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Niobium ceramic powder electrophoresis to address electrochemistry concepts

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ABSTRACT

This article deals with an experimentation committed to the conceptual and contextual formation for the study of electrochemistry concepts from the electrophoresis of niobium ceramics. The experimentation was carried out by students from the 3rd year of high school in a public school, as a complex process of articulation between phenomena, theories, socio-environmental interactions and learning in a historical-cultural perspective. In this sense, we seek references for the complexity of reaction systems, interactions between science, technology, society and ceramics. As a result, we observed that the experiment favored the teaching of electrolysis, electron flow and oxidation and reduction reactions. It was possible to follow the challenges in setting up the experimental activity: the measurement of the dispersion pH and the connection of the battery poles to the corresponding electrodes. It also promoted socio-scientific debate on environmental impacts by using water instead of alcohol during the electrophoresis.

KEYWORDS: STS. Experimentation. Ceramics.

INTRODUCTION

Seeking to understand the learning of physical and chemical processes based on the analysis of material systems and reaction variation problems, this article focuses on the complexity of experimentation with an approach that connects physical, chemical and pedagogical concepts and principles. It addresses mainly processes of (re)reading natural phenomena and active, critical and creative learning.

Historically, the community of researchers on chemistry teaching have adopted experimentation as an important reference for the development of conceptual and contextual approaches committed to more effective education results, which are based on analytical thinking, prediction and generalizing skills, and a phenomenological reading of events that occur naturally in the world as well as those occurring in laboratories (FRANCISCO JUNIOR; FERREIRA; HARTWIG, 2008; SILVA; MACHADO; TUNES, 2011). With the experimental approach, learning sciences has established constant relationships between the scientific doing and thinking. Thus, we report the organization of an experiment seen as a complex process of articulation between phenomena, theories, socioenvironmental interactions and learning in a historical-cultural perspective.

Referring to the complexity of reaction systems and the matter electrical nature, an experiment was proposed based on electrochemistry and the electrophoresis technique, which allows the study of physicochemical concepts. We opted for the use of niobium oxide even if aluminum oxide and zinc oxide could also have been used for being accessible and viable materials in most Brazilian schools.

Regarding the education phenomenon and its relationship with the complexity of the Brazilian sociocultural reality, we understand the relevance of approaching social chemical themes and interactions between science, technology and society (STS), with which a study on social aspects can be organized requiring the students' critical positioning in relation to the possible solutions (SANTOS; SCHNETZLER, 1997).

The STS focus on the education area aims to highlight the "social importance of science and technology to emphasize the need for critical assessment and reflective analyses about the scientific and technological relationship and society", in such approach, "teachers and students start to discover and research together, to build up and/or produce scientific knowledge, which is not considered something sacrosanct and inviolable" (PINHEIRO; SILVEIRA; BAZZO, 2007, p. 74).

> Therefore, when the STS approach is inserted in science teaching, it aims to promote scientific and technological knowledge; however, in such a way that helps students to develop knowledge and skills to guide them in the decision-making about science and technology-related issues and their relationships with society (MOREIRA; AIRES; LORENZETTI, 2017, p. 198).

In this context, we investigate the use of niobium oxide ceramic powder for promoting great technological interest and being one of the most important minerals in the country. Moreover, mining in Brazil involves multiple socio-environmental problems related to the air, water, local and national economy, waste treatment, and the extraction waste, biodiversity loss, and land dislocation among others (MILANEZ; WANDERLEY; SOUZA, 2017).

Given the complexity of learning resulting from the active participation in the classroom, our reference is the historical-cultural pedagogy. It is well-known that the historical-cultural psychology has become a relevant theoretical-methodological reference in science teaching, but it is also recognized that there are misappropriations and certain precariousness in the education of researchers that adopt this theoretical approach (MORI, 2013). For this reason, we adopted a (re)reading of Vygotsky's pedagogical contributions, which point out some meaningful and creative learning possibilities to advance in the understanding of historical-cultural indicators for classroom interactions (MARTÍINEZ; REY, 2017). Therefore, during the experiment, the challenges of participation are proposed in the experiment design and analysis of a problem situation involving the identification of acidity on the surface of the ceramic powder particles for the ceramic formation.

