

We also noticed that 8 students expressed the idea that 'programmed obsolescence' is also related to incorrect disposal, either because 'people dispose of their electronics in the wrong places', and thus 'realise the pollution of incorrectly disposed of electronics', or because 'disposed electronics look like a rubbish dump'.

Regarding these aspects, in activity 2, students were asked whether they disposed of electronic waste incorrectly, and also what happens to their electronic devices that are no longer used. Most students reported that they do not dispose of them incorrectly (9) and that they keep unused devices at home (12). Also in this context, in the final activity, 13 students stated that incorrect disposal can favor the spread of diseases and environmental degradation. In view of this, Rossini and Naspolini (2017) state that due to the evolution of electronics, disposal has become even faster, consequently increasing electronic waste, which has become a global problem.

It is known that "planned obsolescence" can be understood as the limitation of the lifespan of products, so that it is shorter than what technology allows, thus making them obsolete. In the teaching of Chemistry, this topic is particularly relevant with regard to electrochemistry, since it explains several chemical phenomena and processes in our context. In this sense, in their observations, the students pointed out that "planned obsolescence" has been increasing more and more, either due to the increase in consumerism, since the more is produced, the more people feel instigated to buy, or also due to technological innovations and the planning of the devices lifespan, which often leads to improper disposal, generating environmental problems.

In view of the above, we understand that the use of the theme was important to encourage the development and possible critical reflection on sustainability and social responsibility among students, so that they begin to think about their actions regarding the use and disposal of electronic devices, evaluating the possible environmental impacts that may be generated as a result of these.

As for the category "Metal Contamination", the units of meaning emerged in the questions of activity 4, which aimed to identify the students' initial conceptions about metal contamination. We observed that 28 responses had ideas that referred to possible contaminants, or the means of contamination (Table 4). We divided these conceptions into two subcategories: possible contaminants (13 occurrences) and the means of contamination of living organisms by chemical components (15 occurrences).

Table 4

"Metal Contamination" Category

Units of meaning	Subcategories	Categories
"Yes, Cu, Al, Pb, Si, Br, Dy, La, Eu" — A2 "Yes, copper, lead, bromine" — A10 "Yes, summarizing the chemical elements, I consider that all metals can be harmful, it depends on the place and the quantity of disposal" — A13	Possible contaminants (13)	Metal Contamination (28)
"Through contact, air and water contamination" — A4 "Through air, food and soil contamination" — A7 "Living organisms can absorb these components through cycles involving food chains/tracts, secondary consumers of higher order feeding on primary consumers contaminated by products that have absorbed pollutants from the environment" — A13	Means of contamination of living organisms by chemical components (15)	

Source: Own authorship (2023).

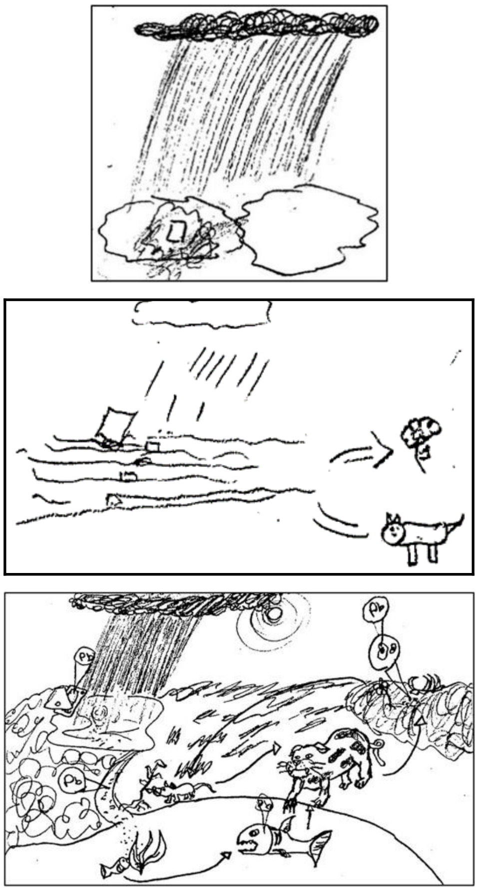
In the first subcategory, we observed these similarities when, while asked whether any of the chemical components present in electronic equipment could be harmful and when asked to try to represent what would happen to lead after several days in the soil, the students (13) mentioned that the components present in electronic devices that could be contaminants were: "*Cu, Al, Pb, Si, Br, Dy, La, Eu*", *"copper, lead, bromine"* and "*I believe that all metals can be harmful*". For the Brazilian Agency for Industrial Development (ABDI, 2013), the direct disposal of electronics in nature is extremely harmful, since the contact of heavy metals with rainwater generates immediate contamination of the soil by leachate, in addition to potential contamination of groundwater, animals and even humans.

