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Metacognitive knowledge and experiences developed by chemistry teachers through the process of research-based teaching: an emphasis on continuing education

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ABSTRACT

There is a noticeable, widely accepted movement in the field of science teaching, which suggests that continuing education should focus on the needs and goals of the teachers. To this end, a viable path is adopting a metacognitive perspective to enable deeper reflections, the construction of meaning, reevaluations and redirections. Given this panorama, this paper aims to present a discussion about the metacognitive knowledge teachers may hold on the subject of research-based teaching, and what metacognitive experiences they may bring up in order to further develop (more) investigative activities in class. Assuming this thesis and relying on action research mechanisms, a training course for practicing teachers was held between August and December 2019, supported with the participation of six Chemistry teachers working in public and full-time schools in the state of Sergipe, Brazil. Based on the audio recording of the first phase of the course, our results point out that these teachers have adequate metacognitive knowledge on research-based teaching, and how to foster more autonomy for students to elaborate their own arguments, propose solutions, make decisions and solve different problems. The discussions conducted throughout the course allowed an expansion of this knowledge, by means of proposals grounded on various types of metacognitive experiences. Therefore, it is understood that taking a metacognitive approach for continuing education, as well as for initial training, leads to certain possibilities: firstly, the chance to properly identify the well-established metacognitive knowledge held by teacher; and then, to reflect on it, with a view to planning new metacognitive experiences that will be built upon this knowledge, expanding and improving it.

KEYWORDS: Continuing Education. Metacognition. Metacognitive knowledge. Metacognitive experiences.

INTRODUCTION

Establishing a professional path is a long, continuous, multi-stage process. One of these stages is known as initial training, which includes the acquisition of knowledge, be it in higher education, associate studies, or technical and vocational programs, in addition to all knowledge/techniques passed on from generation to generation. Another stage, usually set after the initial training, is based on practice, so a professional may be shaped by their experiences in the field. The final stage, although it is never conclusive, is the search for constant qualification and updates, in order to meet all the demands that arise with the modernization of our society and many technological advances.

Teacher training studies also reflects this model of professional development. Regarding this field, it is worth mentioning how the relevant literature highlights the influence of past teachers, even before the initial training, considering that, in addition to providing various formative experiences and educational scenarios (KENSKI, 1997), elements of these memories are evoked by aspiring professionals in order to seek the comfort required to engage with a classroom (GONÇALVES et al., 2008).

Thinking about all these stages, and in view of all the changes that have occurred and continue to occur, teachers can no longer expect the teaching-learning process to take place only as a one-sided transmission or delivery of knowledge to students. Thus, it is necessary that:

> [...] Teachers must understand various contemporary demands, perceive their role as transforming agents and, consequently, encourage students, considering their idiosyncrasies, to perceive, discuss and seek solutions to the social reality in which they are inserted (SILVA; BASTOS, 2012, p. 152).

However, active teachers do not always have an initial training (or first experiences) that encompass all these aspects of their didactic role. In this sense, continuing education is critical, as it allows constant reflection on their condition as teachers, in order to further improve their professional performance.

Even so, although it is established by law, (BRAZIL, 1996), continuing education is not always sought, "greatly impairing the possibility of teachers to foster their professional development" (SILVA; BASTOS, 2012, p. 155). Furthermore, not long ago, many of the courses promoted by Brazilian states proved to be generalistic in nature, and did not attend the specificities of different fields of knowledge. In the case of continuing education for Science/Chemistry teachers, Schnetzler (2002, p. 16) stresses that:

> [...] What is addressed or taught in these courses is not related to the issues experienced by teachers themselves, but rather based on what the professors in charge consider important - be it a new methodology, or the use of a new instructional resource, be it chemical **(scientific)** subjects themselves, which are usually approached according to the same logic as an undergraduate program. (Emphasis added).

It can be argued that alternatives were put into discussion in order to overcome the more technical model of teacher training. For example, in the first decade of the 2000s, Practice Communities were established as means for

reflecting on individual and collective experiences, aiming to build a democratic space, suitable for more critical analyzes on teaching (NICHELE; BORGES, 2015).