In fact, this study object is an experiment that also addresses socioenvironmental, technological, and social themes, and is committed with the kind of learning that connects scientific concepts and the everyday events that involve niobium. In such context, the objective of this article is to reflect upon an experiment with education purposes focused on the reaction complexity, by means of interactions between science, technology, society and environment, as well as meaningful and creative learning with the students' active participation in the experiment.

THE REACTION COMPLEXITY INVOLVED IN THE ELECTROCHEMISTRY EXPERIMENTATION AND THE ELECTROPHORESIS TECHNIQUE

The experiment developed in the classroom involved chemistry knowledge about oxidation and reduction. In the activity, the ceramic approach is seen as a facilitator in the learning of electrochemistry concepts linked to the electrophoresis technique. The simultaneity of multiple physical and chemical processes involved in an electrochemical reaction system enables the investigation of concepts related to electrolytic cells and electrolysis that occur along with the electrophoresis and allows the observation of the electron flow and identification of the oxidant agent, the reduction agent, and the pH of the reaction medium. Moreover, it enables the teacher to address the dynamics of production of the systemic and complex thinking process.

Not only must the electrochemistry learning involve the flow of isolated charges, but also the system as a whole. According to Prigogine (2002; 2009), every liquid is a complex system that corresponds to a huge number of particles in interaction, which are all sensitive to the initial conditions, to disturbance and fluctuations in the system behavior. Every system formed by a lot of particles is crossed by correlations that increase continuously up to their aging, a phenomenon that prevents the elimination of interactions in the reaction medium. Such flow of correlations shows that the appearance of other behaviors is related to the interactions between molecules. The behavior of such molecules results in an unstable system impacted by constructive instability (PRIGOGINE; STENGERS, 1997).

This is the origin of the complex thinking emphasis on the instability and fluctuation conditions and the irreversibility of reaction systems. For this reason, a frequent reference is observed related to the distancing of the system equilibrium, that is, there is no going back to its initial state when the system is disturbed; conversely, the production of new structures and new types of organization is observed, Prigogine and Stengers (1997) called unstable systems with this type of behavior dissipative structures.

This leads us to reflect that multiple physical and chemical processes do not occur separately, so that a reaction medium is influenced by all the particles present. For the complexity science, thinking that the oxide in suspension will simply migrate to the deposit electrode without interacting with the water and its dissolved minerals is a very simplistic view.

The Electrophoretic Deposition – EPD used in the conformation of advanced ceramic materials is a suitable case for complex thinking. EPD allows the production of cheap pieces with complex or flat structures, according to the format of the material deposit electrode. The technique involves the presence of two electrodes connected to the poles of a battery or another energy source, so that the electrical current can be passed by a colloidal dispersion of the ceramic powder. The liquid solvent can be either polar or apolar.

From the experimental standpoint, the electrophoresis ceramic conformation technique can be divided into two processes, as follows: in the first, the ceramic particles dispersed in the liquid (polar or apolar) move toward the opposite charge electrode when the electrical field is applied. In the second process, particles get close enough to the electrode to coagulate and remain deposited, forming a compact structure or a dense and homogeneous film (HEISE; RIVERA; BOCCACCINI, 2019).

In such context, the reaction complexity is noticed when approaching four relevant simultaneous phenomena:

