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The use of Concept Maps as an evaluative resource in the theme Acid Rain in Higher Education

Felipe Alves Silveira[1]
Ana Karine Portela Vasconcelos[2]

Abstract: The elaboration of Conceptual Maps — CM contributes to identifying signs of meaningful learning — ML, as it is an instrument to represent the acquired knowledge. The present investigation aims to analyze the use of the CM tool in teaching during the initial education of chemistry teachers as an evaluative instrument regarding the topic of acid rain, having as input the Theory of Meaningful Learning — TML. In the research, we seek to approach concepts related to the inorganic functions of acids and oxides through an investigative experiment. The methodological field is a qualitative approach based on the case study. We conclude that the CM is configured as a satisfactory evaluative instrument because, during their structuring and restructuring, some cognitive conflicts and spaces raise awareness of the problems, difficulties, and errors that, confronted and discussed, become spaces for advancing knowledge understanding.

Keywords: Instrument. Evaluation. Chemistry Teaching.

El uso de Mapas Conceptuales como recurso evaluativo en el tema Lluvia Ácida en la Educación Superior

Resumen: La elaboración de Mapas Conceptuales — MC contribuye a la identificación de signos de un aprendizaje significativo — AS, ya que es un instrumento para representar los conocimientos adquiridos. La presente investigación tiene como objetivo analizar el uso de la herramienta MC en la enseñanza durante la formación inicial de profesores de química, como instrumento evaluativo respecto al tema lluvia ácida, teniendo como insumo la Teoría del Aprendizaje Significativo — TAS. En la investigación buscamos acercarnos a conceptos relacionados con las funciones inorgánicas de los ácidos y óxidos, a través de un experimento investigativo. El campo metodológico es un enfoque cualitativo, basado en el estudio de caso. Concluimos que los MC se configuran como un instrumento evaluativo satisfactorio, pues en el transcurso de su estructuración y reestructuración surgen conflictos cognitivos y espacios de toma de conciencia de los problemas, dificultades y errores que, confrontados y discutidos, se presentan como espacios de avance en la comprensión del conocimiento.

Palabras clave: Instrumento. Evaluación. Enseñanza de la Química.

O uso de Mapas Conceituais como recurso avaliativo na temática Chuva Ácida no Ensino Superior

Resumo: A elaboração dos Mapas Conceituais — MC concorre para a identificação de indícios de uma aprendizagem significativa — AS, pois se trata de um instrumento

[1] Doctoral candidate in Teaching at the Federal Institute of Education, Science and Technology of Ceará (IFCE). Chemistry teacher at the Ceará State Education Secretariat. Ceará, Brazil. ✉ felipesilveiraquimica@gmail.com https://orcid.org/0000-0003-3851-232X.

[2] Doctor in Civil Engineering (Environmental Sanitation). Professor at the Postgraduate Program in Science and Mathematics Teaching and at the Northeast Teaching Network of the Federal Institute of Education, Science and Technology of Ceará (IFCE). Ceará, Brazil. ✉ karine_portela@hotmail.com https://orcid.org/0000-0003-1087-5006.

para representar o conhecimento adquirido. A presente investigação tem por objetivo analisar o uso da ferramenta MC no ensino durante, a formação inicial de professores de química, como instrumento avaliativo referente ao tópico chuva ácida, tendo como aporte a Teoria da Aprendizagem Significativa — TAS. Na pesquisa, buscamos abordar conceitos relativos às funções inorgânicas ácidos e óxidos, por meio de uma experimentação investigativa. O campo metodológico se trata de uma abordagem qualitativa, pautada no estudo de caso. Concluímos que os MC se configuram como um instrumento avaliativo satisfatório, pois no curso de sua estruturação e reestruturação se manifestam conflitos cognitivos e espaços para a tomada de consciência sobre os problemas, as dificuldades e os erros que, confrontados e discutidos, apresentam-se como espaços de avanço na compreensão do saber.

Palavras-chave: Instrumento. Avaliação. Ensino de Química.

1 Introduction

Chemistry is a science that is not limited to laboratory research and industrial production. It involves studying the properties and behavior of matter, defined as anything that has a mass and occupies some space. Thus, it is a science of paramount importance in everyday life, close to the heart of several problems that plague society, and whose purpose is to solve them. Chemistry studies can promote conditions to improve health and, consequently, prolong lives (BROWN; LEMAY; BURSTEN, 2005).

The discipline of chemistry, which has its own language, is essential for students' education because it is more intertwined with human experience, as long as it is contextualized and not treated in a simplistic way, without the predominance of decontextualized traditional teaching (LEÃO; SANTOS; SOUZA, 2020; PRSYBYCIEM; SILVEIRA; SAUER, 2018).

Assunção, Barros, and Campos (2021) assert that teaching is still conceptual and does not consider innovative methodologies. The students can no longer be treated as mere receivers of knowledge, because an unprovided apprehension of knowledge ends up prevailing, corroborating the formation of possible epistemological obstacles and impairments in learning (BACHELARD, 1971). Commonly, there is some formalism when approaching specific objects, making the educational process unprofessional, since their applicability in everyday life is practically umbratic (ASTOLFI; DEVELAY, 1995).

