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Implications of experimentation as a contribution to problematized activities in understanding the corrosion phenomenon[1]

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ABSTRACT
This study comprises an investigation of the teaching-learning process regarding chemical concepts in a group of basic education students, in order to analyze experimentation contributions in problematizing activities, focused on the meaning of chemical concepts associated with corrosion. Audios from semi-structured interviews and participant observations were recorded and qualitatively analyzed. The observed participant relationships demonstrated links between chemical content and the corrosion theme, advancing the understanding of this phenomenon, suggesting knowledge (re)construction and connections with other contexts, enhancing student learning development, in the context of abstraction of the investigated subject. Therefore, the applied teaching strategy contributed to cognitive and argumentative processes, in which experimentation was conducive to articulations between chemical knowledge and the studied context from interactions promoted by problematization, allowing students to reach conceptual significance.
KEYWORDS: Experimentation. Problematization. Conceptual significance. Corrosion.

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Implicações da experimentação como aporte em atividades por problematização para compreensão do fenômeno corrosão

RESUMO

O objeto de estudo deste trabalho diz respeito ao processo de ensino-aprendizagem de conceitos químicos junto a estudantes do ensino médio, a fim de analizar contribuições da experimentação em atividades problematizadoras, voltadas para a significação de conceitos químicos associados à corrosão. Foram gravados e analisados, qualitativamente, áudios de entrevistas semiestruturadas e de observação participante. As relações observadas dos(as) participantes demonstraram articulações entre conteúdos químicos e o tema corrosão, com um avanço no estado de compreensão de tal fenômeno, o que sugeriu a (re)construção de conhecimentos e conexões com outros contextos, potencializando o desenvolvimento de sua aprendizagem, no sentido de abstração do tema em estudo. Portanto, a estratégia de ensino contribuiu para os processos cognitivos e argumentativos, nos quais a experimentação se fez propícia às articulações entre o conhecimento químico e o contexto estudado, a partir das interações promovidas em meio à problematização, conduzindo os(as) estudantes a alcançarem significação conceitual.

PALAVRAS-CHAVE: Experimentação. Problematização. Significação conceitual. Corrosão.

Implicaciones de la experimentación como contribución a actividades problemáticas para comprender el fenómeno de corrosión

RESUMEN

El objeto de estudio de este trabajo hace referencia a la enseñanza de conceptos químicos a estudiantes de secundaria, con el fin de analizar los aportes de la experimentación en actividades problematizadoras, enfocadas en el significado de conceptos químicos asociados a la corrosión. Cualitativamente fueron grabados y analizados audios de entrevistas semiestructuradas y de observación participante. Las relaciones observadas de los participantes demostraron vínculos entre el contenido químico y el tema de la corrosión, con un avance en el estado de comprensión de este fenómeno, lo que sugirió la (re)construcción de

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conocimientos y conexiones con otros contextos, potenciando el desarrollo del aprendizaje, en el sentido de abstracción del tema en estudio. Por lo tanto, la estrategia de enseñanza contribuyó a los procesos cognitivos y argumentativos, en los que la experimentación propició las articulaciones entre el conocimiento químico y el contexto estudiado, a partir de las interacciones promovidas en medio de la problematización, llevando a los estudiantes a alcanzar una significación conceptual.

PALABRAS CLAVE: Experimentación. Problematización. Significado conceptual. Corrosión.

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Introduction

The difficulty of high school students in applying chemistry to everyday contexts is recurrent in teaching-learning situations (POZO; CRESPO, 2009). Despite some initiatives, these obstacles are still part of the Brazilian educational routine. Santos et al. (2013) attribute this condition to teaching models that lead only to information, formula and knowledge memorization, limiting student learning. According to those authors, such models can also trigger a chemistry disinterest.

Guimarães (2009) points out that fragmented content unrelated to prior student knowledge combined with a qualitatively precarious participation, very present in traditional education, tends to hinder significant learning processes. In light of Ausubel's (1963) theory of Significant Learning, prior student knowledge is, in fact, the primary factor for meaningful learning. Another aspect of this theory concerns student criticality amidst the demands of contemporary society (MOREIRA, 2010).