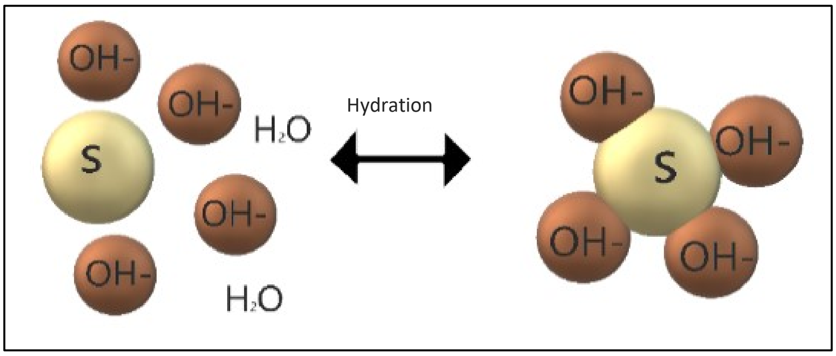
1. The reaction phenomenon, due to the particles dispersed in the liquid, characterizing the coexistence of particles and the reactions that occur, differentiating the materials involved and the simultaneity of reactions;
2. The flow of particles, the direction of the electron flow in the external circuit, and the ion flow in the internal circuit, as a function of the movement of the particles toward the electrodes;
3. The electrical field application and the suitable condition to force the formation of a non-spontaneous reaction;
4. The electrodeposition resulting from the electrolytic deposition on graphite.

Furthermore, the ethanol use as the dispersant liquid requires the passage of a greater electrical current (in the literature there are studies reporting 80 V) through the system for the deposition to occur. In addition, substances, which might be harmful to the environment such as polyacrylates, are needed to disperse the oxide so that it does not flocculate or decant too fast in the container. One alternative would be the use of polar solvents, such as water, which in addition to requiring a lower electrical current, do not require substances that might harm the environment. However, at low voltages (2 V), water electrolysis occurs, which provokes the formation of holes in the final piece, due to H_2 gas bubbles that form in the cathode (SAKAMOTO; GOUVÊA, 2001).

Polar solvents such as water show strong interaction with the oxide surface due to the ionic characteristics of the oxide/solvent interface. The mixture of fine particles with solvent is unstable and over time, sedimentation occurs naturally. The delay in such sedimentation (stabilization process), however, can be obtained by means of ion and/or molecule adsorption on the surface of micro or submicrometric particles, which generate repulsion forces, by means of both electrical charges and spatial impediment (steric) or both (OLIVEIRA *et al.*, 2014).

The development of charges on the surface of the ceramic powder particles is responsible for the dispersion electrostatic stabilization mechanism. When in contact with water (Figure 1), those particles are subjected to hydroxylation or surface hydration.

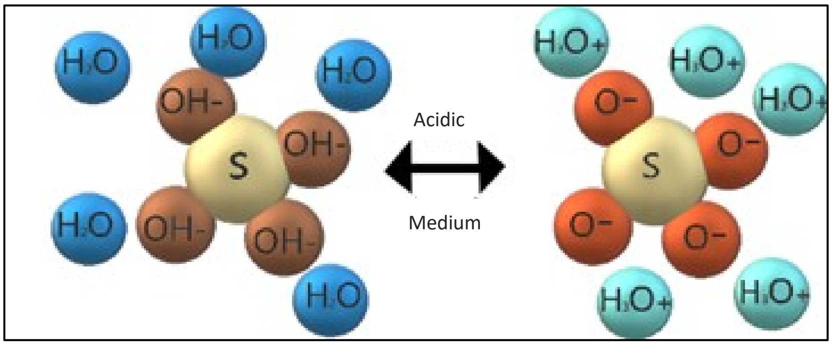
Figure 1: Oxide particle hydroxylation (represented by letter S, referring to the surface)



Source: The authors (2019).

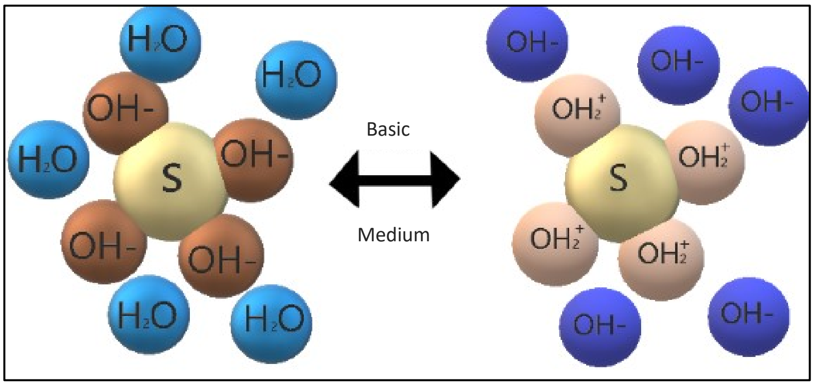
The oxide surface hydration makes it electrically charged. For this reason, the solution pH is so important since based on it, the oxide surface charge can be inferred to decide the pole in which the electrode will be placed for the deposition of the oxide in the electrophoresis technique. Figures 2 and 3 show possible oxide charges in acidic and basic pH, respectively.