In question 1, specifically, we noticed a certain difficulty in understanding metals, although the students mention these as possible contaminants, most of them also initially categorize other elements, which were classified in activity 3, according to the periodic table. Such difficulties are even more evident in one of the questions in activity 4, where, when asked if pure metal could also be considered a contaminant, most of the students (8) answered yes.

Still in activity 4, there were 15 responses about the means of contamination of living organisms by chemical components. When asked if they thought that they could absorb such chemical components and when asked to try to represent what would happen to lead after several days in the soil, the students explained that contamination occurs "*through air, food and soil contamination*", also "*through contact, air and water contamination*", as well as "*through cycles involving food* *chains/tracts*". When explaining the means of contamination through representation by drawings, some students presented the idea of a cycle being formed, or of how this contamination occurs, demonstrating the students' understanding of such means (Picture 4).

Picture 4

Representation showing lead as a means of contamination (a) Student A4; (b) Student A6 and (c) Student A13



Source: Own authorship (2023).

Still on this subject, the BNCC highlights, as one of the skills to be achieved in the area of Natural Sciences and their Technologies,

> Assess the benefits and risks to health and the environment, considering the composition, toxicity and reactivity of different materials and products, as well as the level of exposure to them, positioning oneself critically and proposing individual and/or collective solutions for their responsible use and disposal (Brazil, 2018, p.541).

In this sense, Freire (1996) also highlights that knowledge is an important instrument in terms of transforming reality, since it places people in a position of action in their reality, being able to intervene positively in it and change it. Thus, education must contribute to students' understanding of reality, so that they can intervene in it, consequently, teaching students scientific literacy implies subsidizing their active participation in society (Braga, 2019). From this perspective, proposing activities that highlight students' conceptions, which can help in understanding everyday situations, requires them to take a critical stance towards problems, such as the causes of "planned obsolescence" and metal contamination.

It is known that exposure to heavy metals can have negative effects on health and cognitive performance, including learning ability. In view of this, when students say that the elements present in electronics can be harmful and mention which ones they consider harmful, we understand that although they have difficulty understanding, they are aware that some of the chemical components can be dangerous. We also interpret, by looking at the drawing representations, that students have knowledge about how contamination by metals present in electronics can occur.

In view of this, we infer that the proposed activities were important for us to be able to identify the students' possible difficulties and seek ways to work on them during the workshop, but also to promote reflection and awareness about contamination by heavy metals and how this can occur, in order to provoke possible changes in students' attitudes regarding the correct way to dispose of electronics, avoiding health problems and environmental impacts.

As a final category, the units of meaning revealed the category “Chemical Reactions” (Table 5) in 132 responses, which is more closely related to the scientific concepts addressed. The excerpts were taken from activities 5 and 6, carried out after the experiments, as described in Table 2. From the units of meaning, four subcategories emerged: chemical transformation (63 occurrences), oxidation (42 occurrences), standard oxidation/reduction potentials (19 occurrences) and environmental influences (8 occurrences). It is important to emphasize that all the responses listed in these subcategories come from activities carried out in groups.

Table 5

“Chemical Reactions” Category

Units of meaning	Subcategories	Category
“Yes, the differences between them are as follows: → Steel wool + water: Formation of precipitate/dissolve; → Steel wool + HCl: Release of gases; […].” — A3; A6; A13 “The liquid elements caused reactions in the steel wool elements” — A2; A9; A11 “No, since only zinc and lead demonstrated the formation of bubbles/gases” — A3; A6; A13	Chemical Transformation (63)	Chemical Reactions (132)
“[…] → Steel wool + bleach: formation of rust/oxidation.” — A3; A6; A13 “Yes, there was an oxidation reaction that generated rust” — A5; A12 “Yes, because over time it will oxidize in the soil” — A1; A7	Oxidation (42)	
“Not yet, because when in contact with HCl and metal, they transform, but at different times, because each metal has a different corrosion time, as some are stronger than others” — A4; A8;	Standard Oxidation/Reduction Potentials (19)	

Units of meaning	Subcategories	Category
A10 "No, it is probably used in devices due to its potential" — A3; A6; A13 "No, due to its greater resistance to substances such as HCl not undergoing change" — A2; A9; A11		
"[...] The others had changes due to the elements" — A2; A9; A11 "Yes, because the soil is also moist and can be basic or acidic depending on the circumstance" — A5; A12 "Yes, this is because the pH of the soil can influence a redox reaction" — A3; A6; A13 "[…] Yet the others had changes due to the elements" — A2; A9; A11	Environmental influences (8)	

Source: Own authorship (2023).