Strategically, experimental activities in science education comprise a didactic resource whose function is to assist students in understanding concepts associated to investigated phenomena, contributing to the investigative process and seeking to signify such concepts (ZANON;

UHMANN, 2012). Traditionally, when conducting experimental activities, students follow previously prepared scripts and their actions are guided by teaching instructions or even the text itself, in opposition to emerging teaching-learning needs (OLIVEIRA; HARTWIG; FERREIRA, 2010).

As this is a common current practice, we point out the need for incentives concerning strategies that lead to student. reflections, overcoming reductionist aspects regarding illustrations and proof of theories. In this sense, Francisco Júnior (2008) indicates that knowledge is built as a dialogical process, in which teachers enable students to think and discuss chemical concept relationships in a defragmented and contextualized manner through problematization processes, allowing for a better understanding of social issues.

In this context, we believe that experimentation as a contribution to activities through problematization can be an alternative for significant knowledge construction, and we consider corrosion as a propitious theme to contextualize chemical knowledge in a group of high school students, given student difficulty in learning concepts associated with this phenomenon. According to Cachapuz (2005), problems must be proposed or assumed by students, resulting in a personal sense and constituting an intellectual challenge. Francisco Júnior, Ferreira and Hartwig (2008) add that experimentation should instigate students through curiosity and challenges, leading to reflections concerning issues belonging to their reality and , therefore, proposing more effective actions contributing to troubleshooting.

In a study involving the theme “salt air” in electrochemistry teaching, Sanjuan *et al.* (2009) mention student difficulties concerning the abstraction of chemical concepts associated with corrosion, such as oxidation, reduction and oxidation number. Corroborating our perception, Merçon, Guimarães and Mainier (2004) observed that the contextualization of chemistry contents when evaluating corrosion favors the association of scientific concepts and social, economic, environmental and historical aspects, leading students to a citizen formation (MERÇON; GUIMARÃES; MAINIER, 2011).

In this scenario, the following concern arose: How can the use of experimentation in problematizing activities contribute to the signification of chemical concepts in the understanding of corrosion in a group of high school students? To answer this, we analyzed the consequences of experimentation in problematizing activities focused on signifying chemical concepts associated with corrosion. To this end, we identified situations in which students were able to establish coherent connections between chemical concepts and corrosion and verified their ability to make appropriate inferences in the understanding of everyday phenomena related to corrosion.

Experimentation in problematization activities as a resource for meaningful learning

Traditionally, chemical concept learning in basic education has shown unsatisfactory results. The absence of chemistry contextualization makes it difficult to articulate concepts, and memorization processes have become the norm (LIMA *et al.* 2000). Corroborating Lima *et al.* 2000, Binsfeld and Auth (2011) note that the absence of any relationship between a certain covered content and student contexts tends to hinder knowledge signification.

Contrary to the rhetoric of traditional teaching, Kato and Kawasaki (2011) use contextualization teaching strategies, aiming at bringing teaching and learning processes to student realities, overcoming fragmented approaches that are distant from the student context, but which are present in the curricula.

Contributing to this debate, Chassot (2014), points out that chemistry teaching should be guided under the perception of its social function, in which students may perceive chemical concepts in different

https://doi.org/10.14393/ER-v28a2021-43

contexts, thus attributing meaning to learning, aiming at an approximation between concepts and contexts.

On this, Wharta (2013) opposes the use of everyday situations as a way to illustrate and exemplify chemical concept applications without problematizing and analyzing a more systemic dimension as part of the physical and social world.