As much as it is seen as pavid, it is possible to make it dynamic and contextualized, a fact evidenced by Durazzini *et al.* (2020), who used alternative materials with chemistry degree course students, considering their prior knowledge. According to Alves e Silva (2020), if undergraduates elaborate the problems for solving chemistry exercises from a human and citizen perspective, there will be new possibilities to problematize chemical concepts and, thus, favor their growth as prospective teachers, also benefiting their future students.

Correia *et al.* (2016) claim that higher education has been reinventing itself by using different methods and strategies aimed at teachers' professional growth, in this case, Chemistry teachers. The use of the Conceptual Maps — CM favors learning, as per its association with meaningful learning (ML). It is essential that students' prior knowledge be considered in the school environment so that they feel necessary in teaching. When considering them for the apprehension of new knowledge, we will do justice to the Theory of Meaningful Learning (TML) (AUSUBEL, 2003). A facilitating strategy for the ML to occur is the use of the CM, which represent knowledge, configured as an excellent pedagogical tool through well-planned and executed activities (JORTIEK; BARBOSA; FURLAN, 2020).

Lemke (2006) indicates the individual or group investigations as a proposal for learning to carry out studies, in which team learning, regardless of age, social class, sex or culture, will happen in a shared way, with people helping each other to instigate reflection. The teacher's presence in this process as a mediator is important. Freire (1996) believes that the teacher must be an inventor, daring, curious, persistent, flexible, accepting the new, changing, and promoting changes. Above all, he must be a good researcher. The teacher should reflect on his/her action, always checking whether the student understood the subject and encouraging discussions on the proposed activity.

Therefore, this investigation aimed to analyze the use of the CM tool in teaching during chemistry teachers' initial education as an assessment instrument about acid rain, having TML as input. In the research, we seek to approach the concepts related to the inorganic functions of acids and oxides through an investigative experiment.

2 The use of the CM as an evaluative instrument according to the context of the TML

In short, CM are graphic organizers that facilitate ML, a situation in which they are valid tools to represent knowledge that assists in teaching and information retrieval (AGUIAR; CORREIA, 2013; ROVIRA, 2016). Studies carried out show the importance of promoting ML by using the CMs, as it has been shown high potential to facilitate

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negotiation, acquisition, and construction of meanings.

In work carried out by Dias and Terra (2021), Rodrigues (2016), Lima *et al.* (2017) and Jortieke, Barsosa, and Furlan (2020), the use of CM within the teaching and learning process to promote ML has been satisfactory, given the results presented. They can function as resources for obtaining evidence of ML and even assess the prior knowledge that subjects have about the contents (MENDONÇA; CORDEIRO; KIIL, 2013).

O'Donnell, Dansereau, and Hall (2002) prove that those maps facilitate learning and that individuals locate more information and remember more principles of the content covered through the use of maps, instead of merely informational texts. Students recall more core ideas of content through CMs.

Regarding the shape of the maps, they are constituted by significant relationships between the concepts, usually placed within geometric figures, and the relationships between them are indicated by lines that interconnect them (NOVAK; CAÑAS, 2010; ROVIRA, 2016). The map is a schematic feature of a set of meanings included in a structure of propositions, which is a particular characteristic of it (RODRIGUES, 2016).

These consist of one or two conceptual terms linked by keywords (linking term) or linking phrases written on the lines in order to clearly form a semantic unit (NOVAK; GOWIN, 1984). The propositions express the existing conceptual relationship. They are of paramount importance in making the map (AGUIAR; CORREIA, 2013).

According to Palmero and Moreira (2018), the CMs do not seek to classify concepts, but to relate them for the sake of hierarchy. On the map, it is interesting to check which are the most relevant concepts, which are usually at the top. Although they still typically have a hierarchical organization and continually include arrows in the lines, CMs should not be confused with mind maps, which are associationists. Arrows can facilitate reading so that the proposition is clearer and more understandable.

ML happens when new concepts or conceptual meanings are encompassed under other broader, more inclusive concepts. Therefore, CMs must have this hierarchy, in which the most general and inclusive concepts must be at the top of the map and the less specific ones are hierarchically arranged below (NOVAK; CAÑAS, 2010). The use of lines, regardless of length and shape, links the concepts and

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indicates that the person who made the map finds there is a relationship between them.

Thus, CMs contain four main components: the concepts, the relationships between concepts, the hierarchy, and the cross-links between different structures. Students' identification of such structures suggests the existance of previous knowledge necessary for the learning of new concepts so that ML can occur (SEQUEIRA; FREITAS, 1989).

It is worth recalling that the relationships that must exist on the map are formed by directed lines, usually with arrows that must contain keywords and/or phrases, whose function is to explain their nature (MOREIRA, 2011a). The relationships can be *cross links*, which facilitate identifying them as a concept in a knowledge domain represented in the map that relates to another concept in a domain represented there. In the elaboration of new knowledge, cross links often represent creative leaps on the part of the person who elaborates it, that is, it stimulates creative thinking (NOVAK; CAÑAS, 2010; TAVARES, 2007; DIAS; TERRA, 2021).

In the CM, specific examples on the topic may help clarify the meaning presented by a given concept. In this case, the examples do not represent concepts, since they are specific events about the topic in question (NOVAK; CAÑAS, 2010). For example, if the topic to be approached is water, its usefulness for plants and animals, among other purposes, could be mentioned. In other words, this would exemplify in which aspects it is viable to be used.