Figure 2: Possible interactions between the oxide and H_2O in acidic pH, where S is the oxide particle surface



Source: The authors (2019).

Figure 3: Possible interactions between the oxide and H_2O in basic pH, where S is the oxide particle surface



Source: The authors (2019).

The figures above exemplify what occurs in the reaction medium and might be represented by reactions A and B. We can observe that, in aqueous suspensions, the final pH is a function of the ionization of surface hydroxyl groups:

$$S - OH + H_2O \xleftrightarrow{K_{a_1}} S - O^{-} + H_3O^{+} \quad \text{(A)}$$

$$S - OH + H_2O \xleftrightarrow{K_{b_1}} S - OH_2^{\ +} + OH^{-} \quad \text{(B)}$$

Where: S is the oxide surface, and K_a1 and K_b1 are the acidic and basic dissociation constants in water, respectively.

Science provides improvements, but some reflection is needed regarding all environmental impacts that are involved in the process and in the improper use of some substances. This view of the total process, being careful since the oxide extraction rather than caring only for the ceramic piece product, is provided by the STS approach.

THE COMPLEXITY OF STS INTERACTIONS IN THE NIOBIUM CERAMIC MEDIUM

Science education research has pointed out that experimentation might contribute to the understanding of the human education complexity, which involves the knowledge of scientific concepts and their application by means of a reflective awareness, so that the relationship with the object is mediated by concepts learned and results in better understanding of the concrete reality (OLIVEIRA, 2010; SILVA; MACHADO; TUNES, 2011).

According to Silva *et al*. (2015), experimental activities, most of the time, are used only to demonstrate and confirm theories. Such situation leads students to a false construction of meanings regarding scientific knowledge. Conversely, experimentation allows dialogue between students, teacher, and physicochemical processes. This exchange of experiences does not place the knowledge source on the teacher, thus avoiding the "banking" model of education (FREIRE, 2011).

For this reason, the importance of experimentation articulated with chemistry themes and STS interactions is recognized. Social chemistry themes play a relevant role in the teaching/learning process since they enable discussion, analysis, and reflection upon environmental and economic aspects that impact society. Moreover, the approach to socio-scientific themes allows the development of participation and decision-making skills for bringing discussions of relevant social aspects. These require the students' critical positioning when seeking solutions (SANTOS; SCHNETZLER, 1997). The inclusion of social chemistry themes in the classroom favors the understanding of everyday chemical processes.

Experimenting with ceramics enables some discussion about mining. The multiple socio-environmental problems of mining in Brazil, considering the municipalities where it occurs, involves mainly the accelerated urban and demographic growth, which results in the populations' precarious life conditions; strong dependence of the local economy on an activity based on the exploitation of a non-renewable resource; and the countless types of damage to the environment such as sound, air and water pollution, deforestation, loss of biodiversity, improper disposal of waste, and mining waste, without mentioning the disturbance of land subsidence such as the earth dislocation below certain reference level, such as the average sea level (MILANEZ; WANDERLEY; SOUZA, 2017). Some examples are the mining socioenvironmental problems in Brazil such as the Vale (2015) and Samarco (2019) dam ruptures, both in Minas Gerais. These two are considered the greatest environmental tragedies in Brazil, with several casualties, disappeared families, local devastation, and consequent disaggregation of the social bonds in those communities.

