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The use of concept as meaningful learning strategy in teaching chemistry

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ABSTRACT. The research has been developed based on the use of Conceptual Maps, as a possible meaningful learning strategy, its objective is the implementation of a didactic intervention aimed at teaching, learning and evaluating the contents of batteries studied in electrochemistry. This study has involved 26 high school students from a public school in Campo Grande, MS, Brasil. This is an investigation based on David Ausubel's Theory of Meaningful Learning, presenting a qualitative and intervention type, to which didactic tools such as Digital Information and Communication Technologies (TDICs), experimental activities and conceptual mapping were applied. The criteria for analyzing concept maps corresponded to the following categories: quantity and quality of basic concepts, new concepts and propositions, logical sense of the connecting words, examples on the subject studied, map clarity, hierarchization and the principles of progressive differentiation and reconciliation integrative Ausubel. The results have showed that the students have tried to explain in the conceptual maps the basic concepts involved in the processes of redox and in the constitution and functioning of a pile, thus showing a good cognitive evolution of these concepts. On the other hand, students have had difficulties in the hierarchy of some conceptual maps and in the principle of integrative concept reconciliation.

Keywords: conceptual mapping; meaningful learning; teaching electrochemical.

O uso de mapas conceituais como estratégia de aprendizagem significativa no ensino de química

RESUMO. A pesquisa foi desenvolvida com base na utilização de Mapas Conceituais, como possível estratégia de aprendizagem significativa, cujo objetivo foi a implementação de uma intervenção didática voltada ao ensino, aprendizagem e avaliação para o conteúdo de pilhas e baterias, estudado em eletroquímica. Esse estudo envolveu 26 estudantes do segundo ano do ensino médio de uma escola pública no município de Campo Grande, Mato Grosso do Sul. Trata-se de uma investigação fundamentada na Teoria da Aprendizagem Significativa de David Ausubel, apresentando cunho qualitativo e do tipo intervenção, ao qual foram aplicadas ferramentas didáticas como as Tecnologias Digitais de Informação e Comunicação (TDICs), as atividades experimentais e o mapeamento conceitual. Os critérios de análise dos mapas conceituais corresponderam às seguintes categorias: quantidade e qualidade de conceitos básicos, conceitos novos e proposições, sentido lógico das palavras de ligação, exemplos sobre o assunto estudado, clareza do mapa, hierarquização e os princípios de diferenciação progressiva e reconciliação integrativa de Ausubel. Os resultados demonstraram que os estudantes buscaram explicitar nos mapas conceituais os conceitos básicos envolvidos nos processos de oxirredução e na constituição e funcionamento de uma pilha, de tal modo evidenciando uma boa evolução cognitiva desses conceitos. Em contrapartida, os estudantes tiveram dificuldades na hierarquização de alguns mapas conceituais e no princípio da reconciliação integrativa dos conceitos.

Palavras-chave: mapeamento conceitual; aprendizagem significativa; ensino de eletroquímica.

El uso de mapas conceptuales como estrategia de aprendizaje significativa en la enseñanza de la química

RESUMEN. La investigación se desarrolló a partir del uso de Mapas Conceptuales, como posible estrategia de aprendizaje significativo, cuyo objetivo fue la implementación de una intervención didáctica orientada a la enseñanza, aprendizaje y evaluación de los contenidos de las baterías estudiadas en electroquímica. Este estudio involucró a 26 estudiantes de secundaria de una escuela pública en el municipio de Campo Grande, Mato Grosso do Sul. Se trata de una investigación basada en la Teoría del Aprendizaje Significativo de David Ausubel, que presenta un tipo cualitativo y de intervención, a la que se aplicaron herramientas didácticas como las Tecnologías de la Información y la Comunicación Digital (TDICs), actividades experimentales y mapeo conceptual. Los criterios para analizar los mapas conceptuales correspondieron a las siguientes categorías: cantidad y calidad de conceptos básicos, nuevos conceptos y proposiciones, sentido lógico de las palabras conectoras, ejemplos sobre el tema estudiado, claridad del mapa, jerarquización y los principios de diferenciación progresiva y reconciliación. Ausubel integrador. Los resultados mostraron que los estudiantes intentaron explicar en los mapas conceptuales los conceptos básicos involucrados en los procesos de redox y en la constitución y funcionamiento de una pila, mostrando así una buena evolución cognitiva de estos conceptos. Por otro lado, los estudiantes tenían dificultades en la jerarquía de algunos mapas conceptuales y en el principio de reconciliación integradora de conceptos.

Palabras clave: mapeo conceptual; aprendizaje significativo; enseñanza de electroquímica.

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Introduction

Chemistry is a science that has peculiarities of an abstract and submicroscopic nature. In this sense, they often cause learning difficulties among students. In addition, Chemistry has its own language, which is intrinsically symbolic, and in order to understand it, it is necessary to demonstrate a vast capacity for abstraction and generalization. Therefore, the act of teaching and learning chemical concepts is not a simple task (Costa, Passerino, & Zaro, 2012).

For the Chemistry teacher to be able to work satisfactorily in content with a high degree of abstraction and complexity, it is necessary to consider, for example, the representation of the particles of chemical species, the time allocated to carry out the activities and, above all, the lack of or not of prior knowledge of chemistry (Locatelli & Arroio, 2017).

Regarding the investigation of the students' prior knowledge by the teacher, it is essential that this knowledge is considered for a potentially significant teaching, since the interaction of new meanings with preexisting knowledge in the student's cognitive structure will be essential for the student to learn significantly (Moreira, 2006a).

Based on the Theory of Meaningful Learning (TAS), concept maps are hierarchical diagrams that indicate relationships between concepts and that seek to reflect the conceptual organization of a discipline, or part of it, so their existence comes from the conceptual structure of a knowledge area (Moreira & Rosa, 1986). In addition, concept maps allow the determination of students' prior knowledge, before teaching. On the other hand, they provide an analysis of possible changes in the student's cognitive structure during the course of instruction and, consequently, present data that can serve to feed back teaching and curriculum (Moreira, 2006b).

In the teaching of electrochemistry Silva, Silva and Aquino (2014) applied concept maps as an assessment of high school students, focusing on the study of natural batteries. The authors highlighted that the concept map is a flexible and dynamic tool, which focuses on the teaching and learning of concepts, considering that, in Chemistry, students often do not understand the contents because they are disconnected from their reality and also because there is a vast amount of information and formulas.

Recognizing the importance of learning in electrochemistry, some researches (Caramel & Pacca, 2011; Lima & Marcondes, 2005; Silva & Cintra, 2013) point out that there are obstacles to understanding this content by students and also by teachers, and as a consequence, end up presenting learning difficulties and alternative conceptions to explain electrochemical concepts.

In view of the above, we seek to answer the following research question: How does approaching electrochemistry content, with an emphasis on batteries, through the elaboration and implementation of a didactic intervention with the use of conceptual maps, contributes to learning of electrochemical concepts of second year high school students from a public school in Campo Grande - MS? Thus, the objective of the research was to analyze the use of concept maps, based on the Theory of Meaningful Learning (TAS), as a strategy for meaningful learning, teaching and evaluating electrochemical concepts.