Another element used in the CM is the focal question, which will condition the construction of the map. This question is an excellent way to delimit the subject that will be studied so that there is no distance from it (AGUIAR; CORREIA, 2013). This aspect helps us select the concepts used and the most relevant linking terms during the manufacturing process.

The CMs are a dynamic instrument in which, for the same theme, different maps can be prepared. No single model is considered correct since each student will uniquely externalize their concepts, the result of a personal way of seeing, feeling, acting, and learning, produced from the knowledge present in their cognitive structure. Moreover, the teacher cannot present a map claiming to be the only way to represent the content (DIAS; TERRA, 2021). There must be an explanation about the constructed map, as they are not self-explanatory and were not designed for this purpose, therefore, it requires an explanation from whoever made it. By explaining, students will externalize the meanings, and the CMs are, precisely, suitable for this purpose (MOREIRA, 2011a).

Jortieke, Barbosa, and Furlan (2020) state that the CMs provide the opportunity to monitor a conceptual construction that involves the interaction between the subsumers with the new concepts to be learned. A map can also be used as an assessment tool because it has an individual character, in which it exposes the subject to perceive and relate the concepts covered in the classroom (NOVAK; GOWIN, 1984; ROVIRA, 2016).

In both teaching and/or assessment instrument situations, maps, according to Rodrigues (2016), can help the student to make the concepts or propositions learned explicit, in addition to showing the connections between the new knowledge and the subsumers; they help the teacher to determine the steps for the organization of meanings and to identify the most relevant concepts; allow separating significant from trivial information and allow the student to understand his/her role as an active subject.

Aguiar and Correia (2013) present four parameters of reference relate theory to practice, whose objective is to characterize good CMs. The parameters are: the semantic clarity of the propositions, the question or focal inquiry, the hierarchical organization of the concepts, and the continuous revisions. Regarding propositions, the lack of keywords or linking phrases can prevent an understanding of the relationship between the concepts. It is important that there is a verb so that it can be classified as a proposition.

Regarding the hierarchical organization, which is how the map should be organized, there is more understanding of the presented content. It serves to represent the increasingly detailed levels of concepts. The last parameter concerns continuous reviews, whose purpose is that knowledge is always improved, since learning is a process that does not stop, as it is always changing. Therefore, students and teachers must be educated for its elaboration (AGUIAR; CORREIA, 2013).

Tavares (2007) developed a work classification of the CMs to assess their format, listing four main types: spider, flowchart, input and output, and hierarchical. The only map that expressly uses a cognitive theory in its elaboration is the one classified as hierarchical, which lives up to the theory proposed by Ausubel (TAVARES, 2007). Second Novak and Gowin (1984), the CMs are instruments of qualitative analysis, in which the teacher analyzes the conceptual connections that the

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students make. However, we live in a society ruled by numbers, and grades, where most teachers and students want to score well.

The scoring system, suggested by Novak, is based on TML conceptions in light of the guiding principles of hierarchical structure, progressive differentiation, and integrative reconciliation. It will be from them that a map can be analyzed and scored. The score assigned in the categories to be investigated can be modified by the evaluator at his/her discretion.

The scoring criteria to be analyzed in this work are according to the study below. Chart 1 explains those classification criteria proposed by Novak and Gowin (1984), as well as their respective analysis and scoring:

Chart 1: Analysis of the CM classification criteria

Criteria	Valid analysis to score	Score for valid analyses
Propositions	Meaning relationship between two concepts is indicated by the line that unite them and the corresponding linking word(s). They have semantic meaning.	1 point for each proposition.
Hierarchy	Hierarchy: Subordinate concepts are more specific and less general than the concept written above them. They are consistent with the proposed chemical context.	5 points for each hierarchy level.
Cross links	Significant links between two valid and significant concepts.	10 points for each significant cross link. 2 points for each valid cross link, however, that does not translate any synthesis between groups of propositions or related concepts. Additional points for creative or peculiar cross links. Values at the discretion of the evaluator.
Examples	They correspond to the proposed chemical context.	1 point for each designation.

Source: Adapted from Nokak and Gowin (1984).

According to Mendonça, Cordeiro, and Kiill (2013), one more classification criterion was added in this search, which concerns linking words. We will verify whether they exist under or on the lines that unite the concepts and whether they are per their definition. Two points for each linking word will be given if they meet these precepts.

Their uses express a conceptual relationship clearly and precisely and facilitate understanding. The indispensability of using propositions containing linking words to express the conceptual relationship transfigures the CMs that are more relevant than the other graphic organizers, since they show the relationship between the concepts

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(AGUIAR; CORREIA, 2013). They configure a semantic clarity to the proposition. According to Moreira (2011a):

> Conceptual maps are dynamic; they are constantly changing in the course of meaningful learning. If learning is meaningful, the cognitive structure is constantly reorganizing itself through progressive differentiation and integrative reconciliation and, consequently, maps drawn today will be different tomorrow (p. 134).

Novak and Gowin (1984) attest that progressive differentiation is the principle in which concepts acquire greater meaning as they are approached, i.e., as new connections are established in the cognitive structure of the knowing subject. It occurs when the general ideas and concepts presented are unfolded in other concepts in a more specific way. Using a map can help the teacher evaluate this process through the student's elaboration and, with that, act to solve doubts or misunderstandings about the proposed content.