Ceramics, in this context, appear as the most remote materials used in human activities. They are linked to the survival of primitive beings due to the need for containers to transport water, for example. Those characterized as advanced are special ceramic materials used in electrical, electronic, optical and magnetic applications (CALLISTER; RETHWISCH, 2016).

Niobium pentoxide (Nb_2O_5), used in this study, is a ceramic powder with great interest in the production of advanced materials because it presents chemical and physical properties suitable for the production of ceramic capacitors, optical lenses, heat and abrasion resistant structural elements, gas sensors, semiconductor elements in dye sensitized solar cells, special filters for TV receptors, and electronic components. It mainly stands out as a photocatalyst. This property allows its use for different purposes such as photodegradation of pollutants and microorganisms found in water or air systems, and the production of molecular hydrogen, among others (OLIVEIRA *et al*., 2014).

A survey carried out by the Departamento Nacional de Produção Mineral (DNPM) (National Mineral Production Department), closed in the late 2018 and substituted with the Agência Nacional de Mineração (ANM) (National Mining Agency), indicated that the Brazilian niobium reserves total 842.4 million tons, representing over 90% of the global total, followed by Canadian and Australian reserves. The Brazilian reserves are mainly concentrated in the state of Minas Gerais (75%), in the municipality of Araxá; Amazonas (22%), in the municipalities of São Gabriel da Cachoeira and Presidente Figueiredo; and Goiás (3%), in the municipalities of Catalão and Ouvidor (DEPARTAMENTO NACIONAL DE PRODUÇÃO MINERAL [DNPM], 2015).

METHODOLOGY: EXPERIMENTATION COMPLEXITY AND ACTIVE AND CREATIVE LEARNING

Since scientific knowledge allows reflective awareness. Vygotsky (2005 thought that the formation of concepts is not only the sum of connections made by the memory, but it is rather a complex act, which also depends on permanent interactions that produce knowledge. In this sense, we sought an understanding of concept formation marked by the historical-cultural perspective, according to which the complexity of learning involves an active position in relation to the knowledge originated in other contexts and in the classroom context.

The constructive-interpretive methodology was constituted in a continuous process of interpretation and construction of knowledge from the information produced in the development of instruments that favored the participants' expression. The interpretive process always entails the production of a new meaning about information and events shared in experimentation and data collection, by means of open questionnaires, sentences completed and classroom observation (MARTÍINEZ; REY, 2017).

Martíinez and Rey (2017) explained the importance of meaningful learning and creative learning. In meaningful learning, reflective operations have a central position. The importance of understanding resides in the use of what was learnt in other situations different from that when the learning occurred. Creative learning is marked by creativity, which is expressed as information personalization, when facing knowledge and in the production and generation of one's ideas about the object under study. This includes new alternatives and hypotheses elaborated about the object of knowledge. Thus, such learning expresses the learners' productive and generator character.

The research supported by this specific theoretical background is duly registered with the ethics committee (CAAE: 05803018.7.0000.8088). The information was provided by twelve (12) students in the third year of high school, who were identified using fictitious names to preserve their anonymity.

This was the preferred choice since the school planning provided for the electrochemistry content to be taught in the third year. That school has three classes in the third year and initially all of them were invited to take part in the study. The class which had the highest number of students motivated to collaborate was chosen. Therefore, students from class A of the third year were those included in the research.

The process was divided into experimentation and data collection using open questionnaires, sentence completion, debates, and classroom observation.

The experimentation was divided into two phases. The first involved the challenge of assembling the experiment and measuring the ceramic powder surface pH. The second phase involved the following problem-situation: having the result of the pH measurement and the recognition of the electrical charge acquired by the oxide surface, students would connect the positive and negative poles to generate the ceramic conformation, that is, knowing the oxide charge, they had to adjust the right battery pole to the graphite to obtain the ceramic powder deposition. In all phases, the STS approach involving niobium ceramic was used.