The teaching and learning of electrochemical concepts in high school

The moment when students usually have their first contact with electrochemistry content happens in the second year of high school, because in the first year, in general, the physical behavior of the material is studied, which, in turn, can be easily found in our daily lives, such as the separation of mixtures and the physical states of matter. However, when it comes to electrochemistry, Barreto, Batista and Cruz (2017, p. 52) state that:

> Electrochemical knowledge is complex, as it requires some more elaborate reasoning, making it difficult, at times, to establish analogies with phenomena in the macroscopic world. After all, it is not easy to understand that, in an oxidation and reduction reaction (as, for example, in corrosion phenomena), one substance donates electrons to another, and that this transfer of electrons generates an electric current.

In this aspect, Wartha, Guzzi Filho and Jesus (2012) point out that the production of knowledge in Chemistry results from a dialectic between theory, experiment, thought and reality. An example of this can be seen in electrochemistry, as the idea that electrons and/or ions move through a solution is the biggest source of student errors, so when teachers talk about electrolytes, it is necessary to indicate that the movement of ions constitutes an electric current.

In the investigation carried out by Caramel and Pacca (2011), it was found that most students, when explaining the result of the production of electric current in a battery, point to a single justification, which refers to the transformation of chemical species, that is, to oxidation and reduction, so as not to consider the dynamic aspects of charge movement, both in the wires and in the electrolytes.

We emphasize that conceptual difficulties in relation to electrochemical concepts can also be evidenced by teachers, as was explicit in the research by Lima and Marcondes (2005), who emphasized that they incessantly prefer not to teach this content and, when it happens, it occurs in a traditional.

With the same bias, Marcondes, Souza and Akahoshi (2017) drew attention, in their research, to the non-valuation of the explanation of the submicroscopic level of concepts by teachers, as well as a superficial treatment in the teaching of galvanic battery, since they do not consider equation balancing, half-reactions involved and concepts as a more quantitative approach (potential difference, standard potential). As for the methodology and strategies commonly used by the teachers, it was evident a merely traditional teaching, directing the student only to solving exercises and consulting textbooks, without allowing a dialogic interaction and contextualization between the contents.

In this sense, concept maps are configured as tools that value prior knowledge, and depending on the way the teaching material is organized, it can stimulate interaction in the classroom, provide an integrated view of the subjects and guide students' significant learning.

Meaningful learning theory and concept maps

The Meaningful Learning Theory is considered a cognitive theory of learning, which was created by David Ausubel (1968). For the author, the essence of the process of meaningful learning focuses on the situation that new information interacts in a substantive (non-literal) and non-arbitrary way with what the student already knows (Ausubel, Novak, & Hanesian, 1980). The term substantivity expresses that what is introduced to the subject's cognitive structure is the 'substance' of the new knowledge, that is, the ideas, and not the precise words used to express them, once a concept or proposition can be expressed. in different ways, through different signs, which are equivalent in terms of meaning. The non-arbitrary way means that the interaction does not occur with any previous idea, but with a specifically relevant aspect of the individual's knowledge structure, so called as subsumer (Moreira, 1997b).

In the organization of teaching, Ausubel (1968) presents the following programmatic principles: progressive differentiation, integrative reconciliation, sequential organization and consolidation. In the principle of progressive differentiation, the content is programmed and initially presented from the most general and most inclusive ideas, which are thus progressively differentiated, through details and specificities, corroborating the way in which knowledge is interpreted, organized and assimilated. in an individual's cognitive system.

However, the organization of teaching must not only provide progressive differentiation, but it is also necessary to contemplate integrative reconciliation, which aims to explore the relationships between concepts and propositions, point out significant similarities and differences and reconcile the apparent and real inconsistencies of the subject studied (Ausubel , Novak, & Hanesian, 1980).

In addition to the processes of progressive differentiation and integrative reconciliation, Ausubel recommends the sequential organization, which is a principle that is restricted to sequencing the topics, or units of study, in a way that has a correspondence (observing the principles of progressive differentiation and integrative reconciliation) with the dependency relationships naturally present between them in the teaching subject. Another principle that Ausubel proposes is consolidation, which in turn is related to the mastery of previous knowledge, before introducing new knowledge into the teaching process (Ausubel, Novak, & Hanesian, 1980).

The approach of concept maps in teaching is based on the Theory of Meaningful Learning, and this instrument was developed in the 70s of the last century, by Joseph D. Novak. Novak considers concept maps as a way of organizing knowledge in instruction, and for students it is an important subsidy in the collection of key concepts from lectures, readings, instructional materials, etc. (Novak, 2000). Therefore, until then, concept maps have been an advantageous technique for teaching, for assessing learning and for investigating curricular content.

In this way, conceptual maps are external representations that manifest internal representations, that is, mental representations, of a subject who built the map. Furthermore, they can be applied in the assessment of learning, proceeding as a non-traditional assessment technique, as its main purpose is to ascertain information about the meanings, as well as the significant relationships of the key concepts of the teaching content, according to the understanding of the student (Moreira, 1997a).

In accordance with the teaching of electrochemistry, few studies in the literature seek to use concept maps as instruments that provide evidence of significant learning, as well as for the assessment of learning. This context was verified in the research by Nogueira, Goes and Fernandez (2017), who investigated works from 2000 to 2014 in Brazilian scientific events involving the teaching of redox reactions, which is one of the main subjects of electrochemistry. In a general analysis of the authors, one hundred works were cataloged, however, only two refer to concept maps.

Therefore, the present research is premised on the analysis of a didactic intervention based on the TAS and with an emphasis on the use of conceptual maps as a teaching and learning strategy, as well as the evaluation of the learning process of concepts involved in the content of batteries.

The didactic intervention

This investigation[1] has a qualitative basis and consists of an intervention-type research, in which several teaching and learning situations were analyzed through the use of conceptual maps, in order to facilitate the significant learning of electrochemical concepts, related to the subject of batteries.

One of the characteristics of the qualitative approach in education presupposes that the researcher must attend the place of study because he is interested in the context. Thus, actions can be better understood when they are observed in their natural environment of occurrence (Bogdan & Biklen, 1994). Inherently, this research was carried out through a school setting that involves a teacher (researcher) and students in a directed investigation within the scope of Science Teaching.

The participants of this research were 26 students of the second year of regular high school, with an age group between 15 and 35 years, being considered frequent and regularly enrolled students at night in a public school in the municipality of Campo Grande, in the state of Mato Grosso do Sul.

The didactic intervention was developed in 10 classes, through conceptual mapping activities, the use of Digital Information and Communication Technologies (DICTs) and experimental practices, considering that the classes were prepared according to the programmatic principles of the organization of the teaching content of the TAS. In this context, the first classes addressed the fundamentals of progressive differentiation and integrative reconciliation, and initially an experimental activity entitled "investigating metallic copper in a silver nitrate solution" was demonstrated, which basically dealt with inclusive concepts of electrochemistry, such as the redox reactions, to the most specific ones, which correspond to the oxidation number, reducing agent and oxidizing agent[2].

