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The use of concept maps in chemistry teaching and their possible relationship with metacognition

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ABSTRACT

This research presents a literature review focused on using concept maps (CM) as a tool in chemistry education, exploring the implications of using this tool and identifying potential connections with metacognition. To achieve this goal, articles were searched from the ERIC database. By applying inclusion and exclusion criteria, 27 articles were selected for the review. The results indicated that well-structured CM, employed in two or more stages, whether based on interviews or providing materials for them, proved to be excellent tools in chemistry education. Among the challenges identified were the absence of CM presentations in some articles, confusion between concept maps and mind maps, and a shortage of studies in the field. Regarding the relationship between CM and metacognition, the articles did not incorporate metacognition in conjunction with theoretical frameworks that structure it as the process of thinking about one's thoughts and the regulatory component. This suggests that further research is necessary to understand these relationships.

KEYWORDS: Meaningful learning. Systematic review. Cognitive maps.

1 INTRODUCTION

It is not necessary to conduct in-depth research to find numerous texts presenting data about the difficulty students have in learning chemistry, as well as the lack of purpose in the learning process (Santos *et al*., 2013). Thus, the use of strategies based on theoretical foundations can play an important role in achieving this purpose, which is to enable those who have no interest to become interested through meaningful learning.

For students to develop an interest in learning new information, it is essential that their previous experiences are taken into account when constructing new knowledge, allowing them to learn in a meaningful way, i.e. with purpose. According to Ausubel (2003), meaningful learning occurs through the acquisition of new concepts that make sense in the student's cognitive structure. This cognitive structure must interact with the new information provided, both of which are relevant to the process.

When Ausubel (2003) points out that the student's cognitive structure must be considered, he introduces the concept of subsumers. The term subsumers refers to relevant and stable concepts that already exist in the learner's prior knowledge. They act as cognitive anchors in which new information will be anchored to create meaning for the student (Moreira, 2006). When there are no subsumers, Ausubel (2003) advocates the use of prior organizers, i.e. materials that can be presented before the main material, with the aim of presenting a background so that, from this material, the student can construct meaning, strengthening the subsuming concepts.

Potentially significant material needs to have a logical structure and be able to interact with the learner's specific subsumers, for example, images and symbols (Moreira, 2006). An example of a resource that meets these criteria are concept maps (CM), which were created and based on the theory of meaningful learning (Novak, 1990; Silva, 2015).

Joseph D. Novak developed a hierarchical representation model (Ruiz-Moreno *et al*., 2007), which was later called "cognitive maps" or "concept maps" which, by definition, are knowledge representation tools that relate ideas in different segments through connections (Novak, 2010). These relationships are represented between two or more propositions, usually within rectangles or circles (Novak; Cañas, 2008).

Even with a well-defined structure, it is quite common for CMs to be confused with mind maps (MM). This confusion occurs because of the similarities between the tools, but these similarities remain only in the visual aspect (Silva, 2015).

MMs, due to the absence of linking terms in their structure, are simpler to construct to CMs. For this reason, it is essential to distinguish between the two tools, as both can be useful depending on the intended purpose. According to Tavares (2007), a learner may be familiar with the relationships between concepts, and the CM clearly shows the student's difficulties in constructing knowledge. This is due to the complexity of establishing coherent and concise relationships between concepts based on the linking terms of the CM, an aspect that is generally absent in the construction of MM.

According to Silva (2015), CMs have the characteristic of being built hierarchically, another aspect that is generally absent in MMs. According to the author, it is clear that MMs help the student not to lose focus on the central context, but because the links between the concepts are simple, the construction of this map does not allow the student to create meanings between the concepts since the relationships to explain them do not exist in this tool. Without the connections, the monitoring process can be impaired, thus hindering metacognitive processes.

Regarding metacognition, this refers to monitoring the relationship of processes related to a particular object or piece of cognitive information, usually with a goal to be achieved (Flavell, 1976). According to the author, metacognitive processes prepare learners for future situations, since once they have reflected on a particular metacognitive problem, they will be able to retrieve that information at any time if necessary. When considering science teaching, metacognition has been identified as an important component in this process (Jahangard; Soltani; Alinejad, 2016; Listiana *et al*., 2016; Mathabathe; Potgieter, 2014). In addition, when it comes to chemistry specifically, Locatelli and Davidowitz (2021) point out the importance of considering strategies with a metacognitive/meta-visual bias, so that students have the opportunity to review their chemical concepts, revising them and deepening their knowledge. Furthermore, Shimada, Santana and Locatelli (2022), when analyzing the metacognitive potential of CMs, indicated that the process of drawing up maps provides students with metacognitive thinking, since it is necessary to think and rethink several times when constructing propositions.