To assemble the experiment, students had access to the following low-cost materials: one 12 V battery (from electrical car); two 50cm (at least) 4mm flexible wire connected to alligator clips; one small (15cm x 15cm) stainless steel or aluminum bowl; one 5mm graphite (mechanical pencil); distilled water (add electrolytes) or tap water; one portable pH meter (found in swimming pool or aquarium shops) or pH test stripes (the literature reports other ways of measuring pH, one of them is to use a red cabbage solution); one magnetic agitator (or manual stirring); scales (it can be one of those used in the kitchen).

The following instructions were given:

a) A niobium oxide 10% weight in water colloidal dispersion has to be prepared;

b) An electrolysis reaction will occur along with the electrophoresis and sedimentation of the niobium oxide ceramic powder on the graphite;

c) during experimentation, students must be attentive to the complexity of the reaction medium by observing the electron flow, identifying the anode and cathode, and the chemical species that were reducing and oxidizing.

In electrolysis, anode is the electrode where the anions that lose electrons concentrate and oxidize. That electrode is called positive pole. Cathode, in turn, is the electrode where cations that receive electrons and reduce will concentrate. That electrode is called negative pole. Then, in electrolysis, the electrons flow in the circuit, from the electron-generator center to the positive charge center. If, instead of considering the electron flow, only the electrode is analyzed, the electron goes from the positive to the negative pole. In batteries, the same process occurs, but polarities are inverse, since electrons are generated in the negative pole, where there is a species that lose electrons and oxidizes, and the electrons go to the positive pole, where the other species is, which receives and reduces electrons (ATKINS; JONES, 2006).

The following considerations are also made:

a) the polarities of batteries and electrolysis are many times memorized without giving importance to the electrical charges and the ions involved in the process in general, which results in some confusion when the students fail to understand the process;

b) the electron flow is always from the material presenting greater oxidation to that of lower oxidation, from the anode to the cathode, while in textbooks, the signals for batteries and electrolysis change since they explain that one process is the opposite of the other. However, the electron flow process is the same in batteries and electrolysis, while the spontaneity of the reaction is not, so that the poles – or electrodes – present inverse poles to generate the same electron flow effect;

c) they might seem opposed because our analysis ends in the material and disregards the reaction medium, while everything is continuous. Such fragmentation that disregards the whole process causes confusion and does not allow the understanding of the full reaction (ATKINS; JONES, 2006).

To help students to solve the problem-situation, the following instruction was given: considering that the deposition of the ceramic powder on the electrode is influenced by several factors, among those, the oxide surface charge, they must remember that after the dispersion is prepared, they must measure the pH and then they must have one of the alligator clips attached to the bowl and the other to the graphite.

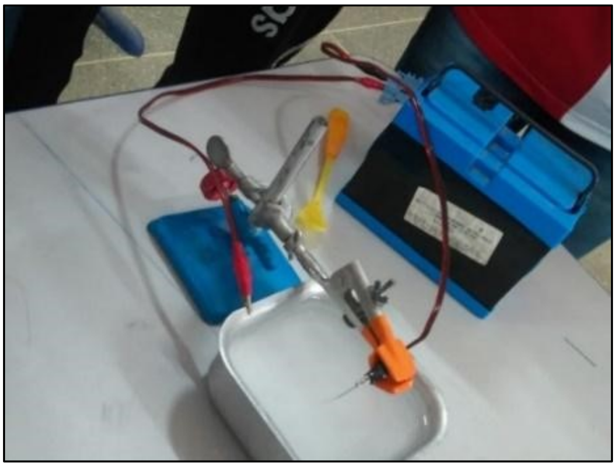
RESULTS AND DISCUSSIONS

As a result of the pH measurement, the niobium oxide dispersion in water (Figure 4) showed basic pH. A claw support (Figure 5) was attached to the pole connected to the graphite.

Figure 4: Niobium oxide suspension in water, pH 9.5

Source: The authors (2019).

Figure 5: Electrophoresis deposition system



Source: The authors (2019).

In the experiment, supported by meaningful and creative learning, the proposition of a challenge and problem-situation was important to monitor students' participation and the creation of a solution. The pH measurement was relevant to find out on which of the poles the deposition would occur, but some students did not measure the pH. Also, some of them placed the graphite on the pole with the same charge as that of the oxide surface and noticed that the deposition did not occur. Therefore, even in those cases, they developed some experiment with the material and could discuss the reason why the deposition did not occur.