The aforementioned authors are in line with educational guidelines complementary to the Brazilian National Curriculum Parameters (Brazil, 2002), which suggest a contextualized approach for greater student participation in the educational process, providing meaningful learning. According to Ausubel, when new information interacts with a sub-concept already present in the student's cognitive structure and information becomes anchored and assimilated in this manner, significant learning is achieved, at the same time that it modifies the sub-concept. Two principles are associated with this process, namely progressive differentiation, when ideas are presented progressively from the most general to the most specific, and integrative reconciliation, which explores the relationship between concepts and propositions (MOREIRA; MASINI, 2001). Moreira (2005) adds the need for learning to be critical, forming citizens better inserted in the social context.

In this sense, Melo, Oliveira and Nascimento (2019) report that the use of experimentation as a contribution to problematizing activities constitutes a relevant alternative for chemical knowledge significance, as it allows students to assume a leading role in the process, which is essential for significant critical learning.

Gonçalves (2005) highlights the mistakes of education professionals when conceiving of experimentation as merely aimed at confirming theories. Furthermore, Giani (2010), Silva, Machado and Tunes (2011) and Suart (2014) add that experimentation under this perspective would make the process restricted to a merely reproductive illustration and/or application of mechanical instruction scripts.

Based on Gonçalves (2005), we understand that investigative experimental activities involve students in learning processes more effectively than in other scenarios, applying interesting problem situations in order to motivate student learning.

In line with Gonçalves (2005), we believe that experimental investigative activities tend to result in student reflection, construction and concept signification processes. Because of this, theses activities may result in the development of argumentation skills, collaborative work and student socialization, as suggested by Galiazzi and Gonçalves (2004). In line with these authors, Zanon and Uhmann (2012), emphasize that student interactions during experimental activities are essential in concept construction or reconstruction based on exposure to new ideas and information.

Breaking with traditional teaching conceptions, which are characteristically contentious, Binsfeld and Auth (2011) defend the importance of spaces where students feel motivated to express their conceptions and become questioners, so they may act in close contexts, understanding the limits and possibilities of their role as citizens. To facilitate the expression of these ideas, we highlight problematization activities that, as Gonçalves (2005) observes, favor dialogical explanations of student knowledge. This same thought is shared by Guimarães (2009) when the author suggests that problematization through language aiming at exposing prior student knowledge requires more than simple concept and information memorization.

Problematization can also be accomplished through the use of problem situations, defined by Meirieu (1998) as didactic situations in which students are proposed tasks that require clear learning, achieved by overcoming task obstacles.

Regarding this discussion, Suart (2014) adds that the methodological path taken to solve the problem situation is more important than the problem solving itself, as the search for the

https://doi.org/10.14393/ER-v28a2021-43

resolution involves reflective, cognitive and interactional processes, considered the main gains for the group. Zanon and Uhmann (2012) and Suart (2014) emphasize the teaching function as a teaching-learning process mediator, responsible for creating situations that require reflection during their investigative stages and for inserting content problematization and contextualization, linking observations and theoretical discussions so that students are able to build arguments and hypotheses to solve the problem situation. Thus, teaching activities can direct practices so that new knowledge is associated to previous student knowledge and, according to Ausubel (1982, *apud* Pelizzari et al., 2002), the substantial association of new content with relevant student cognitive structure aspects leads to meaningful learning.

Methodological design

This study comprised a qualitative assessment that, according to Chizzotti (2010, p. 84) concerning the data analysis, seeks to understand "participant experience, formed representations and elaborated concepts. The manifested concepts and the reported experiences occupy the center of reference of the applied analyses and their interpretations". In this sense, we understand qualitative research as capable of supporting the extraction of relevant information for the understanding of the observable aspects of the investigation process, comprising an interventional study. According to Teixeira and Megid Neto (2017), this type of study aims at process data planning, application and analysis, focusing on the contributions and/or limits of the observed phenomenon.

The empirical field was the Science Laboratory of a public school located in São Bento do Una, in the Pernambucano agreste region, in Brazil. The study was carried out with six students presenting difficulties in inherent school routine situations requiring articulation between scientific knowledge and different contexts and available for study participation. The research was submitted to the institution's Research Ethics Committee (CEP).