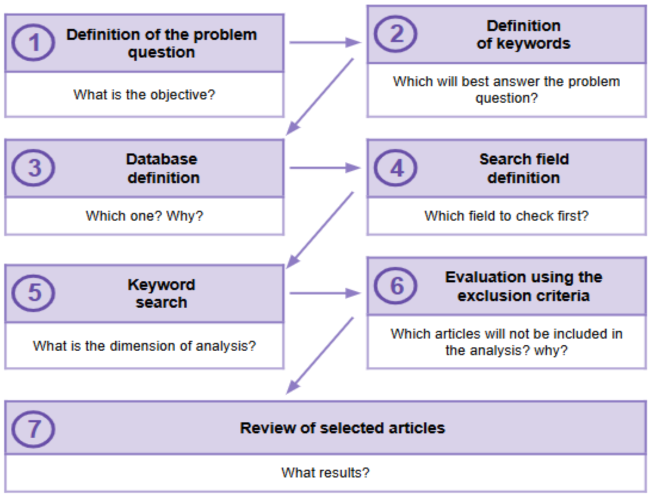
Considering all the aspects listed, the following questions arise: How are CMs used in chemistry teaching? and how are CMs related to metacognition? In other words, this research aimed to carry out a systematic review to investigate the use of CM as a tool in chemistry teaching and to identify possible relationships with metacognition.

2 METHODOLOGY

According to Kitchenham (2004), a systematic literature review is “a way of identifying, evaluating and interpreting all the relevant research available for a specific research question, area, or phenomenon of interest” (Kitchenham, 2004, p. 4). These methods need to be reproducible and for this a detailed description of the stages of the review needs to be presented.

The methodological pathway with its stages and guiding questions can be seen in Figure 1.

Figure 1 - Methodological path



Source: Authors (2024)

Given the problem questions (1) of this review (how are CMs used in chemistry teaching? and how are CMs related to metacognition?), keywords were established (2) to guide the work, searching the database (3) of the Education Resources Information Center (ERIC) platform. This database was chosen because it had the largest number of articles based on a search for the keywords “concept maps” and because it is a reference in the field of education. International articles were exclusively selected for the literature review to provide a broader and more comparative perspective on the subject, aligning with the study’s objective. It should be emphasized that this choice does not exclude the relevance of national scientific production but is simply a methodological decision to limit the scope of the review.

The exploratory search for keywords was necessary not only for the final review, but also to initially check the size of the study and understand, as it progressed, what the impact would be on these productions depending on the number of keywords and their variations that would best answer the research question, as shown in Table 1, the first stage.

Table 1 - Search stages

Stage	Description	Results
1ª	Search in all fields with the first keyword “*Concept maps*”	1399
2ª	Search limited to the abstract field of articles	1350
3ª	Search for Combination A: “Concept maps” AND "*Science education*" AND "*Chemistry*"	46
4ª	Search for Combination B: “Concept maps” AND "*Science education*" AND "*Chemistry*" AND "*Metacognition*"	2
5ª	Articles not considered after applying the exclusion criteria in stages 3 and 4	21
	Selected articles (46+2-21)	**27**

Source: Authors (2024)

After the exploratory search and understanding the volume of articles within the selected criteria, we focused on the ERIC platform with a search only in the "abstract" field of the papers (4), the second stage of Table 1.

Maintaining the search in the "abstract" field, the most coherent combinations for the review were determined (5). Combination A was made up of the keywords: "concept maps", "science education" and "chemistry" to filter out the papers dealing with concept maps in chemistry and science teaching, as shown in Table 1, third stage.

In addition, to verify the interactions between CM in chemistry teaching and metacognition, we searched for Combination A, inserting the word "metacognition", obtaining Combination B, shown in Table 1, fourth stage. It is also important to note that no limit was set on the period when the searches for both combinations (A and B) were carried out, so publications up to the year 2022 were included.

Based on the search results obtained from Combination A and B, exclusion criteria were defined for delimiting the articles and conference papers selected (6). The exclusion criteria defined were: a) articles applied to teaching subjects other than chemistry, b) non-empirical articles c) duplicate articles, d) books, dissertations and theses, e) articles not found and not related to the research. To do this, the titles, abstracts and keywords of the articles were read and, when necessary, the text was read in its entirety to check the relevance of the article to the proposed review.