Therefore, among the possible ways to develop science / chemistry teacher training courses with a more reflective approach, the metacognitive perspective stands out. This is because the integration between didactic and learning processes with metacognition "leads to deeper reflection, the creation of meanings, reevaluation and redirections" (LOCATELLI, 2014, p. 19). Thus, planning and introducing metacognitive activities to the classroom, such as writing and rewriting, concept maps, V diagrams, problem solving, comprehensive assessments etc., contribute to this articulation, and lead to the definition of new roles (for teachers-students), as it centers the process on both students and the teacher (TOVAR-GÁLVEZ, 2008). Corroborating this, the literature shows that studies on metacognition, especially on teacher training, are still incipient (CLEOPHAS; FRANCISCO, 2018; ROSA; VILAGRÁ, 2018; ZOHAR; BARZILAI, 2013).

Zohar and Barzilai (2013), when conducting a review project on metacognition over the ERIC database between 2000 and 2012, pointed out that metacognition research is shifting towards more authentic classroom settings. However, it is still necessary for metacognition to become a routine teaching strategy in science classrooms. Considering future research, the authors suggested studies on the conditions under which teachers (in training and working) can learn better, address various metacognitive components to achieve a wide range of awareness, and educational objectives to employ in class.

In the review project conducted by Cleophas and Francisco (2018, p. 20), the authors pointed out how an approach to teacher training is still rare. For those who evoke this notion, most articles involved self-management activities that "presented elements that denote what teachers say they do with the elements arising from what they actually do in their pedagogical praxis". Rosa and Vilagrá (2018) observed that, when working with problem solving while training physics teachers, knowledge about metacognition and its operationalization is understood as a strategy, both for teachers to teach and for students to learn. As much as it is possible to observe advances in the aforementioned gaps, they are not yet closed.

Accordingly, the purpose of this work is to present a discussion about the extent of the metacognitive knowledge (MK) that teachers may hold on research-based teaching, and what metacognitive experiences (ME) may be conceived by them to (further) develop investigative teaching activities. The proper delineation of their MK is important because it is only by acknowledging it that teachers are able to combine all outlined cognitive components, with a view to formulating strategies to increasingly expand their didactic expertise.

THEORETICAL REFERENCES

As polysemantic as the term "metacognition" has become in view of its wide use since the 1970s (DINSMORE, ALEXANDER; LOUGHLIN, 2008), its prevailing interpretation refers to the knowledge that subjects may have about their own cognitive processes and products, in addition to the management, monitoring and regulation of both teaching and learning processes (FLAVELL, 1976).

Within this proposition, Flavell and Wellman (1977), when conducting studies on metacognition, used the term metamemory. For the authors, this concept is developed through the individual's awareness of the way certain variables interact throughout the conduction of cognitive activities, to the point of influencing them and modifying their results.

When expanding the understanding of metamemory, a system based on two components was established: sensitivity, which sought to describe that memorization was only possible when a subject learns to identify those moments requiring certain strategies; and knowledge of the following variables: person, task and strategy.

Generally speaking, the **person** variable refers to knowledge about oneself; the **task** variable is related to the knowledge resulting from the clash between the nature of information and the subject's value judgments when performing a task; while the **strategy** variable encompasses details about the means, processes or fields that make it possible for the individual to achieve their goals more effectively during the performance of a task (FLAVELL; WELLMAN, 1977).

Later, Flavell (1979) proposed a model of cognitive monitoring with a wide variety of cognitive developments, based on two classes of phenomena: (i) metacognitive knowledge (MK), which includes the components sensitivity and knowledge of the person, task and strategy variables; and (ii) metacognitive experiences (ME).

MK comprises the individual's (a child, an adult) own knowledge of the world, knowledge that is already stored cognitively for the accomplishment of different tasks, objectives, actions and experiences. An example of the use of MK would be a teacher deciding to adopt a certain didactic procedure instead of another, because they believe it would be more effective. This type of knowledge provides a “database”, in which the person may select the information that better fits the framework of the tasks/targets being pursued, when automatic cognitive processing fails and the person needs to manage their cognition (EKFLIDES, 2009).