Research instruments and data analysis criteria

A priori and *a posteriori* semi-structured interviews were applied to identify whether students were able to make appropriate inferences in the understanding of everyday phenomena related to corrosion. According to Manzini (2004), this instrument consists of a script with guiding questions complemented according to circumstances that arise during the interview.

Participant observation was applied to identify situations in which coherent connections between chemical concepts and the proposed context of corrosion were established by the students, which, according to Chizzotti (2010, p. 90) "are obtained through direct researcher contact with the observed phenomenon, to collect the actions of the actors in their natural context, from their perspective and their points of view". The semi-structured interviews, as well as participant observations, were recorded as audio files for later analysis.

The materials characterized as the analysis *corpus* were assessed according to the content analysis procedures established by Bardin (2011). To this end, the materials were broken down into signification units, followed by categorization. Three analysis categories were applied, as follows: understanding corrosion, associations between corrosion and reactivity and understanding the redox process. Established relationships, student difficulties, constructed arguments and chemical concept articulations applied in the understanding of corrosion processes were analyzed.

Didactic proposal

The intervention was developed from the application of a didactic sequence (DS), contained in the supplementary documents of this paper, in which participants were subjected to problematizing dynamics based on the problem-situation, where chemical concepts were articulated in order to understand the corrosion phenomenon. To this end, an experimentation was applied as a support to allow students to articulate experimental observations and different contexts and potentially achieve conceptual significance.

Data analysis and discussion

Some analytical fragments of the observations and interviews applied herein will be presented, analyzed according to the previously described categories. To preserve participant identities, student are identified as letters of the alphabet (A, B, C, D, E and F). The symbolism "..." represents pauses during participant speeches, and "[...]" indicates ommited text.

Category 1: Understanding corrosion

This category comprised the analysis of fragments resulting from questions 1 and 2 of the semi-structured interviews, carried out prior to and after the intervention.

The question **"1. What do you mean by corrosion?"** was applied to characterize aspects refering to the construction and/or reconstruction of student knowledge concerning the corrosion phenomenon.

Prior to the intervention, some student difficulties and misunderstandings concerninf the concept of corrions were identified. Students A, D and F only associated corrosion to rust, while students B, C and E were unable to express any knowledge on the subject. However, when asked to think about what it means to say that a material is corroded, citing iron (Fe) as an example, student B associated corrosion with rust, student C associated corrosion with a lack of material utility and F reported corrosion as material destruction.

"*[...] when it's too old, it's ... it becomes rusty, it changes color*" **(B)**.

"*Corrosion is ... we use it, then when we don't want it anymore, we throw it away...* " **(C)**.

"*[...] it is something that corrodes, destroys... the name already says so ... corrosion, corrode*" **(F)**.

After the applied intervention, all students displayed a better abstraction of the corrosion phenomenon, associating it to material wear and changes in material characteristics, indicating a more coherent view of the subject. Some answers: "*[...] it's worn ... because it's suffering oxidation*" **(A)**.

"*[...] it's when a material ... runs out, loses its luster, loses its top layer [...] the material is being destroyed"* **(B)**.

"*It's changing its shape ... a different shade, it's wearing out*" **(D)**.

"*It's falling apart*" **(E)**.

"*Corrosion is something falling apart, destroying itself*" **(F)**.

Concerning these arguments, we noted that student A coherently articulated a concept between oxidation and corrosion. Student B, in addition to mentioning material wear, also associated the to certain transformations, such as color change and loss of brightness, which is characteristic of the occurrence of a chemical reaction, a corrosion process constant. Student D characterized corrosion as a more comprehensive phenomenon and not only as rust, indicating an oxidation product of materials containing Fe. E and F, despite using colloquial language, associated the phenomenon to material deterioration.