To study the reduction potential of chemical species in redox reactions that occur between magnesium, zinc and copper metals and their ions in solution, the Metals in Aqueous Solutions simulation was used, which made it possible to observe whether a chemical substance behaves whether as reductant or oxidizing agent against the other, as well as investigating whether or not an oxidation-reduction reaction is spontaneous, and understanding the logic of organizing the table of reduction potentials. In order to discuss more emphatically the concepts analyzed in the simulation and in order to serve as anchor ideas for the assimilation of new learning, an expository class was sought, with a lot of dialogue and with wide participation of the students, through specificities , differentiate oxidation reactions and reduction reactions, in order to relate and organize them from the most oxidizing to the least oxidizing and from the most reductive to the least reductive, seeking to explain to the students the origin of the table of standard potentials of reduction.

[1] The research was submitted to an Ethics and Research Committee of a Public University located in Mato Grosso do Sul, being approved and registered under number 2.519.351/CAAE: 79915317.3.0000.0021.

[2] The chemical species that causes oxidation in a redox reaction is called an oxidizing agent; the chemical species that produces reduction is called a reducing agente (Atkins & Jones, 2012).

It is noteworthy that the content of redox reactions was worked in teaching situations (experimental activity and TDICs, such as simulations and videos) seeking to establish the concepts in the students' cognitive structure, which corroborates the ideas of Ausubel, Novak and Hanesian (1980).

The next step involved the study of chemical energy transformations into electrical energy in the functioning of a battery. At first, in a class, the students watched the video produced by the Pontifical Catholic University of Rio de Janeiro (PUC-Rio, 2012), in order to learn about the history of the invention of the battery, especially when he highlighted the discoveries of Galvani and Volta[3], and the *Daniell Cell* Experiments.

Subsequently, the demonstration of the experimental activity was carried out, entitled 'Danill's Pile'[4], this practice was conducted through explanations of the oxidation-reduction processes, which served as anchor ideas, and only then were the more specific concepts treated, which consisted of the elements that make up the pile and the phenomena observed during its operation.

In the next class, the concepts/phenomena verified in the experimental activity were highlighted again to the students, working with the *Voltaic Cell* simulation[5], which addressed the use of the multimeter device and the calculation of the potential difference (ddp) between the poles of a battery. At the end of the intervention, a new learning situation was developed, also based on the TAS, investigating alkaline and dry batteries, introducing reading of scientific articles and specific texts from textbooks, such as classroom discussions and resolution of a questionnaire on the subject.

Construction and analysis of concept maps

As part of the learning evaluation, for later verification of the conceptual evolution and the establishment of relationships between the new concepts and the phenomena verified in the experimental classes and with the TDICs, the use of conceptual maps was used. The main purpose of using the maps in this research was to monitor the effectiveness of teaching and the students' learning performance, which allowed a more reliable verification of signs of Meaningful Learning.

At the time of the intervention, it was noticed that the students already had some knowledge in relation to this strategy, as they had built a conceptual map in another discipline. However, the conception they had about the concept maps was quite wrong, they reported that they did not like the idea of producing this activity again, pointing out that it was very complex, in addition to not knowing the purpose and real function of this instrument in the classes. Given this context, it is argued that students are not used to the constructivist and meaningful process of learning, however, it is essential that the teacher, when introducing some teaching strategy in the classroom, clearly explains its purpose to the student, giving meaning to the pedagogical work.

As a result, two 100 minute classes were intended to explain the concept maps, present their definition, objectives and relevance as a study technique that provides monitoring of learning for both the teacher and the student. Subsequently, the students were invited to build test maps in order to improve the technique, since the map could refer to any theme, which should not necessarily be linked to chemical content. In the socialization of the test maps, it was observed that many of the students prepared maps relevant to their profession, sports, music, training course and activities of their experience in rural areas.

After the concrete interventions of the classes with the TDICs, experimental and expository activities, the students individually built a conceptual map related to batteries. For this, they had two classes (100 minutes) and could not consult any material during that time, so as not to influence the personal analysis of their conceptual evolutions on the content.

The students delivered the concept maps on bond paper, but in order to enable a clearer visualization of the maps, it was decided to transpose them to the *CmapTools* program[6], this being used specifically in the making of concept maps, which allows a personalized edition of the concepts and their connecting phrases, since it was developed by the Institute for Human and Machine Cognition (IHMC) at the University of West Florida (Leite, 2015) .

It is noteworthy that during the didactic intervention, reference maps were used, as exemplified in Figure 1 on the content, aiming to familiarize students with the use of this instrument and also to serve as a guide in the evaluation of the conceptual maps constructed by them at the end. of the process.

[3] Luigi Galvani was investigating the hypothesis of animal electricity, and this study aroused the interest of Alessandro Volta who, at the end of the 18th century, suggested a different explanation for the phenomenon observed by Galvani and, through a simple experiment, managed, for the first time, to , a source of constant electric current (Germano, Lima, & Silva, 2012).

[4] This battery consists of a metallic zinc anode, a metallic copper cathode and an electrolyte formed by zinc sulfate and copper sulfate, so that it demonstrates satisfactory results only to drive equipment that requires low electrical currents (Bocchi, Ferracin, & Biaggio, 2000).

[5] *Voltaic Cell*. Recovered in 31 jan. 2020 de http://www.profpc.com.br/Simula%C3%A7%C3%A3o/Eletroqu%C3%ADmica/voltaicCellEMF.html.

[6] *Cmap* Software (*https://cmap.ihmc.us/*).