Moreover, MK is continuously updated because it is a construction grounded on information from different sources - not all of which are completely explicit, as a large part of them come from unconscious abstraction and inferential processes. On the other hand, this MK, viewed as a model or theory about cognition and people, can implicitly dictate behavior and action, by means the different expectations influencing the interpretation of situational demands and tasks (EKFLIDES, 2009).

Flavell (1979) sought to broaden the notions of the person, task and strategy variables by grouping them together with MK. Within the scope of the **person** variable, the author encompassed everything that an individual believes/knows about their own nature and that of other people, as cognitive processors. The belief that we can learn more about a subject by listening than by reading is an example of this classification (FLAVELL, 1979).

The second variable, **tasks**, concerns all information available for cognitive development. In this sense, metacognitive knowledge "is an understanding of what such variations imply for how the cognitive enterprise should best be managed and how successful you are likely to be achieving its goals" (FLAVELL, 1979, p. 907). An

example of this would be the awareness that some cognitive aspects are more demanding and difficult than others, despite having the necessary information

Finally, the **strategy** variable encompasses a variety of acquired strategies, which are likely to be effective in achieving goals related to cognitive aspects (FLAVELL, 1979). A person, for example, may believe that a good way to learn and retain a lot of information is to pay special attention to the main points of a subject and try to repeat them to themselves, in their own words.

For this category, Schneider (1985) states that the metacognitive knowledge of strategies cannot be easily applied in the processing of tasks, unless the knowledge itself has been previously processed. This means that it is only after becoming fully aware of different strategies that they can be applied purposefully, and in a self-regulating manner, allowing the MK to be used to "process information, solve problems, or guide the person's action and behavior" (EKFLIDES, 2009, p. 78).

When considering metacognitive knowledge, it is important to highlight that it can comprise interactions or combinations of two or three of these categories (FLAVELL, 1979). As the subject is faced with different situations, their MK may be activated in several ways, either consciously or automatically.

With regard to metacognitive experiences, they consist of cognitive or affective experiences that consciously accompany and belong to an intellectual construct, being "the interface between the person and the task" (EKFLIDES, 2009, p. 78). Many ME are correlated to a moment, situation or any progress made, in order to understand what is happening and make new decisions.

These experiences can be brief or extensive, simple or complex in terms of content. According to Langer (1978), they are likely to occur in situations that encourage great care and high awareness of reasoning, especially in the face of new roles or situations in which each important step requires prior planning and further evaluation; situations in which all decisions and actions are impactful and risky, while affective aspects and reflective thinking are supposedly absent.

Furthermore, metacognitive experiences can have effects on both cognitive and metacognitive aspects. This is the case because they "can lead you establish new goals and to revise or abandon old ones", as well as "can affect your metacognitive knowledge base", expanding and restructuring it for other tasks and actions (FLAVELL, 1979, p. 908).

According to Efklides (2009), ME include:

- metacognitive feelings: these involve the emotional aspects faced during the knowledge process and its phenomena, such as feelings of familiarity, difficulty, confidence and satisfaction;
- metacognitive judgments/estimates: these encompass the ability to reflect and value knowledge. Examples: judgment of learning, estimative of effort, estimate of time needed or expended, estimative of solution correctness, and episodic memory judgments, such as know/ remember/guess, source memory (where, when and how information was acquired), or estimates of frequency and recency of memory information;

- tasks-specific knowledge: these comprise information about tasks that are attended to and used. Two examples: (i) the utterance (oral language) of words, ideas or thoughts to make subjects aware of how to deal with a task, as has been pointed out by Lavarda and Pereira (2019), and; (ii) the MK that is recovered from memory in order to process an activity, such as past tasks and procedures, used for comparison with the new tasks.

The last two types of ME are of an analytical and cognitive nature, while the first is of an affective and cognitive nature. Broadly speaking:

> ME can be the product of a variety of different processes, most of which are nonconscious, nonanalytic ones. Moreover, metacognitive feelings have a hedonic quality that makes them unique, in the sense that they have access to processes of both the cognitive and the affective regulatory loop (EKFLIDES, 2009, p. 79).