Up to this point, we noticed an important conceptual student evolution concerning the study object, since, initially, only one student was able to associate corrosion with material deterioration. Therefore,

https://doi.org/10.14393/ER-v28a2021-43

we infered a conceptual alignment with Gentil (1998) concerning the corrosion phenomenon, which was translated into the use of terms such as “destroying”, “wearing out”, “undoing”, “falling apart”, approaching the definition of the phenomenon as material deterioration following interactions with the medium, resulting in alterations such as wear. Therefore, we believe that student changes during the intervention following problematization contributed to a better understanding of the investigated phenomenon, evidencing the reconstruction of scientific knowledge, according to the perspectives established by Francisco Júnior, Ferreira and Hartwig (2008).

In order to identify whether students were able to make appropriate inferences in the understanding of everyday phenomena related to corrosion, we asked question **“2. Can you identify corrosion in any everyday situation? ”** This led to the following answers:

“*[...] the beach, the salt air ... because of salt [...] or iron? Rust! [...] table, gate, car [...]*” **(A)**.

“*[...] like iron corrosion, right ?! ... we tested and there was corrosion ... magnesium displayed that, right?!... zinc too, the one where it didn’t happen was was platinum*” **(B)**.

“*In gates, cars, every metallic object*” **(D)**.

“*[...] construction material [...] gates too, nail [...]*” **(E)**.

We perceived that the students became immersed in an apparent reflection process concerning the experimental activity of simulated oxidation, suggesting an association between corrosion and redox processes, in addition to their articulation regarding the susceptibility of domestic utensils and construction materials to corrosion. Thus, we infered an alignment with Suart (2014), as the applied experimental activity allowed for the integration of both actions and reflections and the students were encouraged to discuss, analyze and interpret the results from concept articulation, fostering conceptual signification.

https://doi.org/10.14393/ER-v28a2021-43

The characterization of salt air as an everyday phenomenon associated with corrosion, as well as the example of platinum (Pt) as a corrosion-resistant material, refer to the appropriation of the chemistry concepts built during the proposed dynamics. We therefore characterized a certain amount of progress concerning student understanding, in due alignment with Zanon and Uhmann (2012) when suggesting that experimentation has the didactic function of assisting students in understanding and, consequently, signifying concepts associated to the studied phenomena. Based on Ausubel (1982, *apud* Pelizzari et al., 2002), we believe that the new information presented during the intervention became substantially anchored in the students' cognitive structures.

Category 2: Association between corrosion and reactivity

In this category, we sought to identify situations in students established coherent connections between chemical concepts and the proposed corrosion context. We emphasize that this category was developed through the analysis of the fragments obtained from the semi-structured interviews, carried out after the scheduled intervention actions and participant observation.

This category suggests the abstraction of chemical concepts concerning corrosion and resulted from both questions "**3. Can all materials corrode? Explain!**" and "**4. What associations can be made between corrosion and chemical phenomena?**" in the semi-structured interview and participant observation records.

Students A and D and student E associated material corrosion with the fact that the material comprises a reactive metal, which they termed "reactive". Student A emphasized the fact that some metals do not donate electrons, differentiating metals that undergo corrosion, such as magnesium (Mg), zinc (Zn) and aluminum (Al), from less reactive metals, with the exception of those displaying certain periodic properties, like Pt. When we asked this student to compare Fe and Pt in terms of oxidation, the student answered:

"*[...]oxidation is donating the electron [...] ",* referring to Fe and *" [...] platinum does not donate electrons*" **(A)**.

Student D, who had initially associated corrosion to metallic materials, stated that "*I think so, it happens more with metallic ones, like car metal, gates, their materials, like iron, but plastic, these types of things don't,*" and went on to argue that not all metals suffer corrosion, citing the following examples:

"*What we were studying [...] does not suffer corrosion ... gold ... because they are less reactive"* **(D)**.

Student F, apparently based on the periodic table reactivity series, was even more emphatic: "*No ... some materials like platinum and copper, which are noble, [...] then they are less reactive, so when they are less reactive they are not easy to oxidize and corrode*" **(F)**.

Student E, when asked about differences between the metal atom Fe, which undergoes corrosion, and another that does not, was able to coherently associate corrosion and reactivity. "*[...] because iron is more reactive*" **(E)**.