Considering the aforementioned exclusion criteria (Table 1, fifth stage), 27 articles were obtained for analysis, which were read in full, thus emerging six categories, namely: 1) the description of the articles used for the review with the works to be analyzed, 2) significant and mechanical learning, 3) construction of CM and its structure, 4) purpose of using CM in chemistry teaching, 5) types of analysis and interviews and 6) relationship between CM and metacognition. Finally, the conclusions drawn from this review.

3 RESULTS AND DISCUSSION

A description and discussion of the 27 articles selected from this research is presented.

3.1 Description of the articles used for the review

Table 2 shows all the articles selected for the review, taking into account their codes and references.

Table 2 - Articles used for the review

Code	Article reference
A1	Huie, E. Z.; Sathe, R. U.; Wadhwa, A.; Santos, E. V.; Gulacar, O. Facilitating concept map analysis: generating and evaluating representative general chemistry concept maps with a novel use of Image J, Gephi, JPathfinder, and R. **Eurasia Journal of Mathematics, Science and Technology Education**, v. 18, n. 1, p. 1-15, 2022.
A2	Ye, L.; Eichler, J. F.; Gilewski, A.; Talbert, L. E.; Mallory, E.; Litvak, M.; Guregyan, C. The impact of coupling assessments on conceptual understanding and connection-making in chemical equilibrium and acid–base chemistry. **Chemistry Education Research and Practice**, v. 21, n. 3, p. 1000-1012, 2020.
A3	Demirci, T; Memis, E. K. Examining the views of preservice science teachers on creating concept maps. **Science Education International**, v. 32, n. 3, p. 264-272, 2021.
A4	Lau, P. N.; Chua, Y. T.; Teow, Y.; Xue, X. Implementing alternative assessment strategies in chemistry amidst COVID-19: tensions and reflections. **Education Sciences**, v. 10, n. 11, p. 323, 2020.
A5	Hauck, D. J.; Melle, I.; Steffen, A. Molecular orbital theory—teaching a difficult chemistry topic using a CSCL approach in a first-year university course. **Education Sciences**, v. 11, n. 9, p. 485, 2021.
A6	Aguiar, J. G.; Kinchin, I. M.; Correia, P. R.; Infante-Malachias, M. E.; Paixão, T. R. Uncovering and comparing academics' views of teaching using the pedagogic frailty model as a tool: a case study in science education. **Educational Research**, v. 62, n. 4, p. 434-454, 2020.
A7	Babinčáková, M.; Ganajová, M.; Sotáková, I.; Jurková V. The implementation of formative assessment into chemistry education at secondary school. In: INTERNATIONAL BALTIC SYMPOSIUM ON SCIENCE AND TECHNOLOGY EDUCATION, 3., 2019, Lithuania. **Anais** [...]. Siauliai, 2019, p. 9-13.
A8	Hanson, R.; Seheri-Jele, N. Assessing conceptual change instruction accompanied with concept maps and analogies: a case of acid-base strengths. **Journal of Turkish Science Education**, v. 15, n. 4, p. 55-64, 2018.
A9	Dmoshinskaia, N.; Gijlers, H.; de Jong, T. Does learning from giving feedback depend on the product being reviewed: concept maps or answers to test questions? **Journal of Science Education and Technology,** v. 31, n. 2, p. 1-11, 2022.
A10	Ekinci, S.; Şen, A. İ. Investigating grade-12 students' cognitive structures about the atomic structure: a content analysis of student concept maps. **International Journal of Science Education**, v. 42, n. 6, p. 977-996, 2020.
A11	Akkuzu, N.; Uyulgan, M. A An epistemological inquiry into organic chemistry education: exploration of undergraduate students' conceptual understanding of functional groups. **Chemistry Education Research and Practice**, v. 17, n. 1, p. 36-57, 2016.