Since ME involve many different processes, providing continuous training for teachers, while exploring metacognitive elements, reinforces both the acknowledgment and self-assessment of their teaching practices. Thus, it is argued that this metacognitive approach gives teachers the opportunity to grow, by examining their knowledge, self-managing themselves during their own pedagogical practices. As much as studies on metacognition have progressed over time, it remains a challenge to fill the gaps pointed out by Zohar and Barzilai (2013) concerning teachers' knowledge on metacognition, as pertaining to the practice of teaching science.

METHODOLOGY

This research has a qualitative character and is based on the action research approach. Accordingly, rooted in action research, its core idea is that the researcher and the public, together, should discuss possible interventions that could allow them to investigate various theoretical-practical factors in a critical and reflexive way, in order to foster professional development (STENHOUSE, 1998).

It is through planned interventions that teaching scenarios are sought to be discussed with the public. Therefore, "action research" begins with research, based on the attempt to understand every question, and only then to proceed with action. “There is a pair: 'action research'; action is what happens, while research is the movement to understand what happens” (SIMEÃO; MOCROSKY, 2018, p. 243). Another aspect that connects this investigation to an action research approach is the fact that all processes are presented in cycles. This research model comprises an interactive and recurring process, based on planning, acting, observing and reflecting cycles (COUTINHO, 2011).

Thus, this joint work was carried out in a continuing education course held for teachers between August and December 2019. Six Chemistry teacher, from public and full-time schools in the State of Sergipe, with a range of experiences from 7 to 15 years, took part in this process. Additionally, these teachers were engaged in the PIBID and Pedagogical Residency programs, therefore, they have an ongoing partnership with the university. It should be noted that participation in the course was voluntary, several teachers from different schools were invited, even those who were not involved in the programs mentioned above.

For the production of data, it was decided the course should have its audio recorded. The preparation and organization of the course were designed with a metacognitive perspective, following the three-stage metacognitive model of Továr-Galvez (2008), adapted to our contextual framework:

- reflection dialogues: when subjects are encouraged to recognize and evaluate their own cognitive structures, methodological possibilities, processes, skills and disadvantages in relation to a topic or subject;
- monitoring dialogues: when an individual, already aware of their conditions, proceeds to conjugate the different cognitive components they have identified, with the purpose of formulating strategies to solve reflective tasks;
- production/evaluation dialogues: when the subject appraises the implementation of their strategies and the degree to which their cognitive goal were reached.

In this vein, these three types of dialogue always start with just a couple of pre-determined questions and, based on the first answers, proceed into an informal conversation (chat). Reflection dialogues aim to determine the conceptions and knowledge that teachers may have on the subject (research-based teaching), describing their practices and, accordingly, how teaching-learning activities may be developed in class. Given this information, the meeting then focus on how this knowledge dialogues with other theoretical-practical perspectives, in order to allow their practice to be self-regulated, as well as to outline new experiences. This was the stage of the monitoring dialogues. After this new round of debate and joint construction, the participants reached the Production/Evaluation dialogues, which emphasize future actions in class, in response to the approaches that were discussed to that point.

This article presents data resulting from the first meeting, when theoretical and practical aspects of research-based teaching were discussed. Specifically, only excerpts from reflection and monitoring dialogues were selected. It should be noted that the recorded data was adjusted to more formal language standards, while respecting its originality as much as possible.

These dialogues were chosen because they facilitate the definition of the metacognitive knowledge held and employed by these teachers in their practices. Additionally, this allows teachers to self-assess their own practices (and knowledge) for greater didactic control and future metacognitive experiences.

RESULTS AND DISCUSSION

In order to encourage the **reflection dialogues** in the first stage of the course, aiming to promote the recognition of the teachers' pedagogical-didactic praxis, the researcher started with the following scenario:

> RESEARCHER: Our reflection dialogues start like this: What words do you think define/explain research-based teaching? That is, what comes to your mind, considering your prior knowledge, your teaching practice, what do you think defines or explains research-based teaching?