For the first subcategory, there is mention by some students (63) of evidence that shows that there was a chemical transformation in the experiments carried out, which can be exemplified by the following excerpts: "*precipitate formation*", by the "*formation of bubbles/gases*", or because "*the elements of the liquids caused reactions in the elements of the steel wool*". In this sense, Silva, Souza and Marcondes (2008) highlight that many students understand chemical transformation to be any and all changes in the appearance of a substance, that is, when there is the presence of physical evidence. In view of this, although they are correct, because there was in fact a chemical transformation, the students' presentations may also have been made based on the idea that this only occurs if there is visual physical evidence.

In the second subcategory, still based on observations from the experiments they had performed, 42 students expressed ideas about the oxidation of metals, showing that "*there was an oxidation reaction*" that "*generated rust*" and that "*it will oxidize in the soil*". Still on this idea, when explaining what happened to these metals through the chemical equation, they all correctly represented the oxidation reactions. For this subcategory, there is also a drawing representation, which we understand to be directly related to oxidation (Picture 5).

Picture 5

Representation showing oxidation (A9)

Source: Own authorship (2023).

In this sense, when students have the opportunity to carry out experimental activities, they have the possibility of trying to justify the observed phenomena, testing their hypotheses, and learning about the phenomena under study (Suart & Marcondes, 2009).

In addition to chemical transformation and oxidation, 19 students mentioned the potential oxidation/reduction patterns when asked in different questions about the changes undergone by metals in experiments and other contexts in everyday life.

In this sense, they highlight the idea of standard oxidation/reduction potentials when they say that "*each metal has a different corrosion time*", or that "*due to its greater resistance to substances such as HCl, it does not undergo alteration*", or even, when questioned about gold, they explain that "*it is probably used in devices due to its potential*". Here it is observed that some students have the idea that standard potentials are time-dependent, which is in line with what is evidenced by Lima and Marcondes (2005) regarding conceptual difficulties. Thus, some students have the idea that the potentials of a standard voltaic cell are time-dependent, however, the potential of a given cell depends on the specific reactions that occur at the cathode and anode, the concentrations of products and reactants and the temperature (Brown et al., 2005).

For the last subcategory, 8 students presented ideas that relate to the influences of the environment on the occurrence of an oxidation reaction, explaining that "*the pH of the soil can influence a redox reaction*", or that "*the soil also remains moist, and can be basic or acidic depending on the circumstances*", or even that "*the others underwent changes due to the elements*". Here, we understand that the ideas expressed by the students may refer to the fact that oxidation reactions are dependent on the conditions of the environment in which the reaction will occur.

Based on the discussions presented, through the activities developed during the proposed workshop, we understand that the students showed signs of understanding about chemical transformations, oxidation, standard reduction/oxidation potentials and the influences that the environment has on chemical reactions, since they demonstrated equations and even represented such concepts through drawings.

Considering this, it was possible to observe that the proposition of the thematic workshop with experiments contextualized from the theme of "planned obsolescence" was important for the learning of electrochemistry and contributed not only to the understanding of the concepts that involve chemical reactions, but also to minimize conceptual difficulties and promote discussions that related scientific content to the students' daily lives.

FINAL CONSIDERATIONS

We therefore consider that after the process of categorizing the responses, it can be inferred that the ideas expressed by the students throughout the activity refer to the idea of "planned obsolescence", contamination by metals and chemical reactions. Although the way in which they express their conceptions is different at times, they are complementary and do not deviate from what was worked on, showing the potential of proposing such activities.

In view of this, we agree that the traditional approach is not sufficient for the educational context, since the student is unable to understand the environment in which he or she lives, as well as to make sense of what is taught to him or her. Within the scope of this approach, there is no promotion of the student's curiosity, since he or she is merely a receiver of information, and for this reason, does not satisfy his or her doubts when they arise. Thus, the proposition of activities that value the exchange of ideas and knowledge between the subjects of the educational processes and that consider that scientific knowledge is fundamental for the understanding of social problems related to the students' context, such as "planned obsolescence" and the study of electrochemistry, are extremely important for learning.

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