In order to understand the relationship between corrosion and reactivity, student dialogues associated redox characteristics to submicroscopic metal structures after reading texts and simulating atoms/ions through a software. The students cited protons, neutrons and electrons, indicating that protons and electrons have electrical charges.

When simulating the hydrogen ion (H^+), using the software, we emphasized that the hydrogen atom should be neutral and student A suggested: "*Put a negative [...] electron*," demonstrating an understanding that the amount of protons equals that of electrons in atoms.

When assembling the helium atom, students were able to understand how to produce an ion from a neutral atom and identify the

https://doi.org/10.14393/ER-v28a2021-43

central region as a nucleus containing both protons and neutrons, with electrons orbiting the nucleus. When assembling the lithium atom, we asked the students to observed differences in relation to the previously assembled atoms, so student F commented: "*Look! The electron is not on the same line! [...]*". When discussing Bohr's atomic model, we questioned whether a lithium atom would be larger than a helium atom, and student E stated: *"[...] bigger, it has more layers*."

We realized that student E's response did not take into account that, for the stated reasoning, the atoms should be in the same group. However, later on, when contructing the atomic ray concept, we observed that students easily understood the sense of increasing radii in a periodic table group with an increasing number of atom layers, while they associated reduced radii with more intense interactions in atoms with more electrons in periods: "*one of them has more electrons, so it's a smaller atom ... more interactions ",* indicated student E.

During the applied experimentation, in which copper (Cu) reduction was simulated, when we questioned what happened to Fe, they replied that it suffered oxidation. Concerning atom structure changes, student F suggested that it donated electrons. We questioned what would be necessary for this donation and the same student stated: *"[...] to deposit energy*." Subsequently, the concept of ionization energy was discussed and the students suggested that it would be easier to remove electrons from a large atom and associated increased ionization energy in the periodic table with the experimental activity, from which the argument arose: "*When iron donated an electron, it left that layer and went to copper*."

We infered that the students presented evidence of understanding electron transfer, associating ionization energy with atomic radii, through their dialogues.

Both electronegativity and electropositivity concepts were being constructed in dialogues concerning reactivity, assisting students in understanding electron transfer processes. During one of these moments, student F presented the wrong definition of electropositivity: *“[...]proton attraction*.” This misunderstanding was overcome, after emphasizing the atom’s tendency to donate electrons: "*in electropositivity it will expel electrons*."

Regarding Mg, which was classified as very reactive in the experimental activity, students were able to answer that this is a large atom, with low ionization and electropositive energies. When asked what it would mean for this element to be electropositive, student D replied that it would easily donate electrons. We realized that, although the student referenced reactivity based on periodic properties, he was not able to perceive platinum as an exception. However, after discussing the peculiar characteristics of transition metals, such as the presence of the sub-level d, students suggested that Pt would be a less reactive material, which is why it is used in bone restructuring plates.

In the course of the study it became evident that a long path was taken so that students could signify knowledge and not only memorize information or uncritically abstract it. This is in accordance to Zanon and Uhmann (2012) and Suart (2014) concerning the role of teachers in the mediation of the teaching-learning process. In this context, teachers are responsible for creating situations that require reflection during investigations, as well as for inserting the applied problematization, linking theoretical observations and discussions so that students are able to build arguments and hypotheses to solve the problem situation solution.

Category 3: Understanding the redox process

This category comprised the analysis of the post-intervention interview data. It is importante to note that, for better result consistency, we also used data from participant observation.

https://doi.org/10.14393/ER-v28a2021-43

The development of this category refers to the contribution of the applied experimentation in the understanding of corrosion alongside chemical concepts. The question "**5. How would you describe the observed phenomenon (metal wear) at the submiscroscopic level?"** led to the following statements:

"*[...] it is donating the electron [...] oxidation donates the electron and reduction [...] iron took copper's place"* **(A)**.

"*The particles are becoming agitated ... They come out and go to another*" **(B)**.