The suggestion to list words, according to their own knowledge and experiences, aims to explore their knowledge on the subject. This metacognitive intentionality is intended to lead those teachers themselves to recognize their control over this knowledge, as well as the cognitive processes that research-based teaching can provide.

What is perceived in teachers' responses on the topic of research-based teaching, is a convergence of ideas, especially concerning the matter of situating students as active players in the entire learning process. It is observed by the selected excerpts of these teachers' speeches (1, 2 and 3) that, for them, research-based teaching leads students to act, to seek answers to the problems posed to them, providing them with greater freedom to think, express themselves, develop actions and learn.

> TEACHER 1: Curiosity. Observation. [...] The experimentation factor, additionally. The students are not going to just stand there, listening. They are going to act, to position themselves as agents, because they have to work for it. […] And I think that, in research-based studies, the student has to seek this knowledge constantly. The have to pursuit what is being covered, what is being questioned. […] It is research-based because they have to search for it. To search information surrounding what they are observing, discussing in that moment. It is a challenge. And it's this challenge that motivates students to find answers for what is being questioned, what is being studied. That is, more or less, how I see research-based teaching. I have to inspire a lot of curiosity. This motivates them, because they will want to know, to search, how to express this knowledge, how to interact with it. I think this covers all three scopes.
>
> TEACHER 2: The students have to act. They have to work to answer these questions, they have to explore them.
>
> TEACHER 3: I think it's a matter of giving them more freedom, because students are used to being guided, and now it's up to them to guide the process, to present solutions. […] When they are in charge of research, it's their accomplishment. They play a major role in this story, so I think this motivates them, because it's a greater challenge. I think it's a matter of freedom to construct something, we can build up concepts with them. […] With research-based teaching, I can see that the students have the freedom to think, to decide. They are able to express themselves as agents.

These conceptions about research-based teaching (as pointed out in the excerpts) demonstrate the metacognitive knowledge held by teachers, grounded on the task category, and their capacity to understand the course and the results of different cognitive factors. According to Flavell (1979), the task factor, as related to metacognitive knowledge, is an understanding of how cognitive aspects must be better managed in order to achieve a certain goal.

Accordingly, these first perceptions about research-based teaching are in line with what the literature has been pointing out, especially what was presented by Carvalho (2018, p. 766), who defines research-based teaching as "the teaching of contents in which the teacher creates the conditions for students to think, speak, read and write" about the relevant knowledge, throughout their class activities.

Figure 1 was designed to summarize the list of words pointed out by teachers, taken directly from their answers:

Figure 1 – Assortment of words brought up by teachers

Source: The authors hereof (2019).

The frequency of the words is represented by their font size, as well as color-coded: red, green, blue and orange correspond to 4, 3, 2 and 1 repetitions, consecutively. Many of these words (search, answer, solve, express, think, autonomy, etc.) comprise the creation of the four conditions for research-based teaching. The words "freedom, conduction and construction" point out to the strategy category of metacognitive knowledge, because it portrays characteristics of investigative activities.

Carvalho (2018) argues that teachers should pay special attention to the degree of intellectual freedom given to students, and the elaboration of each problem. These components are very important, “because it is the problem proposed to them that will trigger students' reasoning skills, and without intellectual freedom they will lack the courage to expose their thoughts, reasoning and arguments” (p. 767).

Therefore, when teachers quote the words "freedom", "conduction" and "construction" within the aforementioned framework, there is a noticeable perception of their knowledge as related to the **strategy** variable. That is to say, acquired knowledge on which strategies are likely to be effective to achieve their goals, based on the cognitive aspects of research-based teaching.

Then, the researcher invited the teachers to connect the words they initially suggested, considering what comes to be research-based teaching, in view of their teaching practices:

> RESEARCHER: That's very interesting. Our dialogue was already leading us towards the second part. Think about any investigative activity that has already been conducted by you, in class, or that you have been developing. **How would you apply or relate the words you said in our first dialogue to this activity?**

The invitation to establish relations between what teachers think about something and what they do in their teaching practices is a form of cognitive self-regulation. This encompasses their control over the current state of things, that is, what they do, with the very understanding of what is research-based teaching.