A12	Schreiber, D. A.; Abegg, G. L. Scoring student-generated concept maps in introductory college chemistry. In: ERIC Document Reproduction Service No. ED 347 055, 19991, Wisconsin. **Proceedings of the National Association for the Research in Science Teaching.** Wisconsin, 1991.
A13	Fang, S.; Hart, C.; Clarke, D. Identifying the critical components for a conceptual understanding of the mole in secondary science classrooms. **Journal of Research in Science Teaching**, v. 53, n. 2, p. 181-214, 2016.
A14	Aydin, S.; Aydemir, N.; Boz, Y.; Cetin-Dindar, A.; Bektas, O. The contribution of constructivist instruction accompanied by concept mapping in enhancing pre-service chemistry teachers’ conceptual understanding of chemistry in the laboratory course. **Journal of Science Education and Technology**, v. 18, n. 6, p. 518-534, 2009.
A15	Reiska, P.; Soika, K.; Cañas, A. J. Using concept mapping to measure changes in interdisciplinary learning during high school. **Knowledge Management & E-Learning: An International Journal**, v. 10, n. 1, p. 1-24, 2018.
A16	Ward, G.; Haigh, M. Challenges and changes: developing teachers’ and initial teacher education students’ understandings of the nature of science. **Research in Science Education**, v. 47, n. 6, p. 1233-1254, 2017.
A17	Ratinen, I.; Viiri, J.; Lehesvuori, S. Primary school student teachers’ understanding of climate change: comparing the results given by concept maps and communication analysis. **Research in Science Education**, v. 43, n. 5, p. 1801–1823, 2013.
A18	Kaya, O. N. A student-centered approach: assessing the changes in prospective science teachers’ conceptual understanding by concept mapping in a general chemistry laboratory. Research in Science Education, v. 38, n. 1, p. 91-110, 2008.
A19	Jaber, L. Z.; Boujaoude, S. A macro–micro–symbolic teaching to promote relational understanding of chemical reactions. International Journal of Science Education, v. 34, n. 7, p. 973-998, 2012.
A20	Boujaoude, S.; Attieh, M. The Effect of Using Concept Maps as Study Tools on Achievement in Chemistry. **Eurasia Journal of Mathematics, Science & Technology Education**, v. 4, n. 3, p. 233-246, 2008.
A21	Markow, P. G.; Lonning, R. A. Usefulness of concept maps in college chemistry laboratories: students' perceptions and effects on achievement. **Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching**, v. 35, n. 9, p. 1015-1029, 1998.
A22	Francisco, J. S.; Nicoll, G.; Trautmann, M. Integrating multiple teaching methods into a general chemistry classroom. **Journal of Chemical Education**, v. 75, n. 2, p. 210-213, 1998.
A23	Pendley, B. D.; Bretz, R. L.; Novak, J. D. Concept maps as a tool to assess learning in chemistry. **Journal of Chemical Education**, v. 71, n. 1, p. 9-15, 1994.

A24	Liu, X. Using concept mapping for assessing and promoting relational conceptual change in science. **Science Education**, v. 88, n. 3, p. 373-396, 2004.
A25	Ruiz-PRIMO, M. A.; SCHULTZ, S. E.; LI, M.; SHAVELSON, R. Comparison of the reliability and validity of scores from two concept-mapping techniques. **Journal of Research in Science Teaching**, v. 38, n. 2, p. 260-278, 2001.
A26	Nakhleh, M. B.; Krajcik, J. S. The effect of level of information as presented by different technology on students' understanding of acid, base, and pH concepts. In: ANNUAL MEETING OF THE NATIONAL ASSOCIATION FOR THE RESEARCH IN SCIENCE TEACHING, 347, 1991, Lake Geneva. **Anais** [...]. Wisconsin, 1991.
A27	Ross, B.; Munby, H. Concept mapping and misconceptions: a study of high-school students' understandings of acids and bases. **International Journal of Science Education**, v. 13, n. 1, p. 11-23, 1991.

Source: Research data (2024).

Next, in order to briefly contextualize the contents of the articles in the review, a description was created in the form of a summary.

In A1, the authors analyzed the CMs of 344 general chemistry students using Johnstone's triangle (1991). After analyzing the CMs of low-performing students, there was no clarity or standardization in the use of the levels of Johnstone's triangle. In addition, in this work the authors indicate the use of the Bubbl.us website for constructing CMs. In A2, it was analyzed whether the combination of CM and creative exercises helps students to better understand topics in general chemistry. When interviewing the groups that used the combination of tools, they realized that these students constructed good scientific answers related to general chemistry.

A3's study was carried out with trainee teachers on a general chemistry course. As a result, the teachers found that CMs are useful not only for knowledge, but also for retaining what has been learned. In A4, CM was used to teach chemistry at a distance due to the COVID-19 virus pandemic. The teachers, who had no experience of CM, realized that by using the tool they could better monitor their students' development. Similar to distance learning, in A5 the authors found that students were able to create CM, individually and in groups, on the topics covered. The learners rated the CMs as attractive and useful. The article states that the students used CMAP tools, the digital interface built for this purpose.