Regarding integrative reconciliation, the same authors determine that AS improves when the new relationships between concepts or propositions are recognized, when they are, in a differentiated and straightforward way, in their cognitive structure. In general, it is related to how students make conceptual connections that belong to different branches on the same map, in this case, cross links.

Silveira, Vasconcelos, and Sampaio's (2019) work with the MixQuímico game, developed by high school students, demonstrated that there was an ML during the applied activity. The subject's cognitive structure presented a conceptual change through the interaction of subsumers with new concepts. This took place through the integrative reconciliation, as observed in concomitance with the progressive differentiation in view of the applied game and the questionnaire. It is worth mentioning that those programmatic principles happen simultaneously (MOREIRA; MASINI, 1981).

According to Novak and Gowin (1984, p. 39), "Once students have learned to prepare concept maps, they can be used as powerful assessment tools". It is essential that they are guided and trained so that they can prepare their CMs for the activities that will be addressed. Conceptual ML does not depend exclusively on concept maps, as it can occur without using them; however, the use of this resource is essential for student development to be relevant, as it is a potentially significant metacognitive

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educational resource (PALMERO; MOREIRA, 2018).

3 Methodological procedure

The study was guided by a qualitative approach, whose focus was the process carried out for different ways of interpreting the information that will be collected before the theoretical study that underlies the research. Data analysis tends to follow a path linked to induction as long as it is based on the theoretical framework that guides the main study (BOGDAN; BIKLEN, 1994). This goes beyond a mere discovery, as it demands investigation and planning. It also involves intensive observation in the execution of activities.

According to Minayo (2002), the qualitative approach is the pathway for thought to be used and occupies a central place in the theory. It is basically the set of techniques to be adopted to establish reality. This will take place in the natural space of participants, students, and teachers during their school activities (LUDKE; ANDRÉ, 1986). Complementing, Godoy (1995, P. 62) attests that "[...] qualitative research has the natural environment as a direct source of data and the researcher as a fundamental instrument".

The important thing in the qualitative approach is to be objective, allowing the work instruments to mediate between theory and methodology with empirical reality. Research that generally works with people, respecting their opinions, beliefs, and values. Their speeches and answers around the research are rich and revealing. The sample of a group is valid in this type of approach that is representative, i.e., it conditions the study of the phenomenon so that it can reach the desired objective in the research (MINAYO, 2002).

Qualitative methods consider the researcher fundamental in data discussion. The researcher's subjectivity, as well as that of the participating subjects, becomes part of the study (FLICK, 2009). This research goes beyond a simple discovery, as it requires investigation, interpretation, and understanding, and, for that, planning of activities is essential in this process. Data collection follows as a path in an intuitive process (LÜDKE; ANDRÉ, 1986).

The qualitative researcher, according to Moreira (2011b), transforms data and, incidentally, uses tables, charts, and/or summaries; however, what prevails is a descriptive analysis in which there is no concern with statistical inferences. In turn, the quantitative researcher uses questionnaires and/or tests, looks for correlations, and makes inferences, among other aspects. This research is qualitative. However, data analysis of the questionnaires contributed to this discussion.

In the field of qualitative approach, we carried out a case study as a research method that should provide a trustworthy and more accurate image as possible of the researched reality in its various dimensions, within its real complexity. It can be characterized as a study of a well-demarcated entity, such as a college, the place we chose to conduct the research (YIN, 2005).

Gil (2002) points out that this type of study does not accept a rigid script for its delimitation, however, it is necessary to follow a path, a strategy to achieve the objective. The student also needs to be motivated and predisposed to learn, a fact that is also linked to TML, since it is one of the conditions for an ML to occur (AUSUBEL, 2003).

The use of this approach applies to a specific case, which is the investigation of the use of CMs according to the context of the TML, in a delimited space of time, which was in the last academic semester of the undergraduates in Chemistry of the Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE), *Campus* Maracanaú, located in the metropolitan region of Fortaleza — Ceará. The investigation took place during the school activities of the nine participants who proposed to participate.

For data analysis, the research subjects were identified through the numbers 1 to 9 to preserve their anonymity. Reinforced by: “[...] resolution CNS 196/96 adopts in its scope the prevention of procedures that ensure confidentiality and privacy [...]” (BRASIL, 2012). The anonymity is necessary for the participants to feel comfortable during the investigation.

4 Procedures and instruments used

In the case study, more than one technique is always used for data collection (YIN, 2005). According to Gil (2002), this type of analysis, in terms of collection, is the most complete of all designs, as the people’s data are worth as much as the data obtained in the questionnaire. The analysis and interpretation procedure are as varied as possible, in which the process involves different ways of study, and this is consistent with this approach (FLICK, 2009). Data analysis is predominantly qualitative.

One procedure used is a questionnaire, an excellent technique for collecting

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data, which consists of elaborating a standardized, structured form (MEIRINHOS; OSÓRIO, 2010). A questionnaire is applied at the beginning, the pre-test, and later, the analysis and interpretation of the data will be carried out with maximum scientific rigor. Verifying that all the data will be useful in the proposed research is necessary.