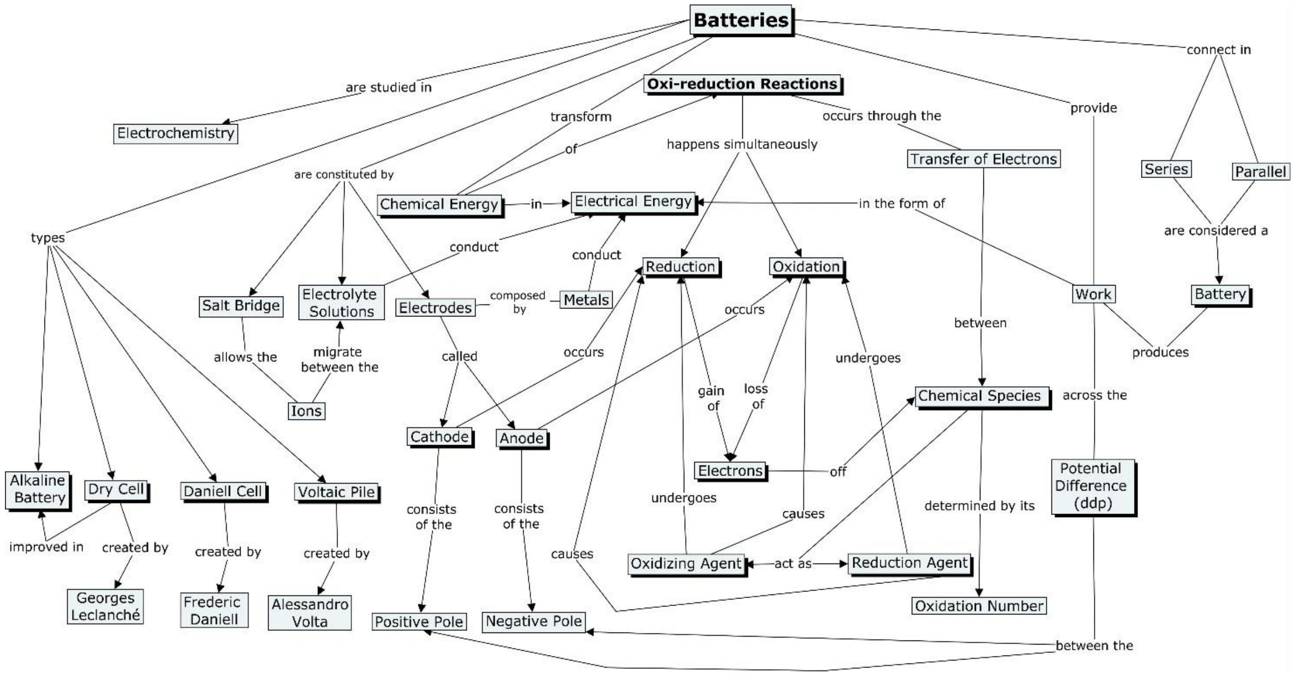

Figure 1. Conceptual map of reference on the piles, created in the CmapTools program.

Source: Own elaboration.

Regarding the analysis of the conceptual maps built by the students, this research was based on the criteria adapted by Trindade and Hartwig (2012), who organized categories for the evaluation of concept maps, showing whether they present basic concepts and new concepts of the investigated knowledge, links between concepts, organization and hierarchy of the map and the principles of progressive differentiation and integrative reconciliation. In this sense, the authors approach qualitative and quantitative aspects for the analysis of the categories that are expressed in Table 1.

Table 1. Categories of analysis of concept maps.

Categories	Description of criteria in the form of focus question(s)
1 - Basic concepts	Does the map have at least 50% of the basics from the list provided/or the reference map?
2 - New concepts (creativity)	Are there any new concepts relevant to the subject at hand?
3 - Links between concepts	Are all concepts connected by well-crafted lines?
4 - Linking words (connectives)	Most linking words/link phrases form a logical sense with the concept to which they are linked?
5 - Examples	Does the map present appropriate examples for the subject at hand?
6 - Clarity and structure of the map; geometric symbols (boxes, circles)	Is the map legible and easy to read? There is clarity in the map to the reader?
7 - Propositions (concept-connecting word-concept)	The map has at least 50% of the number of valid propositions the reference map? Do propositions have logical meaning from the scientific point of view? Are the connections in line with what is scientifically accepted?
8 - Hierarchy	Is there a successive ordering of concepts? Was a good hierarchy of concepts demonstrated, represented by at least 03 hierarchical levels? Is the map tree-shaped (dendritic) rather than aligned (linear)?
9 - Progressive differentiation	Is it possible to distinguish the more inclusive concepts from the subordinate ones? Is it possible to clearly identify the most general and the most specific concepts? Is there a progressive conceptual differentiation that shows the degree of subordination between the concepts?
10 - Integrative reconciliation (creativity)	Is there a recombination, that is, a rearrangement of concepts? Are there cross or cross-relationships between concepts belonging to different parts of the map?

Source: Adapted from Trindade and Hartwig (2012).

In the evaluative aspect, 26 conceptual maps of students present were analyzed through the aforementioned categories.

Results of da analysis of concept maps

In the analysis of the students' conceptual maps, support was sought from the ideas of Novak and Gowin (1984), who emphasize that these instruments are essential for the negotiation of meanings, since they can be shared, discussed and negotiated among the subjects who participate. of this teaching and learning process.

The conceptual maps constructed by the students were analyzed and qualitative criteria adapted by Trindade and Hartwig (2012) were established. Thus, of the total of 26 maps built individually by the students, only 38.46% were considered satisfactory and 61.54% had unsatisfactory performance.

In relation to the categories, it is observed, in Graph 1 of Figure 2, that the students showed a better performance in the connections between concepts (92.31%), in the connecting words (77%), in the clarity of the map (75%) and in the basic concepts (53.85%).

However, it is noted that students had greater difficulty with categories involving new concepts (15.38%), integrative reconciliation (19.23%), and valid and significant propositions (21.15%).

From the data collected, an analysis was made from a qualitative perspective of the MCs, in order to highlight the conceptual relationships addressed by each student, through their understanding of the knowledge studied. In this sense, we present below some MCs that elucidate satisfactory and unsatisfactory aspects of the ten aforementioned categories.

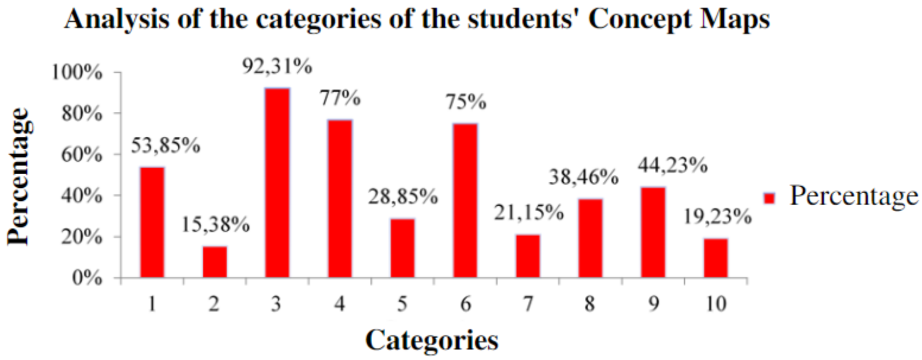

Figure 2. Analysis of the categories, in percentage, of the conceptual maps evaluated.

Source: Self elaboration.

The MC built by student C4, shown in Figure 3, addresses a good part of the main concepts that concern the study of stacks. It explains the energy transformations that take place during the operation of a battery, but it does not relate that the chemical energy present in the batteries comes from the oxidation and reduction reactions, which occur simultaneously, and that is why we call them as oxidation-reduction reactions.

An important detail demonstrated in this MC that was not present in the other maps analyzed were the relationships established with the concept of oxidizing agent and reducing agent, which supposedly shows a certain understanding of the new knowledge by the student. It is noted that the student exemplifies the electrodes of the cell, such as zinc and copper, which are immersed in an electrolyte solution, which possibly indicates that the student remembered the analysis performed in the experimental activity of building the Daniell cell and the use of the 'Voltaic Cell' simulation on the assembly and operation of this type of battery that generally uses these metals.

In the MC it is also observed that the student identifies the concept of stacks as the most general, but does not corroborate the concepts subordinated to the stack, such as energy transformations and oxidation and reduction reactions that should be in higher parts of the map, to encompass specific and non-inclusive concepts, such as those referring to the constitution of the stack and its types.

As verified in the data compiled in Graph 1 in Figure 2, students demonstrate obstacles in relation to category 8 (38.46%), which refers to the hierarchy of MCs. In this bias, Vinholi Júnior and Gobara (2017), who used CMs as a strategy for teaching, learning and evaluating the content of cell biology, noticed difficulties in the ranking of concepts by students. The authors point out that this situation may have an influence on the students' own study history, given that most of them are graduates from a teaching in which the way of ranking was not what is usually addressed by the TAS, because the teaching The traditional approach of most schools is still based on machine learning, so as not to praise the principles of hierarchy.