"*[...] loss of electrons ... to the substance that it is interacting with [...] we saw this ... redox! [...] oxidation is the loss, as in iron"* **(D)**.

"*[...]material is oxidized in corrosion [...] loss of electrons ... then it would be like iron for some substances [...]redox ... one substance will suffer oxidation and the other will suffer reduction*" **(F)**.

From the presented arguments, we realized that the students resorted to experimental activities to explain the redox reactions that occur during corrosion, demonstrating that experimentation may have fulfilled its function of assisting in the understanding and signification of chemical concepts associated with corrosion, contributing to the investigative process, in alignment with Galiazzi and Gonçalves (2004) and Suart (2014).

Although student B did not explain the electron transfer process between atoms during the redox reaction, a coherent association between corrosion and electron loss/gain by atoms mas made.

Student F was able to better abstract chemical concepts, coherently articulating corrosion and the redox process. It became evident that the student applied such articulations to support the electron transfer reactions that occur during corrosion. We also emphasize that the fact that the student cited Fe as an oxidation example, converging with the experimental activity in which a simulated reduction was carried out.

https://doi.org/10.14393/ER-v28a2021-43

Student A suggested that material wears out during corrosion because it undergoes oxidation and, when attempting to associate corrosion with chemical phenomena, the student added the occurrence of reduction as a simultaneous process to oxidation, defining the process as redox. We also emphasize that, despite using colloquial language, the student demonstrated an understanding of the simple exchange reaction that occurred in the simulated redox reaction.

During the experimentation, when asked about particle loss/gain in the atoms of the material undergoing corrosion, student D replied that this would comprise loss of electrons, which would be transferred.

When asked about the possibility of preventing the redox reaction, Student E, suggested and electron transfer between substances if the material was composed only of the same or unreactive substances.

When applying charts in the construction of chemical equations to mathematically represent the reagents and products of the observed redox reactions, we simulated reduction reactions and asked students to find copper sulfate. During this moment of the intervention, we perceived cooperative associations between the students, in line with Galiazzi and Gonçalves (2004) who associate experimentation with cooperative student work and socialization, as well as the development of argumentation skills.

When asked what would have happened in the reaction, students A, D and F demonstrated an understanding of the redox reaction as the transfer of electrons between Cu and Fe, evidenced in the following responses: "*There was that thing of losing electrons to another...* "(**F**); "*Redox ... redox!"* (**A**); "*Copper is reduced*" (**D**).

To assist the students in understanding the displacement reaction, we approached the chemical reactions in terms of disruption and the formation of new bonds. We questioned what would happen to Fe, and student F, although using colloquial language, demonstrated an appropriate understanding regarding simple exchange reactions: "*Iron is alone, but it's* *reactive, it doesn't like to be alone ... copper manages to be more alone than him [...] he's going to kick copper and take his place*" **(F)**.

Student cooperation was also observed when representing the reaction products, and evidence of student understanding the exchange between Fe and Cu was also noted, as suggested by B: "*[...] because copper moved from its place to another.",* reiterating that Fe was able to displace Cu because it is more reactive.

After determining the chemical species oxidation numbers, we asked the students to compare Fe values for the equation reagents and products, and student F said: "*It had nothing! [...] it had zero nox and went to ... +2*". Regarding the meaning of this variation, student E, recalling electric charge atom interactions, added: "*Lost*!"

When we asked students to write down the constructed equation, they had difficulties in identifying the Cu aggregation state. We then recalled that Fe had displaced Cu, and student E noted: "*So it was solid*!" This helped student F to identify the material that had formed on the nail in the experimental activity simulating the reduction: "*Is it copper? WOW!*", referring to the fact that Cu went from ionic to metallic form.