Seeking to understand teachers' views on the importance of the link between the disciplines of natural sciences, social sciences and science education, in A6, they realized from the CMs that perceptions of the teaching of these disciplines are very individual depending on the structure in which that teacher is inserted. In A7's study, they analyzed the use of various assessment tools in students' education, such as CMs. Statistically, the researchers found that the use of tools in chemistry teaching promotes the development of these students' knowledge.

When studying conceptual changes in acid-base content in chemistry, in A8 the authors concluded, using CM and analogies, that visual and interactive materials help in the learning of chemical concepts. Using CM and open questions, A9 studied the effect of feedback on student learning. The authors found that the effort students put into this feedback was of great value. The cognitive structure of students on the subject of atomic structure was investigated in A10. The results indicated that although the students had studied a certain topic in class, they still had conceptual gaps.

Gaps in students' knowledge of the concept of organic chemistry were highlighted by MC in A11, noting that for students to be able to develop concepts in organic chemistry, a knowledge base of general chemistry concepts is fundamental. Similarly, A12's work concluded the same idea about general chemistry concepts. These works are 25 years apart and yet there were similarities in their conclusions. Not unlike the previous studies, A13 studied the critical concepts for understanding the concept of mol. It was noted that the students solved stoichiometric problems, but they were unable to relate the subtopics of the subject.

The participants in A14's survey were teachers who were at the beginning and end of the course. The results showed that the teachers cited last had conceptual gaps and that, despite having studied chemistry for longer, they still had some alternative conceptions. In secondary school, the authors of A15 used CM to identify changes in interdisciplinary learning. They realized that there are differences, but the school context was the biggest impact factor.

In A16, CM was used before and after an activity to analyze teachers' knowledge about the nature of science. The results indicated that CM is an excellent tool for highlighting the knowledge that its creator possesses and making it reflective. As in the work mentioned above, A17 also used CM before and after an activity. The topic chosen was the combustion reaction of steel wool and its impact on climate change. This work showed the importance of contextualization.

Studying science teachers, in A18 MC were used to analyze the change in understanding of concepts in a general chemistry laboratory course, as an evaluative tool, the MC were valid and reliable to describe their understanding.

The CMs in conjunction with Johnstone's (1991) triad were used in A19. Statistically, they concluded that Johnstone's triad promoted students' conceptual improvement. In A20, CMs were analyzed as a study tool for homework. According to the authors, when students use CM frequently in homework, they revise and modify their maps, continually improving their understanding of the subject. In addition, in order to see how beneficial it would be to use CM in chemistry laboratories in a school, the study by A21 found that the students responded positively to the type of approach and the tool used.

Using four different methods in a general chemistry course, including CM, it was concluded in 22 that the integrated use of different methods helps students become metacognitive, as well as assist teachers in understanding and exploring students' cognitive structures. In A23 it was shown that the CMs highlighted the changes or lack thereof in concept comprehension. Likewise, they highlighted the importance of interviews for understanding students' cognitive processes. However, it is noted that, although interviews are known to be advantageous, their frequent use in the daily classroom setting is not feasible.

Within the ontological, epistemological and social/affective domains, A24 found that the construction of a computerized collaborative CM on chemical equilibrium was able to explain the conceptual change in these domains. In A25, unlike previous studies, CMs with blank fields for students to fill in, as well as the creation of maps from scratch, were used. Thus, it was found that both techniques explore similar aspects.

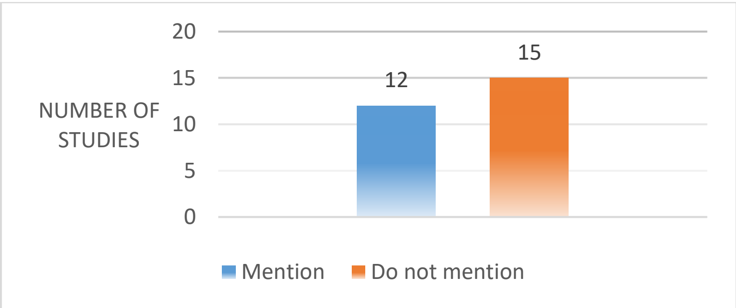
The CMs were used to synthesize what the authors of A26 called the students' computer-based laboratory activities. It was found that the activity helped students to deepen their knowledge of acid, base and pH concepts. And finally, in A27 it was concluded, statistically through the maps, that the students had more information about everyday concepts compared to scientific concepts related to the topic of acids and bases.