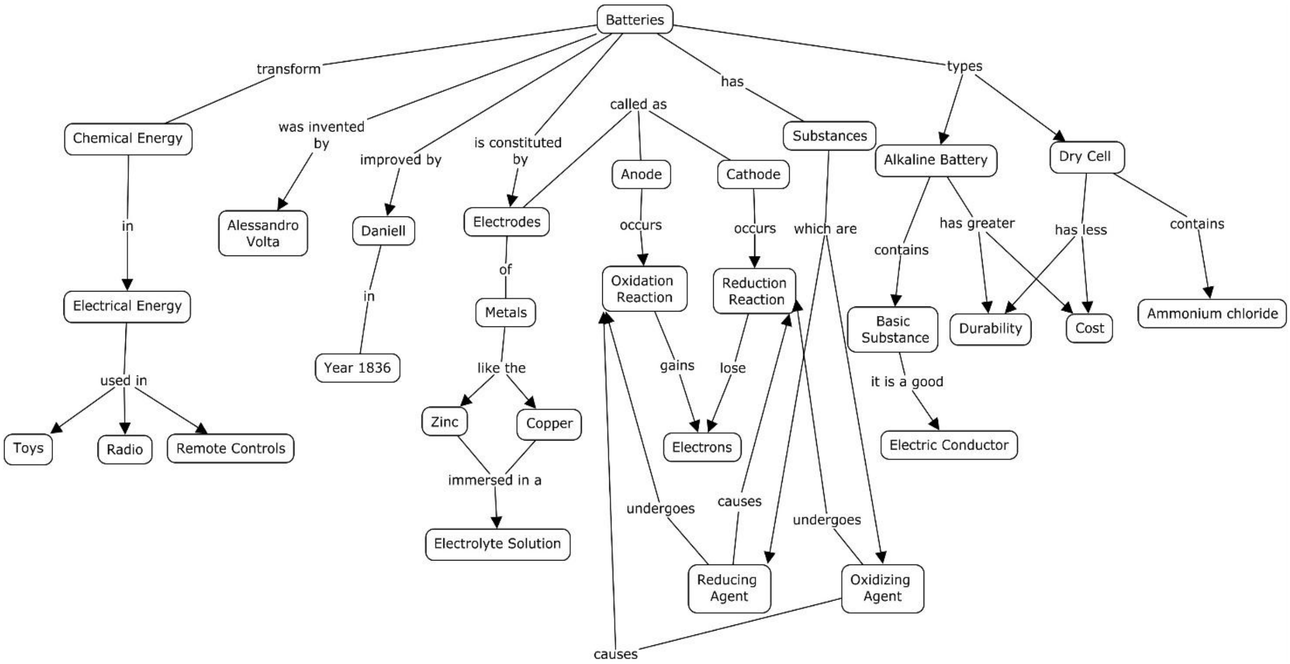

Figure 3. Concept Map built by student C4
Source: Self elaboration

Student C11 presents the batteries at the top of his MC (Figure 4), differentiating the concept in terms of its composition, elements, energy transformations and the oxidation-reduction process. However, the student does not associate the concept of electrodes with the cathode and anode of the cell, nor does he indicate the oxidation and reduction processes that take place at each pole of the cell. It is also noticed that the student understands that the set of batteries forms a battery, but, when transposing this idea in his MC, he shows difficulties in organizing and differentiating the concepts.

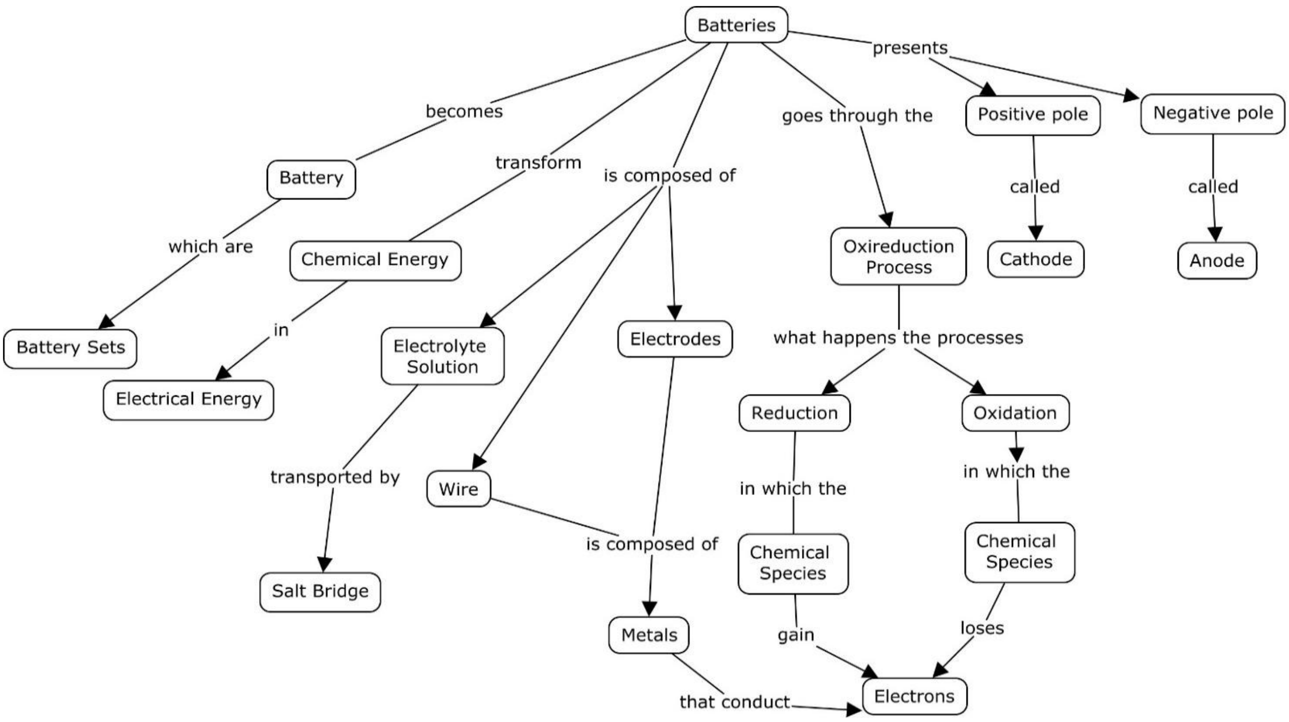

Figure 4. Concept Map built by student C11.
Source: Self elaboration Elaboração própria.

However, it is worth emphasizing that the student approaches the term 'metallic wire' and makes a correspondence with the concept of 'metals' and, consequently, with electron conduction. Eventually, this demonstrates that the student seeks to characterize, even in a simplified way, the battery's external circuit and the chemical species (electron) responsible for the circulation of electric current. In addition, the student explains that the electrolyte solution is transported through the salt bridge, that is, the internal circuit. Therefore, such relationships point to a certain understanding of the student about the function of the external and internal circuit of the battery, which are important elements for the proper functioning of this device.