To construct the equation representing Fe oxidation by hydrogen, using the letters, student F commented: "*You have to find which is less reactive than iron.*" When comparing Fe and hydrogen in the reactivity series, we demonstrated an electron transfer process abstraction by student A: "*Iron is more reactive ... the same thing that happened with copper will happen*", rescuing their conclusion that Fe cannot be used in bone reconstruction plates because it participates in the redox process. When questioning whether this would also be a displacement reaction, student E commented: "*Yeah ... it changed here [...]*", referring to Fe and hydrogen. This speech demonstrates an understanding of the displacement reaction concept, since the exchange was noted.

When asked to hypothesize about what would happen as a result of the interaction of Mg with hydrogen, student F indicated that a

https://doi.org/10.14393/ER-v28a2021-43

hydrogen displacement would occur. The students identified Mg oxidation and hydrogen reduction, realizing the simple change: "*It sent the hydrogen away and took its place.*"

In the Zn oxidation equation, the students easily determined oxidation number variations and oxidation and reduction processes, with student D indicating that "*it lost two electrons and suffered oxidation*.", referring to Zn.

When we raised the hypothesis of Cu oxidation due to hydrogen, some comments emerged, such as *"And will that happen?! ... I don't think so ... there won't be any oxidation!"* We asked what happened to Cu in the experimental simulated oxidation activity and the students stated that there were no changes, with student F explaining: *"[...] because it is less reactive than hydrogen.*" Concerning the significance of Cu being less reactive than hydrogen, student A suggested that the reaction did not occur. When asked about Pt stability, similar comments emerged: *"It will do the same thing, right? ... it will not react."*

From this dialogue, students evidenced an understanding of metal reactivity and emphasized their conclusion that Fe could not replace Pt, as it was more reactive. From the reactivity series, they concluded that the use of Pt in bone reconstruction is, in fact, due to its low reactivity. We understand that the present study dialogues with Francisco Júnior (2008), as students undesrtood that knowledge is built throughout a dialogical process, in which teachers allow the opportunity to understand and discuss chemical concept relationships in a defragmented and contextualized manner through problematization processes.

Conclusion

Aspects concerning student understanding of the corrosion phenomena based on chemical knowledge articulations in solving a problem situation were evaluated herein. All students were able to establish coherent connections between the proposed context and the covered chemical concepts, making appropriate inferences concerning the discussion of metal behaviors. Such facts lead us to the research question: How can the use of experimentation in problematizing activities contribute to the signification of chemical concepts in the understanding of the corrosion phenomenon in a group of high school students?

The applied instruments used to obtain the data and construct the theoretical frameworks that supported the analysis allowed for the following inferences:

An important conceptual evolution concerning the study object in the category "Understanding corrosion" was perceived, as students demonstrated better conceptual abstraction, associating corrosion to material wear after the intervention. They came to understand rust as an iron corrosion product and associated corrosion to material oxidation, including iron, in addition to linking corrosion the wear and tear of other everyday corrosive materials.

The category "Association between corrosion and reactivity" suggested that students were able to signify knowledge by articulating concepts like atomic structure and periodic properties, as well as oxidation and reduction, to understand corrosion, as well as associating metal stability to the fact that some metals do not donate electrons through oxidation processes.

The category "Understandings about the redox process" demonstrated student understanding concerning metal reactivity and electron transfer processes in the redox reaction, allowing them to conclude that iron would not be an option as a platinum substitute in bone reconstruction plates, attributing this evidence to the fact that iron is a very reactive metal. Through the reactivity series, the students concluded that platinum is the most resistant metal among the studied elements, and suggested that this must be the reason why this metal is used to assist in bone reconstruction.

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In view of the above, we suggest that the intervention applied herein contributed to the developed cognitive and argumentative processes. Furthermore, the applied experimentation was conducive to student articulations between chemical knowledge and the studied corrosion context, from the interactions resulting from the problematization, leading them to reach conceptual meaning in a critical manner.

We emphasize that the teacher's position in promoting dialogue and mediating interactions in investigative experimentation is directly associated to the results obtained herein. Therefore, we believe that further investments in continuing chemistry teacher education concerning basic education is paramount, which can contribute to adequate teacher posture in proposals similar to the one presented herein.

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