3.2 Meaningful and mechanical learning

When working with and analyzing CM, it is essential to know its constructive basis, i.e. meaningful learning. In this review, in the works analyzed, this approach was observed and followed up in order to understand the significant or mechanical construction of concepts.

Novak (1990) based his work on the idea that new concepts are acquired through assimilation with the students' existing cognitive structure, but the challenge was how to present this structure and the changes that have occurred in it. To do this, she used the concept of hierarchy from Ausubel's theory of meaningful learning. However, from the review carried out, it was noted that in more than half of the papers analyzed, meaningful learning was not mentioned (Figure 2).

Figure 2 - List of articles citing Ausubel



Source: Authors (2024)

This may indicate a mismatch, since CMs are prior organizers created on the theoretical basis of Ausubel's meaningful learning. Thus, since this theory was not mentioned in the texts, it could be suggested that mechanical learning processes may have been used instead of meaningful ones. In mechanical learning, the new information does not interact with the subsuming concepts and is therefore easily forgotten. Ausubel (2003) states that this process is arbitrary and literal and does not contribute to possible development.

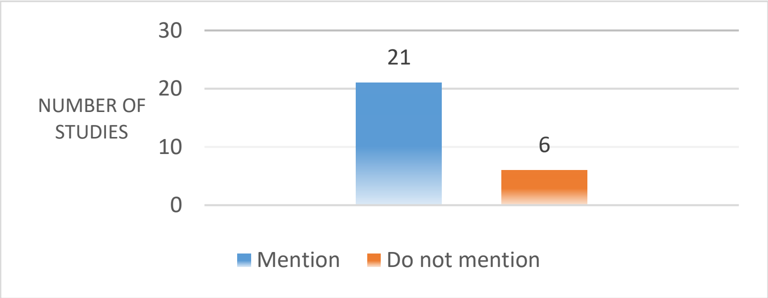
It is worth pointing out that despite the differences, there is no dichotomy between meaningful and mechanical learning. At times, it is necessary to use mechanical learning and, as Ausubel (2003) argues, these processes are continuous and are situated at extreme points, even so, they can sometimes interact.

In the case of chemistry, as it is a subject that can involve calculations, it is common practice to develop schemes so that formulas can be learned, for example. It should be noted that although some processes involving memorization can be important in order to move on to more complex reasoning, this should certainly not be the focus, but rather the understanding of scientific concepts.

3.3 Construction of the CM and its structure

As for the theoretical framework, Novak, the creator of CMs, was cited in most of the papers (Figure 3).

Figure 3 - List of articles citing Novak



Source: Authors (2024)

It was possible to see that the works that didn't mention Novak used CMs only as a visual tool to present something of interest to the authors or used the nomenclature incorrectly, and in some cases, there was confusion between MMs and CMs.

MM was developed by Tony Buzan in the 1960s to help people take notes and, over time, it was realized that it could be a tool to enable people to think more creatively (Buzan, 2018). In order to understand the cases in which there was confusion between MM and CM, it was observed that the structure of the maps lacked the linking terms that connect the concepts, as well as the characteristic structuring of MM, whose hierarchy in the arrangement of concepts is absent and the construction done creatively, as proposed by the creator of MM. A1 and A4, for example, suggest using a website to build CM, but when accessing the homepage of this website, there is a proposal to build MM, showing the confusion between the use of the tools.

Davies (2011), in his article on the differences between CM, MM and argument maps, argues that there are clear differences between the maps and that the use of one or the other will depend on the purpose or objective of their use. According to the author, MMs combine concepts because they don't have the linking terms that characterize CMs, and are useful for associating concepts. On the other hand, CMs not only perform the function of MMs, but also allow concepts to be explicitly related.

In the works by A19 and A27, knowledge representation schemes similar to the MM structure are presented, but the linking concepts and the hierarchization of concepts are absent. With regard to hierarchy, in order to organize all the concepts and learning paths, Ausubel (2003) introduces the concept of progressive differentiation and integrative reconciliation, thus describing the functioning of the hierarchical structures formed. This structure is important in the MCs, as it served as the basis for their construction.

Progressive differentiation works with the development of the subsuming concept almost always through processes of subordination, developing it, i.e. when the same concept serves as a basis for the development of ideas to make it more elaborate, progressing more and more in order to explain it (Moreira, 2012). In superordinate and/or combinatorial processes, the more complex process of integrative reconciliation takes place, linking different concepts in the cognitive structure (Moreira, 2006), relating ideas, concepts and propositions, a reorganization.