In Figure 5, student B12 presents part of the main concepts involving the study of the pile, but there is a new concept in his MC (spontaneous reaction), which is not present in the reference map and which can be considered relevant for understanding of the electrochemical processes of a cell. According to Trindade and Hartwig (2012), when the student demonstrates new concepts in the CM, it reveals that the instructional material provided the learners with subsidies to understand the content.

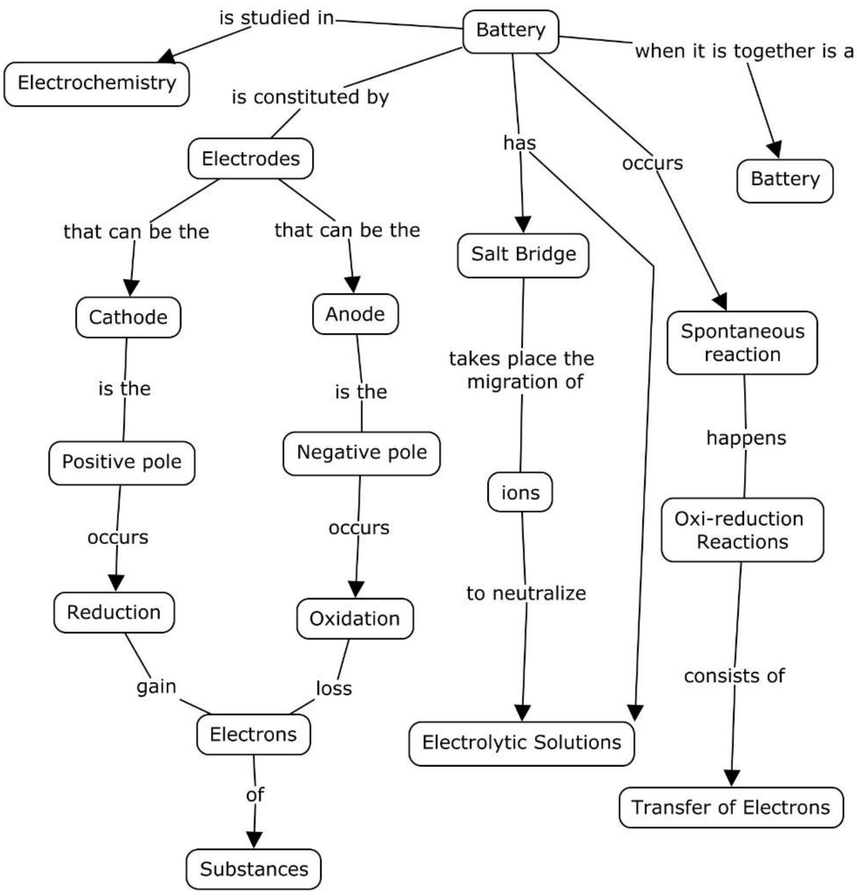

Figure 5. Concept Map built by student B12.
Source: Self elaboration.

Although this student explained a new concept in his MC, the results show that only 15.38% of the students corresponded to this category of map analysis. This data is supported by the TAS, which sets out the basic conditions for the occurrence of meaningful learning, so that the material must be potentially significant and the learner needs to manifest a predisposition to relate, in a non-arbitrary and substantive way, the new knowledge to his/her cognitive structure. In this sense, when the student is trying to appropriate the new knowledge, he seeks new concepts to produce his map, that is, he has a predisposition to learn, thus not only sticking to the concepts previously listed by the teacher/researcher (Trindade & Hartwig, 2012).

Student B17's MC (Figure 6) exemplifies the types of batteries, mentioning in particular alkaline and dry batteries. Graph 1 (Figure 2) shows us that 28.85% of the students' MCs present examples that mostly sought to detail the types of batteries studied, namely: the voltaic cell, Daniell cell, dry cell and alkaline cell. Therefore, it is noted that student B17 seeks to detail that, in dry batteries, when they are not in operation, chemical reactions occur, on the other hand, this phenomenon does not happen with alkaline batteries. However, dry cells contain ammonium chloride, which would be the reagent responsible for causing substances to leak in this device.

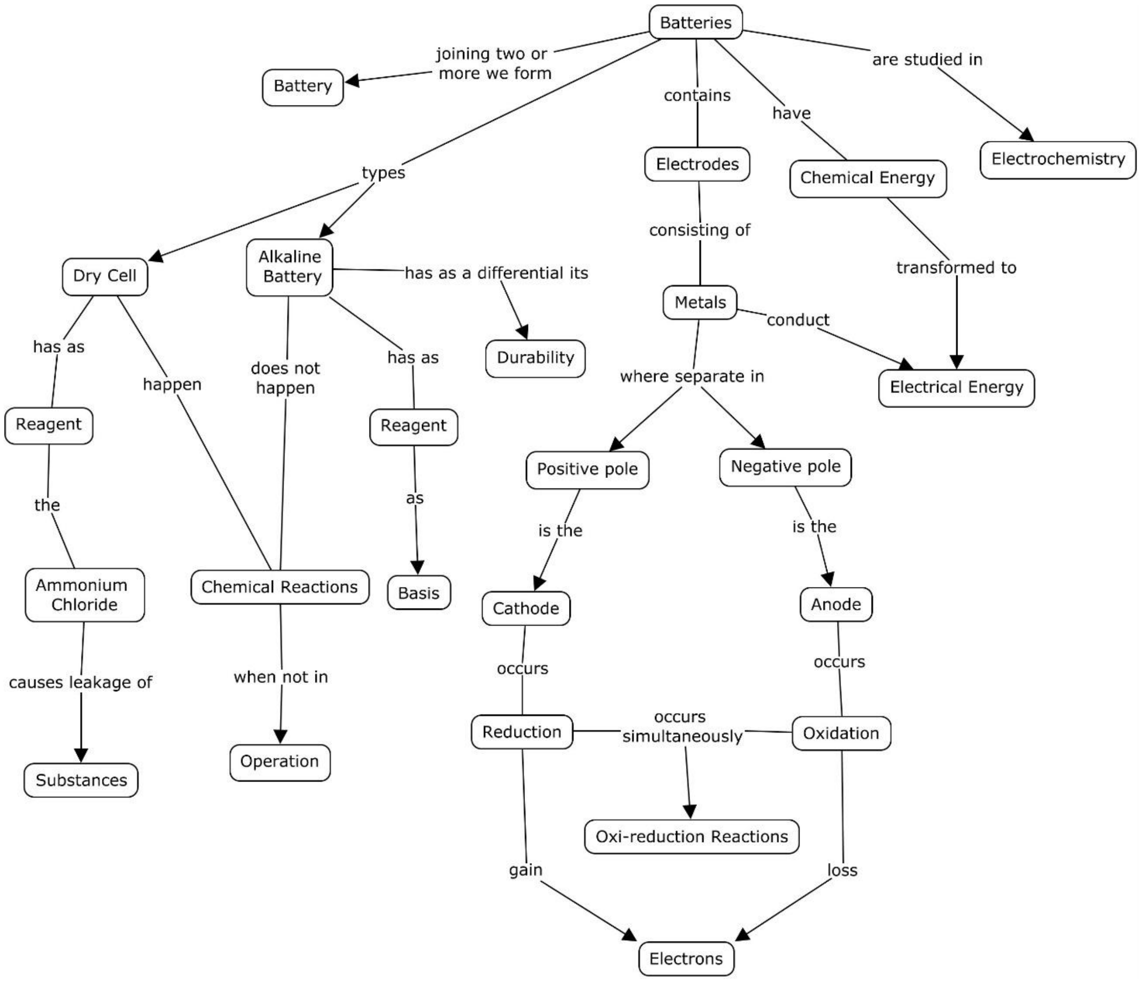

Figure 6. Concept Map built by student B17.
Source: Self elaboration.