The statistical representation of the results referring to the applied questionnaire reflects the careful observation of the data, which made it possible to analyze them quantitatively. Qualitative research considers that for each problem to be investigated, there may be a need to choose specific procedures and instruments (FLICK, 2009).

Another instrument used was the elaboration of the CM. In this analysis, according to Novak (1981), we seek to integrate new concepts into the student's cognitive structure. Therefore, when analyzing the maps, one should be aware of whether there was a hierarchy of concepts, progressive differentiation, and integrative reconciliation throughout the process, aspects that are related to the TML (SILVEIRA; VASCONCELLOS; SAMPAIO, 2019).

The activities followed five steps to consolidate the research. In the first one, the classes were observed for familiarization with the group that would be investigated. Yin (2005) this is an important aspect to provide some additional useful information about the phenomenon. The objective of the pre-test, in the second stage, was to seek information about the identification of students and existing subsumers about the content. The questions were objective and discursive.

The third stage consisted of an expository and dialogic class, with a workload of two hours, in which we approached concepts about the CMs, discussing how they can be used and their relevance, the construction process as an educational tool, following the guidelines of Novak and Gowin (1984). The scoring criteria were used to verify the understanding of the content and, with that, confirm or improve the concepts learned.

In the fourth stage, there was an expository and dialogic class, with three hours of workload, to work with the proposed theme, acid rain, addressing the basic concepts of acids (according to Arrhenius) and oxides. For this, we presented the following question, based on Silveira (2018), to incite the discussions: "Why does a flower or plants change color when in contact with acid rain?" From this, hypotheses were put into focus to answer this question.

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The last stage was carried out as a didactic strategy for investigative experimentation through teams, which brought hypotheses to answer the problem question presented. No roadmap was presented for the execution of the activity. At the end of this process, the maps were built to verify the evidence of an ML. The participants presented it to the others, as the maps are not self-explanatory, and an explanation is necessary. In view of this, the group debated the maps aiming to improve them. They were scored and discussed in line with the TML.

Thus, the qualitative research makes it possible to observe the microcosm of the room focused on the teaching-learning process of the concepts of acids and oxides related to the environmental theme of acid rain. Through this study, it is possible to systematically register, analyze, and evaluate each sequence of map construction, showing that the use of this teaching tool allows students to reach the ML.

5 Results and discussion

Here we try to present the discussions about data collection in confrontation with the theoretical framework addressed. For this, there are three sections entitled: *Perception of students' prior knowledge, Activity on the main aspects of a conceptual map, and Discussion of the CM elaborated after experimentation*.

5.1 Perception of students' prior knowledge

Regarding the pre-test on the subject of *acid rain*, most subjects answered that they had already studied it during graduation, which means that it facilitated the learning process, as they, in principle, have subsumers that corroborate the learning of new concepts (PALMERO; MOREIRA, 2018). However, when faced with questions about which acids and oxides participate in this process, most could not explain.

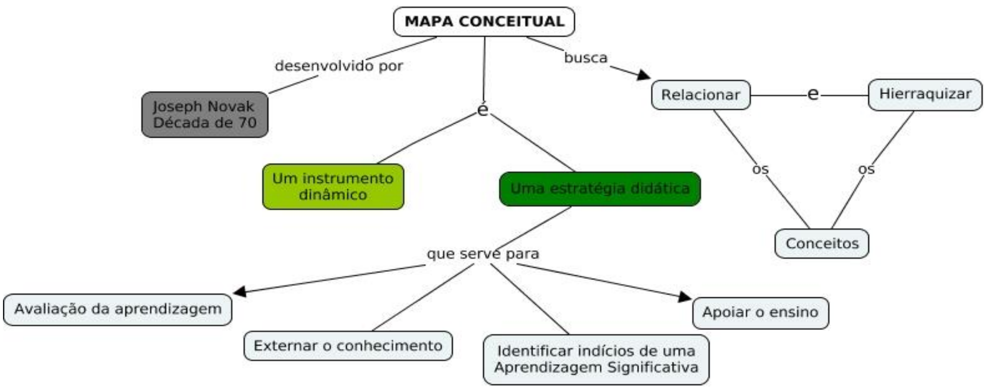
In a subjective question of the questionnaire, students were requested them to write down the causes and consequences and the formulas or names of the substances responsible for the phenomenon. All stated that the main cause is pollution. However, the answers were not well discussed, as there was no mention of the responsible chemical compounds. In this case, sulfur oxides (SO_x) and nitrogen oxides (NO_x), as well as sulfuric acid (H_2SO_4) and nitric acid (HNO_3) (BROWN; LEMAY; BURSTEN, 2005).

The pre-test will support identifying possible gaps in concepts that matter to understanding the subject. The teacher always needs to consider previous knowledge, however, they will not achieve the TML. This highlights the importance of prior knowledge as the most relevant isolated factor in determining the teaching-learning process, in which it is the primary variable for the theory in which the new interaction, the relationship, modifies it by acquiring new meanings (AUSUBEL; NOVAK; HANESIAN, 1980).

Hence the need for dialogued expository classes, through investigative experimentation, to address the proposed theme to facilitate the teaching-learning process (JÚNIOR; PIRES, 2019; LIMA *et al.* 2017). Experimentation must go beyond mere observation of facts and events. It requires understanding the procedure performed so that the subjects acquire new knowledge. Besides, it can enable discussions and problematizations of the execution process and the results obtained (DURAZZINI *et al.,* 2020; JÚNIOR; PIRES, 2019).