At this point, Teacher 1 mentioned the creation of a workshop on radioactivity, carried out based on the knowledge acquired in a continuing education course. From this workshop on, the main goal was to work on the

concepts of radioactivity by correlating them with students' daily lives (home appliances), providing meaning to scientific knowledge as pertaining to everyday life, arousing curiosity and solving problems.

> TEACHER 1: For example, in the course I gave, we built a workshop and I chose radioactivity. Then I worked on the dangers of everyday household appliances, which they have at home, [...] We tried to bring the course closer to the students' daily lives. Their reality, so that it makes sense. Then we can arouse their interest in learning [...] I called it "Radiation: Constant danger or good for everyone?" because, despite the trouble, radiation is good when used for diagnosis, like in a tomography. I brought some experiments, videos that show the benefits of radiation. How do I apply this science to solve a problem? Because this is something we have to bring up to research-based teaching as well. How are we going to use science to solve what is being presented [...] in what situations, when could this help us, in our day-to-day lives? Because we have to establish this connection, so it makes sense to the students [...].

The use of workshops associated with experiments and videos is pointed out by Teacher 1 as an investigative activity previously completed. By triangulating this statement with the words they initially said (highlighted herein), there is a **connection** between scientific knowledge (radiation and radioactivity) and students' daily lives (home appliances). Furthermore, **problem-solving** is explored through the question ("Radiation: Constant danger or a good for all?"), and **curiosity** is used as a springboard for interest in learning.

Another connection that can be inferred is the **search** for information to **answer** the questions or the **challenge** proposed in the workshops. Thus, scientific knowledge helps the student to solve the problem and **express** what they have learned.

Here, the metacognitive knowledge of Teacher 1 consists of interactions or combinations between the person, tasks and strategy variables. It starts on a personal level, as the didactic structure is based on the teacher themselves recognizing which investigative activities have already been conducted. Then, there is a focus on acquiring information throughout a continuing education course (task), aiming to expand knowledge and enable an assessment of how the activity could be done. This culminates in the use of the best strategies to achieve the planned goals, based on all this knowledge.

According to Továr-Galvez (2008), this metacognitive reflection allows the teacher to plan their activities and use different instruments that allow them: (i) to value other concepts, previously developed by their students; (ii) to establish connections to the solution of the problem; and (iii) understand the didactic process in order to identify potentials and obstacles for future interventions. These results are in line with the notion of a metacognitive profile, proposed by Passos, Corrêa and Arruda (2017), as it is possible to understand how teachers perceive their practices to help students learn.

For Teacher 2, although they have not carried out investigative activities with a radio transmitter yet, their speech highlights the possibility of working on the theme of radioactivity and its effects. To that end, they suggest a research project on the relationship between electromagnetic waves and their frequency:

> TEACHER 2: I was thinking about radioactivity, because electromagnetic waves have a whole spectrum, from radio waves to gamma rays. I could explore this... They all have the same electromagnetic nature, but differ based on frequency. So, the students could investigate, what is the frequency of a certain wave, and work on this frequency, to see why radio waves are harmless to our health. Then, we could explore what is frequency, the subject of waves themselves.

The words mentioned at the first stage were: **act, answer, work** and **manipulate**. However, even with an awareness on how to relate frequencies to the type of electromagnetic wave they produce, Teacher 2 did not detail how this investigative activity could be performed. What we have here are metacognitive experiences described as elements of metacognitive knowledge.

As EM are memories of cognitive experiences, i.e., previously appropriated experiences, Teacher 2, through socialization, established connections with known situations (different types of radiation and the electromagnetic spectrum). Thus, metacognitive knowledge becomes increasingly more conscious, as metacognitive experiences are better understood. Accordingly, when developing an activity, suitable ideas about the structure, production and organization of the didactic process are added to this metacognitive knowledge, as pointed out by Campanario (2000).