Student B14 in his MC (Figure 7) differentiates batteries based on their composition, oxidizing and reducing chemical species, and explains a very pertinent proposition to the study of batteries that corresponds to the potential difference, correlating it with the poles of the batteries. batteries and their importance for the production of electric current. However, there is not a good conceptual organization in the map, since the student only highlights the main concept, which is the stack, but does not correctly dispose of the intermediate concepts to it, which are the oxidation-reduction processes, to then deal with it. of its composition. It can also be verified that the student does not express examples, but the linking words are coherent and present cross-links.

The maps of students C13 (Figure 8) and C15 (Figure 9) were considered satisfactory, but they demonstrate some inconsistencies, such as, for example, the absence of a coherent hierarchy of concepts in the maps. Student C13 pointed out the main basic concepts studied, while student C15 addressed only a part of these concepts, however, in his MC, a new concept is observed - a guiding thread, which, although not present in the reference map, does not to be important and should be highlighted, as this element explains the external circuit of the battery. It is also noted that some concepts in certain propositions in the C13 student's MC are repeated, such as: 'electrochemistry studies reduction reaction and oxidation reaction' and 'batteries transform chemical energy causing oxidation-reduction reaction that happen at the same time reduction and oxidation'.

Furthermore, student C13 did not make a correspondence with the redox processes that take place at the anode and cathode, he only superficially indicated that the positive pole is the cathode and the anode is the negative pole. In this same bias, student C15 was able to relate that, at the cathode, reduction occurs and, at the anode, oxidation occurs. Furthermore, when student C15 dealt with the concepts of oxidizing agent and reducing agent, he established coherent relationships by pointing out that the reducing agent causes reduction and undergoes oxidation, and the oxidizing agent causes oxidation and undergoes reduction. However, student C13 vaguely presented these concepts, only highlighting that the oxidizing agent causes the oxidation reaction and the reducing agent causes the reduction reaction.

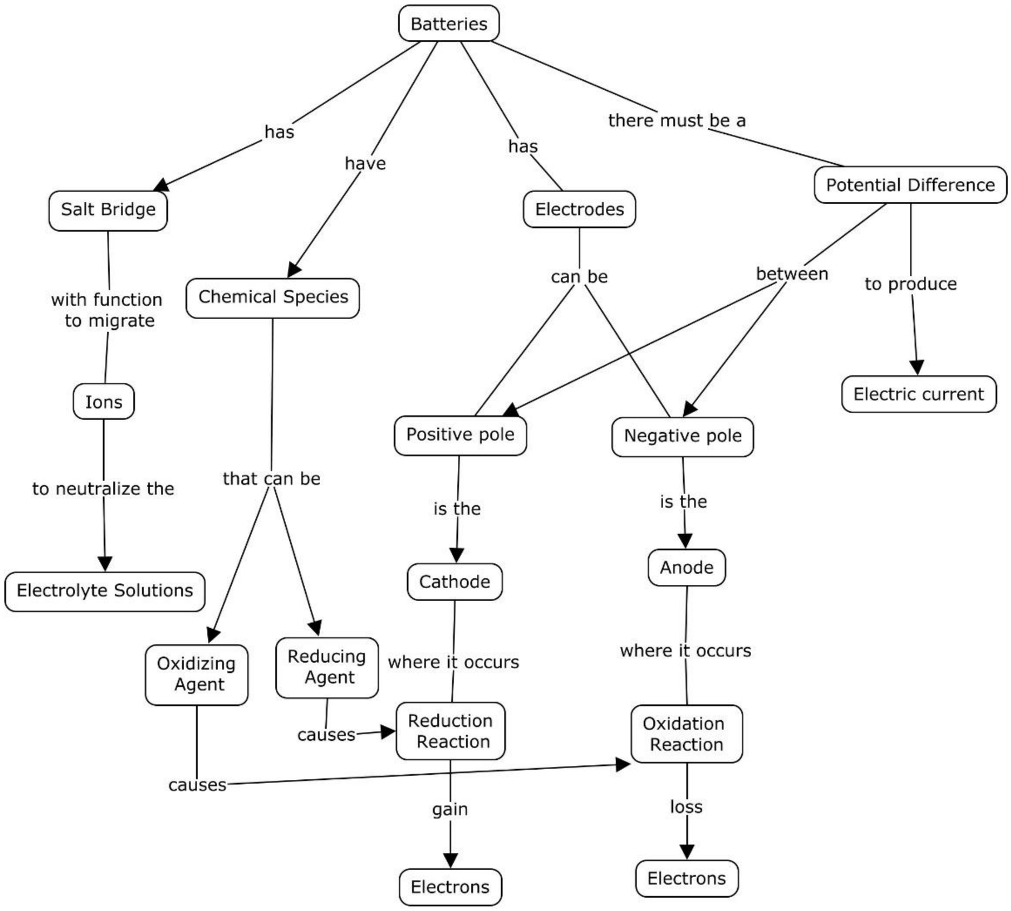

Figure 7. Concept Map built by student B14.
Source: Self elaboration

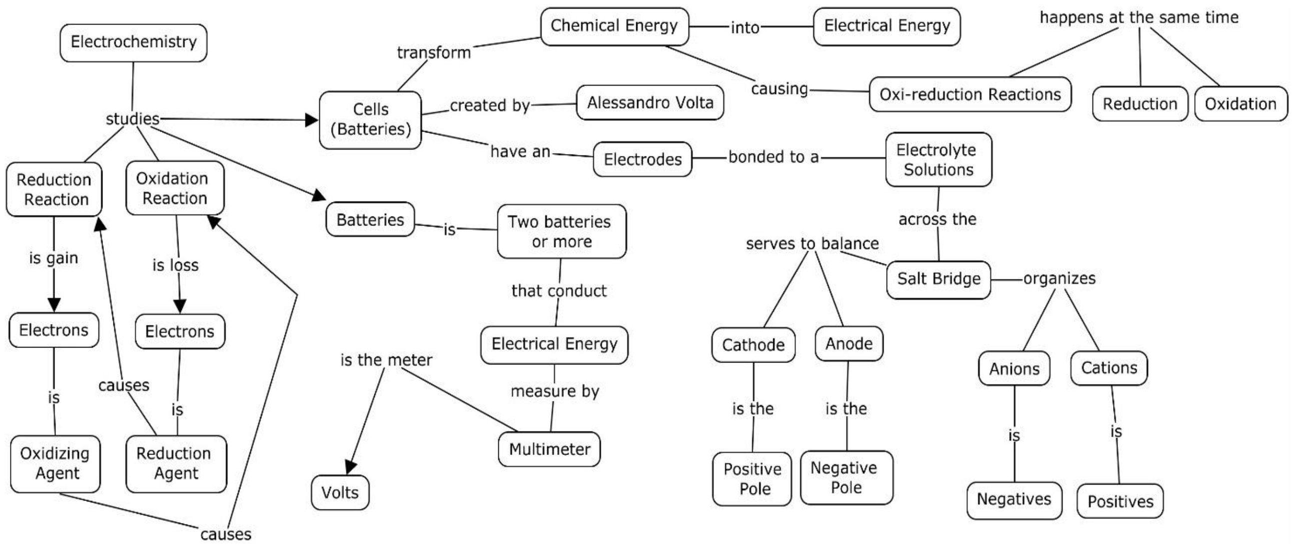

Figure 8. Concept Map built by student C13.
Source: Self elaboration.