3.4 Purpose of using CMs in chemistry teaching

The chemistry topics in which the CMs were used were: general chemistry; inorganic chemistry; mixtures; acid-base; atomic structure; organic compounds; mol; laboratory experiments; education; the nature of science; climate change; chemical reactions; Avogadro's number, conservation of matter, nomenclature; formulas and pH. In cases where general chemistry was used as the main topic, other subdivisions were created for analysis, such as: atoms, bonds, energy, matter, changes, forces, stoichiometry, structure, reactions, equilibrium, spontaneity, solubility, electrochemistry, kinetics, coordination chemistry, periodic trends, preparing solutions, dissolutions, molecular models, strong and weak bases and acids, quantum chemistry and thermochemistry (A1, A2, A3, A4, A18 and A22).

The questionnaires showed that the use of CMs followed two different paths: those that questioned the CM itself (A3, A4, A21 and A24) and those that questioned the participants' chemical knowledge (A8, A9, A14, A17, A18 and A19).

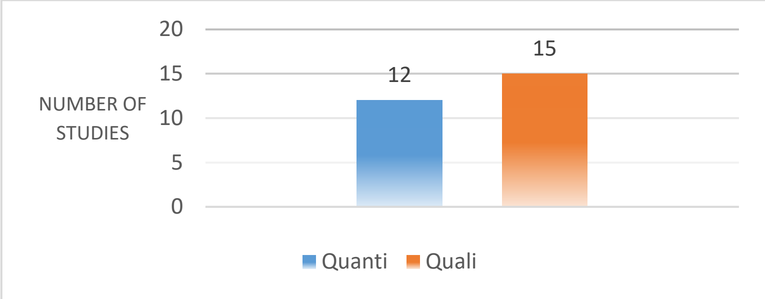
In A3, the authors used the CMs focused on questions related to the construction of the maps, with questions such as: “Do you like the CMs?” and “As a teacher, would you use the CMs in class?”. In this sense, chemistry ends up playing a background role for the CMs. On the other hand, for example, A9 inserted questions about atomic structure into the questionnaire, with the CM being a tool to show what is known about the subject.

Regardless of the chemistry focus used and how the subject was highlighted, the CMs proved to be a useful tool for the teacher to find out what the students already knew in their cognitive structure at various times, being a good tool both for a lesson and for all the planning (Moreira, 2012; Ruiz-Moreno *et al*., 2007), fitting the criteria of potentially significant material.

3.5 Types of analysis and interviews

For the treatment of data obtained from the use of CM, at first, no clear preference between qualitative or quantitative approaches could be identified (Figure 4).

Figure 4 - List of articles using quantitative and qualitative analysis



Source: Authors (2024)

Both analyses were used, but in some papers the analysis ended as soon as the quantitative data was obtained, and the reader lacked an explanation or a more in-depth conclusion about the usefulness of the CM in that context.

In the work with interviews, it was possible to understand what Yin (2016) cites as qualitative interviews as "conversational mode", where there is interaction between interviewer and interviewee, and questions may even arise for the interviewer, and group interviews, in which it is not necessary to collect data from just one participant. According to Yin (2016), this approach represents a complex social reality from the perspective of a participant, and can explain, in depth, the results that were obtained when using the CM.

Minayo (2011) emphasizes the importance of recording when interviews are carried out, stressing that it is crucial for this record to be as close to reality as possible, so that the logic used to carry out the task can be understood. The author mentions recording conversations as a method, and even filming if the participants agree. Recording the interviews was useful for the authors to understand the students' conceptual gaps, their knowledge construction processes and possible improvements in the use of CMs. However, as Aguiar *et al.* (2018) point out and as observed in the works analyzed, interviews can be very time-consuming and need to be applied by experts in the field, reducing their applicability in the classroom context.

3.6 The relationship between CM and metacognition

When analyzing the interactions between CM and metacognition, it can be seen that the subject is rarely dealt with in chemistry teaching. In the two (2) papers found (A2 and A22) that made this connection, none of them mentioned references from the field of metacognition, such as Flavell (1976), for example. In these papers, metacognition emerged from the qualitative analysis of the data and not as a methodology established at the beginning of the work and, as a result, the subject was not addressed in depth in any of them.

In A2's article, metacognition emerged in the structure of the CM as integrative reconciliation, relating the CMs to creative exercises. The students emphasized metacognitive aspects and the interviews proved important so that the researchers could perceive these interactions that were not part of the scope of the work. In this sense, interviews are useful tools for verifying the metacognitive activities and experiences that students have when constructing CMs, as demonstrated in the study by Silva and Bizerra (2022).