According to Teacher 3, the investigative activity they have developed was an experiment on how to contain/remove oil from water. From there, it expanded on how to seek solutions to the issue of improper disposal of oils in the sink, which directly affected a river in the city:

> TEACHER 3: We worked with oil. Recycling. It all started with a practical class, when I was working with containment. So we reproduced an environment, a basin with water, and oil was spilled in that basin [...] so they needed to present a solution for this oil problem, in the Saco River. They started to notice, at the school, how much oil was poured into the sink. They started to question what could be done with that oil. We developed a recycling project, filtering and obtaining some products from that oil. And this work was extended to the community. [...] This issue led to higher awareness in the community, because three or four streets stopped spilling oil... an almost absurd amount of oil. And we had high levels of production. For almost six to eight months, the school saved a lot. It was one thing to spend around 400 Reais in reagents for us. Another thing was to spend 5,000 Reais on products. [...] We ended up involving other classes. So, just for arousing this curiosity in younger students, the experience was very rich. I really, really, really learned a lot at the time. The children's curiosity... It's very powerful, so I still do research-based classes to this day.

Drawing a parallel with the words suggested in the first reflective stage of the interviews, it is observed that Teacher 3 proposed an experimental construct with the students, aiming to launch a challenge on how to solve the issue of the oil spilled in the river. From this, their students had the freedom and autonomy to investigate and think about the problem, proposing the conduction of a study in order to decide which solutions to take (oil recycling), and to express a resolution and the conceptual appropriation (synthesizing different products, saving school funds), experimental techniques, community engagement, etc.).

It is possible to point out how the metacognitive knowledge of Teacher 3 also involves the person, task and strategy categories. The personal aspect is

highlighted by the identification of the importance of practical classes and the creation of a study environment, aiming to provide the students with an environmental issue.

The task category is identified in the formative chemical knowledge on experimental techniques and syntheses to guide students throughout the recycling process proposed by them. The strategy emerges in the mobilization of the community to obtain the oil, which required collaborative work, with a view to raising awareness about proper disposal and the mutual benefits of generating products and savings for everyone.

According to Campanario (2000), this entire metacognitive process favors the active role of students during the learning process, encouraging them to think for themselves on the use of science in their daily lives. Furthermore,

> This motivates the students and foster positive attitudes towards scientific subjects. Finally, this guidance helps students to develop more appropriate ideas about scientific knowledge, as something closer, applicable to their reality. This dimension is fundamentally rooted in the metacognitive potential of this type of activity (CAMPANARIO, 2000, p. 372).

To further develop the components already identified in the reflection dialogues, the course proceeded to the **monitoring dialogues**. Here, it was sought to discuss which metacognitive experiences teachers suggest to provide new solutions (or proposals) for working with research-based teaching.

These dialogues started shortly after the researcher and the teachers debated on some theoretical-practical concepts of research-based teaching. The works by Carvalho (2013) and Carvalho (2018), in which they explore notions of degrees of freedom and problem development, were major references. For the author, “these two concepts are essential for teachers to create conditions in class for students to interact with the material and build their knowledge through research-based scenarios” (CARVALHO, 2018, p. 767).

In addition, during the mutual exchange, the researcher directed the conversation in order to address how investigative cases fit into research-based teaching. This subject would be further addressed in subsequent meetings. This dialogue sought to encourage teachers to correlate those activities previously mentioned (already conducted by them in class) with the concepts of research-based teaching, discussed in this meeting:

> RESEARCHER: Now we are going to enter the monitoring dialogues. Here is our prompting: Analyze the investigative activities you mentioned at the beginning of the reflection stage, the ones you carried out in the class. Think about it, you described some of the investigative activities you have conducted, as we discussed some points about research-based teaching. Having said all that, how do you analyze what you have already done? How do you analyze it, considering a structure based on thinking, speaking, reading and writing? How do you analyze it in terms of intellectual freedom? How do you analyze in terms of development, what did you do?

The search for this correlation intends to promote the transition between external and internal controls found in the teachers' educational process. That is to say, to understand the way in which they have been fostering the learning process among the students, while exercising self-management, monitoring their

actions, aiming to reflect on them and apply possible changes. In Teacher 1's response, there is an emphasis on the concept of different degrees of intellectual freedom given to students when working with research-based teaching. They explain that their activities mostly allow the 1st and 2nd degree:

> TEACHER 1: **So, I'd say they have a level 1 or 2 of freedom**. I think it's already quite freeing, at most a 2. There are students who already earned a 3. Sometimes I just intervene to avoid accidents, because I might be worried. So there are some who earn a 3, but most are still at a 1. **We try to work consistently at a level 2, leaving that 1st degree, and projecting a possible 3rd**.