We applied an activity after the presentation of the theoretical contribution on the CMs, since it was verified in the pre-test that the subjects had never worked on the topic, in order to corroborate the understanding of the subject. The activity was intended to identify the main aspects that are part of a map. Figure 1 shows the map constructed with the *Cmap Cloud* software, in which the main elements should be analyzed.

Figure 1: Map built with *theCmap Cloud software*



Source: Authors

When asked about the identification of the focal question and the hierarchy, all did it correctly. The focal question delimits the content to be mapped and is the most efficient way to control the size of the map, which also conditions the presentation of hierarchies (NOVAK; GOWIN, 1984).

Another essential criterion for the construction of maps and which relates the relationships between concepts so that they present semantic meaning (propositions)

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is the linking words, which should inform how many there are. The total of 67% stated that there are seven linking words, while 33% said that there are six. The correct total is seven linking words.

Regarding cross links, only subject 2 stated that there are two, while the others were correct in stating that they do not exist. Therefore, the elaborated map lacks in this aspect. Hence the importance of this activity to reinforce the understanding of this subject. The discussions of the questions also allowed for a deeper understanding of the content.

The map presented in the question does not present examples of the CM. 78% of the subjects stated that they exist, and only 22% said that they do not exist. Other examples of maps were presented in order to exemplify this aspect. In short, a new class was proposed so that there was a better familiarization with the relevant elements on the map.

The CMs are a learning resource that allows the student to reconcile, integrate, and differentiate the concepts. New ideas are learned as there are anchor points, where changes take place in the cognitive structure (DIAS; TERRA, 2021). The importance of this activity provides a greater understanding of the elaboration and analysis of the main characteristics, which allows a better approach to the new concepts acquired through the classes. Therefore, it will help identify signs of an AS.

The questions allow the student to reflect on the theory addressed in the classroom about CM and, with this, to support the construction of their maps for the presentation of the concepts portrayed in the classroom. The map legitimacy as an evaluative tool allows the teacher to see how the student is organizing or reorganizing his cognitive structure given the new knowledge (NOVAK; CAÑAS, 2010). During the construction, the teacher can intervene in real time, helping the students to overcome misunderstandings and doubts (O'DONNELL; DANSEREAU; HALL, 2002).

5.2 Discussion of the MCs created after experimentation

In the last meeting, after the activity carried out in the laboratory, the subjects prepared a conceptual map referring to the subject addressed to help identify signs of an AS.

Regarding the types of maps proposed by Tavares (2007), we found that all performed the hierarchical, starting from the most general concept to the most specific.

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This analysis is important to verify the way the map was built. The hierarchical type is consistent with the assumptions made in the TAS (MOREIRA, 2011b). AS is easier when broader concepts are presented first and, progressively, differentiation in specificities is promoted, i.e., there is an idea of a hierarchy of the concepts placed (NOVAK; GOWIN, 1984).

In this work, the CMs elaborated by the students underwent a quantitative analysis, following Joseph Novak's guidelines. There were no correct or wrong maps. The aim was to see whether they were organized given the study carried out and whether there was evidence of an AS based on the cognitive associations performed on the issue. A qualitative analysis was also carried out to verify the mentioned aspects, in this case, if the concepts are present in a significant way in the cognitive structure. At the end, there was an oral explanation about the map prepared.

When the completion of a learning task occurs, the CMs show a schema of what has been learned (NOVAK; GOWIN, 1984). Additionally, Rovira (2016) asserts that the use of those schemes contributes to facilitating learning, as they facilitate the understanding of scientific knowledge. Correia *et al.* (2016) point out that the inappropriate use of this technique can provide obstacles and, therefore, learning does not progress, meaning that a good job is needed when using this tool. The students' map production was carried out individually. After that, they were analyzed. Below is Chart 2 with the scores.

Table 1: CMs scores prepared at the end of the survey

Identification	Criteria	Quantity	Score
Subject 1	Hierarchy	1	5
	Linking words	12	24
	Propositions	13	13
	Cross links	0	0
	Examples	0	0
			Total: 42 points
Subject 2	Hierarchy	1	5
	Linking words	8	16
	Propositions	8	8
	Cross links	0	0
	Examples	0	0
			Total: 29 points
Subject 3	Hierarchy	1	5
	Linking words	9	18
	Propositions	10	10
	Cross links	1	2
	Examples	6	6
			Total: 41 points
Subject 4	Hierarchy	1	5
	Linking words	12	24

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	Propositions	11	11
	Cross links	0	0
	Examples	1	1
			Total: 41 points
Subject 5	Hierarchy	1	5
	Linking words	11	22
	Propositions	15	15
	Cross links	1	2
	Examples	2	2
			Total: 46 points
Subject 6	Hierarchy	1	5
	Linking words	9	18
	Propositions	12	12
	Cross links	0	0
	Examples	1	1
			Total: 36 points
Subject 7	Hierarchy	1	5
	Linking words	0	0
	Propositions	0	0
	Cross links	0	0
	Examples	0	0
			Total: 5 points
Subject 8	Hierarchy	2	10
	Linking words	11	22
	Propositions	11	11
	Cross links	1	2
	Examples	3	3
			Total: 48 points
Subject 9	Hierarchy	1	5
	Linking words	5	10
	Propositions	5	5
	Cross links	0	0
	Examples	0	0
			Total: 20 points

Source: Authors

Given the analysis, we noticed a significant evolution of the concepts on the issue. The students had no difficulties making the map and explored relevant concepts within the proposed theme. Analyzing Subject 4's map, with 41 points, we noted conceptual advances, since the subject places some reactions involved in the acid rain phenomenon and explains the causes and consequences. See Figure 2 as follows.