This evidenced the growing need for experimentation in a systemic and complex perspective. When approaching the complexity of the reaction system, it was possible to clarify that for the electricity conduction to occur, there must be two free ions that will be responsible for the electron transfer. Experimentation requires a suitable approach to the relationship between the macroscopic behavior, the manifestation identified with the instruments, and the theoretical explanation referring to the microscopic behavior of the particles in movement. Because students cannot see the electrons in movement, they find it difficult to conceptualize electrical conductivity and, consequently, oxidation and reduction. Moreover, the experiment enabled socio-scientific debate about the use of water instead of alcohol during the electrophoresis, and, therefore, about the impacts and environmental care related to the theme.

The use of alcohol as dispersant requires greater electrical current throughout the system for the niobium oxide deposition on the graphite. In addition, to prevent the oxide fast flocculation or decantation, certain substances must be used such as polyacrylates, which can be harmful to the environment. For this reason, the best alternative would be the use of polar solvents, such as water, which, besides requiring a lower electrical current, does not require substances that can damage the environment; however, at low voltages (2 V), water electrolysis will occur (ATKINS; JONES, 2006).

Data was collected using open questionnaires, sentence completion, debates, and classroom observation. Groups of “meaning zones” related to the study of reality (previous knowledge) about ceramics and their technologies were also included since the scientific concept allows reflective awareness and is mediated by another concept already learnt, with relevant role in education and learning (VYGOTSKY, 2005).

When analyzing the students’ productions described, we observed that Antônia thought about the technique when she reported that in electrophoresis “water does not require so much energy, while the ethanol required a greater charge”. She forgot the problems related to the environment, maybe because this is not a concern in current learning, which, many times, is only concerned with concepts instead of relating the interactions between science, technology and society.

As explained by Freire (2011), developing literacy in individuals is more than allowing them to read words, it is about provoking critical reading of the world. For this reason, Auler (2002) points out the importance of approaching references of the STS movement and Freire’s principles since they contribute to scientific education for ascribing the school pedagogical political project the reinvention of society. Therefore, defending the human beings’ ontological vocation of being historical rather than a simple object is necessary to enable the reinvention of those that remain in the silence culture with a critical understanding of the STS interactions in teaching.

Although advancements in technology are important, a better approach to the interactions between science, technology and society in the classroom is needed to provide some understanding of the process complexity.

Other students such as Danúzia and Elza revealed feelings of responsibility and concern in their production since in addition to observing that the electrophoresis technique is more easily developed with water, even with the electrolysis, they thought about the environment. This is shown in Danúzia's report: "*Water requires less water than ethanol and does not use substances that harm the environment*", while Elza described: "*The technique with water uses lower electrical current and does not require substances that damage the environment, and then, in low voltages, water electrolysis occurs*".

About the concepts learnt and the importance of relating sciences content with the resulting environmental impacts, Elza reported: "*I didn't know the concept of advanced ceramics, electrolysis, or electrophoresis*"; and added "*Discussing STS makes people aware of what has been happening, making us see the world in another way"*.

We observed that Antônia, unlike Danúzia and Elza, tended to think a lot about the technique and presented a good performance regarding the understanding of electronic flows, advanced ceramic materials, and their importance. Some evidence of such learning appeared when she answered confidently and calmly to the questions proposed during the experimentation. In one of her answers, she stated that "*the electronic flow is always from the anode to the cathode*"

Antônia reported that: "*The experiment was differentiated and fun, and the students were interested in understanding better while experimenting*".

In Danúzia's sentence completion, she revealed that: I learned in the lessons "*that we can create our own experiments*"; and added: Experimentation is *"very good*". Her answers show indicators that experimentation was important for her. She reveals a sense of participation and dedication to accomplishing the practical task proposed.