The two MCs addressed the term 'salt bridge', but students C13 and C15 have some difficulty in approaching what their real role is in the pile. Student C13 indicated that the salt bridge organizes anions and cations and that it serves to balance the cathode and anode, that is, the student probably points out that the salt bridge transports ions between cells in the cell. Student C15, on the other hand, demonstrates that the salt bridge has the function of neutralizing the positive and negative poles, supposedly this student intended to emphasize that, with the salt bridge, it is possible to solve the issue of electrical neutrality of the solution, in both cells of the cell.

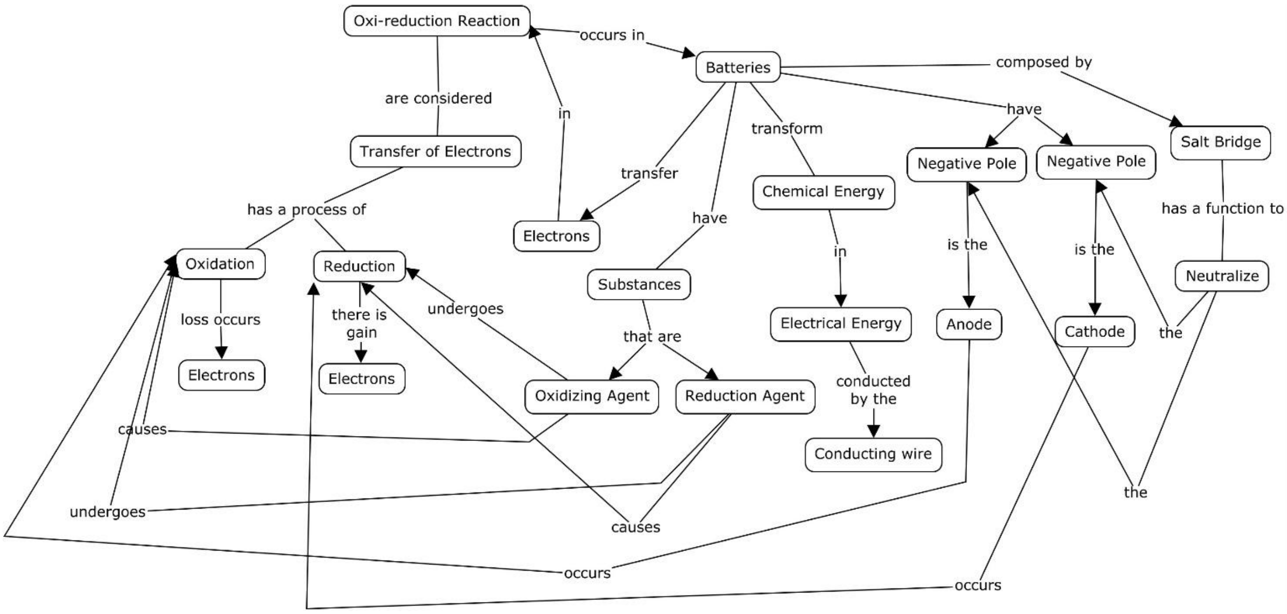

Figure 9. Concept Map built by student C15.

Source: Self elaboration.

Therefore, in a global analysis of the MCs of this study, it was mainly noticed that some students demonstrate difficulties in establishing integrative reconciliation, as they were not able to reorganize the similarities and differences between the concepts or propositions. Therefore, this result can be interpreted in the light of studies by Conceição and Valadares (2002), who emphasize that this difficulty expressed by students about integrative reconciliation should be considered natural, when it comes to students who have no previous experience with the use of MCs or any other learning context that addresses TAS, which, in this case, resembles the real situation of our students in this research.

Final considerations

The purpose of this research was directed to the implementation of a didactic intervention based on the use of conceptual maps as a teaching, learning and evaluation strategy for the content of batteries, verifying through the principles of TAS the process of significant learning of electrochemical concepts.

In general, the students showed an initial predisposition to learn, due to a good acceptance of the methodological proposal for the construction of concept maps, use of TDICs and experimental activities. However, in the stage of construction of the conceptual maps, the students showed some resistance in relation to this technique, as they had already had an experience in another discipline, and they brought with them a mistaken conception, in which they pointed out that they did not like this activity, because it was too complex and did not understand its real purpose in the learning process.

However, during the classes, the researcher teacher tried to explain the content and guide the students through the MCs, making them understand the technique and meaning of the entire organization of the conceptual map. Thus, the students realized and highlighted that this activity was different, as it required a deep understanding of the content studied, because at that moment it was necessary to revolve and select the essential concepts studied, as well as to plan how the concepts and propositions would be arranged, in order to in order to integrate, relate and differentiate them. Therefore, it is evident in this study that concept maps are valuable assessment tools for both the teacher and the students who can appreciate the progress of the knowledge construction process.

In this sense, the results of this research indicate that the conceptual maps analyzed respect the scientific rigor of the basic concepts, but few bring new concepts. From the chemical point of view, the conceptual maps seek to explain the oxidation-reduction processes, presenting some difficulty to relate the concepts of oxidizing agent and reducing agent, they almost always deal with the constitution of the cell, highlighting the electrodes, the salt bridge, the electrolyte solutions, but few bothered with the stack examples.

As mentioned above, it was found that the students detailed in their conceptual maps mainly in relation to redox reactions and the elements that constitute the pile. In theory, it is understood that the nature of the teaching material, that is, the way in which the classes were structured, seeking to meet the principles of progressive differentiation and integrative reconciliation, encouraging negotiation between prior knowledge and new knowledge, can have contributed to the construction of concept maps by students, in addition to making them find meaning in the concepts studied, through experimental activities and the use of TDICs.

Thus, in the maps considered as unsatisfactory, most of them presented few basic concepts, and none expressed new concepts. A great difficulty was noticed in the principle of integrative reconciliation, as well as in the hierarchy of the concepts involved. For the conceptual maps considered satisfactory, the main concepts of the study of batteries were found, the connecting words presented a logical sense with the concept to which they are associated, it was noted that there is a clarity of reading of the maps, as also demonstrated the principles of progressive differentiation and integrative reconciliation. In this sense, the Ausubelian theory offered a favorable theoretical and epistemological basis for the creation of new situations in the teaching and learning of electrochemistry contents.

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