In addition, still in A2, in some interviews, aspects of metavisualization were also mentioned, sometimes making some interactions with Ausubel's meaningful learning, in the relationship that once the student visualizes the construction of knowledge, they create meanings for that learning. Metavisual activity allows knowledge to be reconstructed through visualization (Locatelli; Davidowitz, 2021), which can contribute to the teaching of chemistry concepts.

A22 mentions metacognition as a thought process and uses it as a category constructed from the students' responses to the method used. Without definition, metacognition ends up having no connection with the rest of the work, as it is not contextualized, leaving the reader to understand that metacognition is just a category constructed to represent some moment in the students' thinking. It is important to conceptualize metacognition when approaching it in research, since the term is considered polysemic (Shimada; Santana; Locatelli, 2022), which can cause confusion in the reader's interpretation of what the author is referring to.

The fact that only two articles were found linking metacognition and concept maps, and do so in a superficial way, shows that within the scope of this study, considering international research, there is a scarcity of publications dealing with both themes. Thus, further studies exploring CM and metacognition in greater depth are recommended.

4 CONCLUSION

The analysis of the papers made it possible to understand that the uses of CM are diverse in chemistry teaching and, as the reading of the articles progressed, the importance of their use in conjunction with other techniques and familiarity with the subject matter became more evident. Even when applied in the most diverse contexts, by using the points mentioned above, it was possible to see that good results were obtained when applying these maps.

Well-structured CMs, interviews based on the CMs and tests using maps in two or more stages have proved to be excellent tools for teaching chemistry so that the teacher understands the context in which they inserted.

Another important factor, which corroborates Novak and Ausubel, was that by using the CMs, teachers could observe how students structure and synthesize concepts, making it easier to visualize these aspects schematically.

Among the obstacles encountered were the lack of presentation of the CMs constructed in some studies and the confusion between MM and CM. The absence of the CMs in the work makes it difficult for the reader to understand the conclusion of the constructions, going against what the CM has as its strong point, i.e. visual evidence. Confusing MM and CM can lead to distortions in the construction of knowledge, since the different types of maps are tools with different purposes

In order to understand the current scenario of CM in chemistry teaching, we looked at the years in which the articles were published and it was possible to see that, although the number of publications has increased recently, there are few dealing with the subject, which is a fruitful scenario for future research since CM, as observed in the analysis of the articles, helps chemistry teaching.

One aspect requiring further attention is the interaction between CM and metacognition. The reviewed articles did not address these interactions nor referenced theoretical frameworks from the field, making it difficult to understand metacognition in the context in which it was inserted.

The aim of this review was to provide an overview of the use of CMs in chemistry teaching so that new research in the area can be carried out in the light of what has already been built and concluded since the creation of CMs. Further studies in the area of CM and metacognition are recommended to see if the interactions between these two areas produce what is theoretically proposed, i.e. concepts of meaningful learning from CM interacting with the rethinking of one's own thoughts in metacognitive processes. In this way, we hope to create a structure that can provide material for more robust CM and knowledge constructions.

O USO DE MAPAS CONCEITUAIS NO ENSINO DE QUÍMICA E SUA POSSÍVEL RELAÇÃO COM METACOGNIÇÃO

RESUMO

Esta pesquisa apresenta um recorte da literatura a respeito do uso de mapas conceituais (MC) como ferramenta no ensino de química, as ramificações do uso dessa ferramenta e a identificação de possíveis relações com a metacognição. Para esse fim, foram pesquisados artigos na base de dados ERIC. Dessa forma, filtrando os artigos encontrados por critérios de exclusão e inclusão, 27 trabalhos foram selecionados para a revisão sistemática da literatura. Os resultados indicaram que a utilização de MC bem estruturados, utilizados em duas ou mais etapas, baseados em entrevistas ou fornecendo material para elas, mostraram-se como excelentes ferramentas no ensino de química. Dentre os entraves encontrados, pode-se citar a falta da apresentação dos MC elaborados em alguns artigos, a confusão entre mapa mental e MC e a escassez de estudos na área. A respeito da relação dos MC com a metacognição, os artigos encontrados não utilizavam a metacognição em conjunto com os referenciais teóricos que a estruturam como processos do repensar sobre os próprios pensamentos e o componente regulatório, indicando que mais pesquisas na área são necessárias para entender essas relações.

PALAVRAS-CHAVE: Aprendizagem significativa. Revisão sistemática. Mapas cognitivos**.**

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