Elza completed the sentences as follows: I learned in the lessons *"that we can make electrophoresis*"; and added Experimentation is *"extraordinary for our learning*". The way they completed the sentences enabled us to open a set of hypotheses leading to the meanings that show their excitement with experimentation. It also indicates their perception and attention, which reveal feelings of confidence and attention to the experiment.

During the socio-scientific debate, critical arguments regarding environmental impacts and the mining workers' work conditions were addressed. This was evidenced in the excerpt of one of the students' oral report, as follows:

> There are environmental impacts from raw-material production since the search for the minerals that are used in the ceramics production end up harming the environment due to excavations. Depending on the mining company, the conditions are precarious and present high risk of accidents for the workers (ANTÔNIA, 2019).

The student Danúzia showed a feeling of concern by mentioning that: "*mining companies promote impacts*" and danger for those working in that environment since "*workers are not protected*" and the mining companies exploit the environment. Likewise, Elza shows a sense of responsibility in her speech, in the excerpt where she refers to the lack of responsibility and posture of mining companies: "*The mining companies do not think about the pollution they cause and the harm to the workers in those places*".

The teaching and learning process based on constructivism and STS interactions favors increased zones of proximal development and a movement from common sense to scientific meaning.

Gathering scientific, technological, social and environmental knowledge in learning contributes to the theory-experiment association, as observed in the students' indicators, and to contextualization and environmental education (SANTOS *et al.*, 2011).

FINAL CONSIDERATIONS

This report sought to emphasize that the complex organization experiments developed favored the articulation of scientific theory and electrochemical phenomena by students learning sciences. With the experiment, they could study electrochemistry concepts such as electrolysis, electron flow, and oxidation and reduction reactions using the electrophoresis technique to produce a highly technological piece, which can be used in photocatalysis, a process that is used to treat water. It was also possible to monitor the challenge of participation and creation of a solution for a consistent problem situation in the action of measuring the dispersion pH to connect the battery poles to the corresponding electrodes. It was also possible to address STS interactions involved in the production of ceramics and the socio-environmental problems resulting from the mining activity.

Finally, we would like to share some recommendations regarding the experimentation proposed in this article. Experiments requiring low-cost materials are important in teaching since they are affordable and easily supplied. In this study, niobium oxide was used, but it could be developed with other oxides that are also considered ceramic such as zinc oxide observing the dispersion pH to connect the graphite to the right pole. Also, the oxide used in the experiment does not have to be discharged, it can be recovered by simple filtration and drying, which enables its reuse.

This study employed mechanical pencil graphite for deposition since it is easily found, and in a future burn of the deposited ceramic the graphite does not influence the final piece for being reduced to powder. In addition, graphite was used for allowing a larger deposition area during electrophoresis, and after the piece is burnt, for producing a tubular piece with a wide contact area that might be studied for photodegradation, for example. However, other types of graphite such as the one found in pencils, can also be used.

ELETROFORESE DE PÓ CERÂMICO DE NIÓBIO PARA ABORDAR CONCEITOS DE ELETROQUÍMICA

RESUMO

Este artigo trata de uma experimentação comprometida com a formação conceitual e contextual para o estudo de eletroquímica a partir da eletroforese de cerâmica de nióbio. A experimentação foi protagonizada por estudantes do 3º ano do ensino médio de uma escola pública, como um processo complexo de articulação entre fenômenos, teorias, interações socioambientais e a aprendizagem em perspectiva histórico-cultural. Neste sentido, busca-se referências para a complexidade dos sistemas reacionais, interações entre ciência, tecnologia, sociedade e cerâmicas. Como resultado, nota-se que o experimento favoreceu o ensino de eletrólise, de fluxo de elétrons e de reações de oxidação e de redução. Foi possível acompanhar os desafios na montagem da atividade experimental: a aferição do pH da dispersão e a conexão dos polos da bateria aos eletrodos correspondentes. E promover o debate sociocientífico sobre impactos ambientais por meio do uso de água em vez de álcool durante a eletroforese.

PALAVRAS-CHAVE: CTS. Experimentação. Cerâmica.

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