In the pre-test, there was no explanation of the gases, nor of the acids formed in the reactions. The explanations were quite vague on the issue, so, with the map analysis, the evolution of concepts is noticeable, as the individual mentioned the gases that decrease the pH of the water, such as the responsible oxides.

In the process of interrelation between new and existing knowledge in the student's cognitive structure, at the same time, the person is progressively differentiating their cognitive structure; they are also making an integrative reconciliation to identify similarities and differences and reorganize their knowledge.

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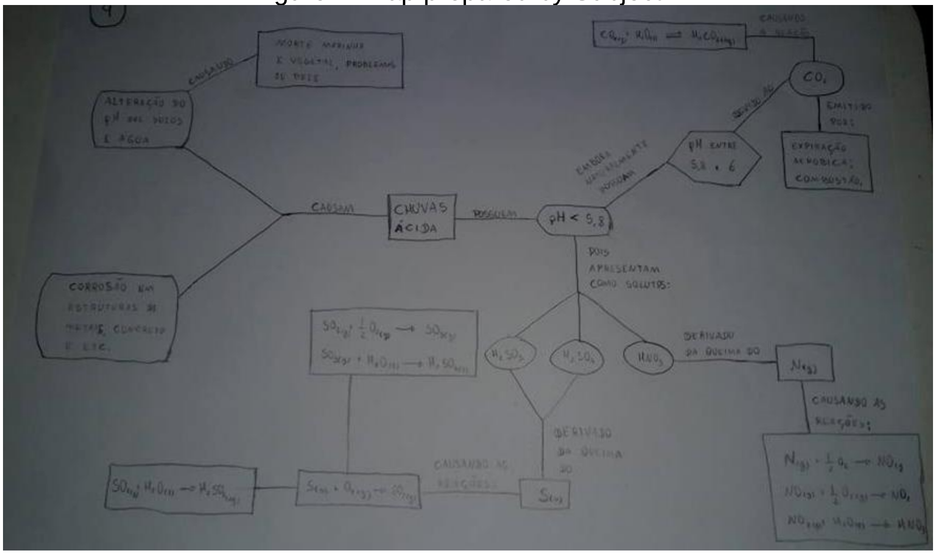
That is, the learner builds and produces their knowledge. They are not passive beings in the teaching-learning process (LEMKE, 2006).

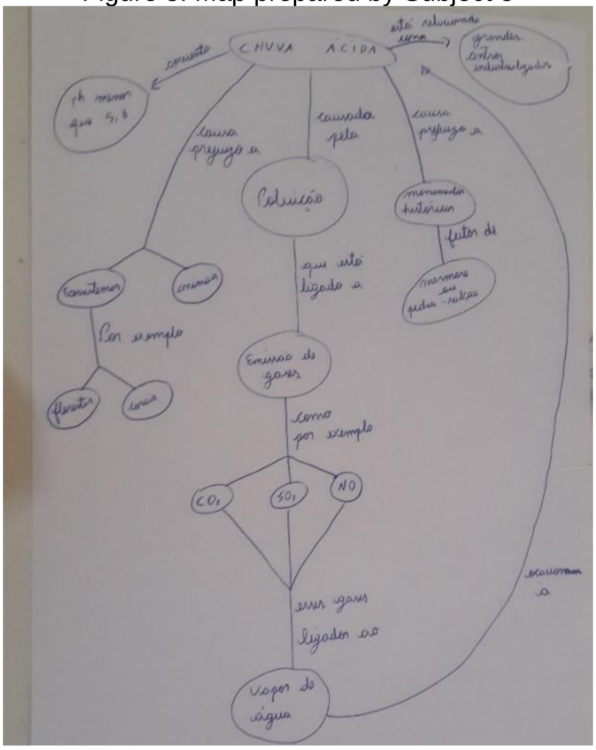
Figure 2: Map prepared by Subject 4



Source: Research Collection

The CMs used in laboratory activities can facilitate understanding the content, as it makes it easier for students to perceive the evolutionary character of scientific knowledge, in which it is not presented as an absolute truth that cannot undergo changes (SEQUERIA; FREITAS, 1989). We can also notice in the map below built by Subject 5, the third best in the rank (Figure 3), that there was also an evolution of the concepts, considering their previous conception.

Figure 3: Map prepared by Subject 5



Source: Research Collection

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In this map, we perceive the presence of a cross link that is related to the way in which the subjects make the conceptual links. In this way, there was an integrative reconciliation in which new relationships between concepts or propositions are recognized. Progressive differentiation is the principle in which concepts acquire greater meaning as they are approached (MOREIRA, 2011a).

These gain stronger meanings as new connections are established in the student's cognitive network. This fact was also observed with the exemplification of the oxides and the causes and consequences that were little addressed in the pre-test.

According to Dias and Terra (2021), the diagnosis of prior knowledge at the beginning of the implementation, through the pre-test as it was called, was of paramount importance, as it attributed meaning to prior knowledge, a crucial element for the ML. The oral explanations of the maps after construction were consistent with the proposal, showing evidence of an ML, as hierarchization and progressive differentiation were verified in the diagram.

As evidenced, the students already had the necessary subsumers in their cognitive structure, which allowed them to anchor new ideas; therefore, the occurrence of interaction between them is likely. This enhancement of conceptual meanings in cognitive structure concerns progressive differentiation. There was also integrative reconciliation due to those new interrelationships between the concepts, in the sense of highlighting the aspects of similarities and differences (MENDONÇA; CORDEIRO; KIILL, 2013).

The CMs used with other teaching strategies can facilitate the understanding of the nature of scientific knowledge, either by enhancing its evolutionary character, stripping it of its dogmatic character, or illustrating the way this knowledge is constructed (NOVAK; CAÑAS, 2010). Briefly, the TML presents a different view of the way in which the individual organizes and integrates knowledge into existing structures, attributing new meanings to effective knowledge or simply incorporating new knowledge into the built structures. At the time of drawing up the maps, there is reflection together with the activity carried out in the laboratory. Through the use of the CMs, signs of a ML can be identified more easily.

It is worth mentioning the map prepared by Subject 7, which obtained only 5 points. The map does not present linking words and propositions, proving that there was no ML. He explained in his speech that

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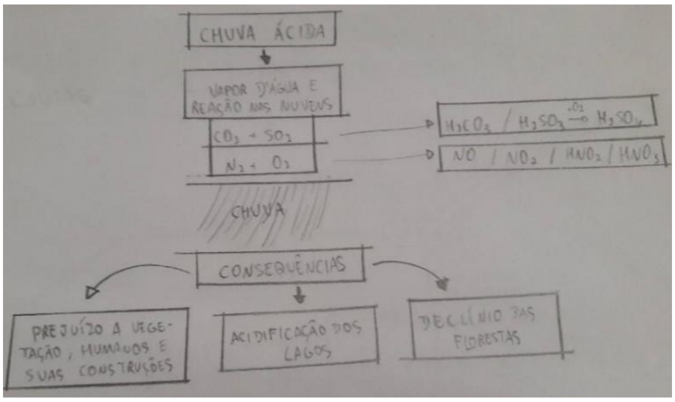
Acid rain is composed of water vapor in the clouds, and its acidification is due to the release of oxides and the formation of acids, such as the sulfuric (H_2SO_4) and the nitric (HNO_3) acids. The consequences are damage to vegetation, humans, and their buildings, acidification of lakes and forest declines (SUBJECT 7).

Subject 7's oral explanation was somewhat satisfactory about the content, however, we noticed some unwillingness to explain. See the map made in Figure 4:

Figure 4: Map prepared by Subject 7



Source: Authors.

No linking words were presented under the lines that unite the concepts. Given this, we can infer that the subject did not understand many concepts. One of the requirements for ML to occur is the predisposition to learn, a determining variable in this process. In other words, we say that the students are predisposed to learn when they are interested in learning the contents that will be exposed by the teacher, i.e., they do not want simply to memorize the issue (AUSUBEL, 2003).

It is necessary to use new situations to intensify the teaching-learning process. The use of challenges corroborates this, as evidenced. The process of understanding and learning depends on what the subject already knows. The development of new goals is essential and must contribute to the teaching-learning process (LEMKE, 2006).

In general, the CMs, when used as an evaluation instrument, allow both the teacher and the student to perceive the identification of the most relevant concepts and the relationships established between them.

Using them as a strategy for teaching and learning in an evaluative character is to provoke reflections and even debates within the teaching of chemistry, in the search for understanding the chemical concepts under construction, which make it possible to guide actions to promote overcoming and advances for the sake of knowledge.

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6 Final Considerations

The teachers must be constantly questioning throughout their professional career and always seek more knowledge. They are always students open to constant reflection. It is about a continuing education and renewal that goes beyond the mere transmission of knowledge.

Therefore, the initial education of chemistry teachers must be brought into debate. Thinking about this emancipation, this education should lead the student to achieve a pedagogical concept in which the questioning of reality, the discussion, and the interpretation of knowledge are established.

Graduate students may find difficulties in the teaching and learning process, however, using the Theory of the Meaningful Learning (TML), they can present positive effects as they stimulate concrete learning. Therefore, it is necessary that teachers develop skills and promote methodologies that provide interaction, in a substantive and non-arbitrary way, between the knowledge that students already have and the new content so that learning ceases to be mechanical and becomes meaningful.

Given the studies carried out, we concluded that the Conceptual Maps (CMs) facilitate the understanding of scientific knowledge and are a potentiating instrument for the occurrence of meaningful learning (ML). This is a strategy that can help the student to prioritize the concepts, as well as facilitate the understanding of the topics covered. When maps are used with other teaching methodologies, they can facilitate the understanding of the nature of scientific knowledge, highlighting its evolutionary character.

The work can help prospective teachers and research in the academic environment to corroborate the teaching-learning process in favor of a ML through CMs as an evaluative methodological strategy in favor of the TML.

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