At the meeting, it was stressed that all these levels, 1, 2 and 3, already constitute freedom for research-based teaching, but that this freedom gradually increases from level 1 to 3. According to Carvalho (2018, p. 767), the higher the intellectual freedom, the more students "will have the courage to expose their thoughts, reasoning and arguments".

It is observed, from this excerpt, that the teacher is able to recognize the degree of freedom allowed to students during their activities, while also attempting to grant them greater levels. This reveals the creation of a metacognitive experience, because it is leading the teacher to establish new goals and review old ones.

This ME involves an estimate of effort on the part of the teacher, who aims to be able to allow a 02nd or 03rd degree of freedom in future activities. In addition, it also invokes a metacognitive evaluation process, because upon recognizing their own didactic status, this turns into a feedback exercise, with a view to modifying actions/strategies, in line with what has been found by Ladino and Továr-Galvez (2005).

For Teacher 2, there's a commitment to establish a structure that allows the conditions for students to be able to think, speak, read and write, as described by Carvalho (2013):

> TEACHER 2: I brought a circuit for them to figure out in class, and just let them try to think about it, to analyze the problems I presented. They reflected, analyzed everything, and proposed their own answers, as I questioned them: if the voltage reached a certain level, would lamp be brighter? If the lamp were to overload, what could happen? So I was trying to suggest different scenarios for them to answer me based on their knowledge, and only that, not on formulas.

The monitoring dialogues made Teacher 2 remember a problem that gave students the possibility to think and analyze first, and then create hypotheses that could be stated or written. From this, the questions made by the Teacher 2 aimed to critically interpret and review what the students were doing, fostering their cognitive aspects in order to monitor the whole process.

The activity developed in class constitutes a prediction-observation-explanation process, as pointed out by Campanario (2000). In this case, the author argues that these activities mobilize students and make them aware that learning sciences requires abstraction efforts.

It is noted that, at this point, the teacher started to reflect on the structured process of thinking, speaking, reading and writing about the subject, and correlates it with a certain activity conducted by them, involving an electrical circuit, which is not the same as they had mentioned in the reflection dialogues. For Efklides (2009), this is characterized as ME of episodic memory judgments, specifically in view of the Know/Remember/Guess triad.

Teacher 3, on the other hand, identified similarities between what they have done in class and the theoretical basis detailed in this course, only with certain caveats, in didactic-structural terms. Additionally, it was also pointed out that the syllabus must be taught following a "think-speak-read-write structure":

> TEACHER 3: Look, I'd say I'm a little bit surprised with everything we have been discussing, because that's more or less what we have been doing, it's just not in such a structured way. I can see some of this investigative approach in our activities in class. Not as organized, but I can see these steps, I can see certain traces in what they do, I can distinguish some of these results. With some structure, following this line you brought up, I think we could achieve better, greater results. Now I'm really considering to radically change some things in class next year, in my working methods... I don't want anyone to become a chemist, but I want those kids to think, to analyze things, to be responsible for their decisions, in such a way that these decisions lead them to expand their knowledge... I'm really considering how I could apply all that to my work methodology next year.

When the teacher says **"...I can see some of this investigative approach in our activities in class"**, they are identifying their own knowledge. This type of self-management comprises metacognitive experiences, described as elements of metacognitive knowledge that have entered their consciousness. This is a step towards articulating new ways to work in the classroom.

At the same time, when they say that **"...I'm really considering how I could apply all that to my work methodology next year"**, these metacognitive experiences are affecting their metacognitive knowledge base, allowing it to be reviewed and built upon. In this way, this can be understood as a feeling of familiarity, which is classified as ME of metacognitive feelings (EFKLIDES, 2009) and stresses the search for solutions for new activities to be carried out.

This whole process of regulation and affectivity favors the articulation of new paths to be taken in their teaching practice, reinforcing the directing of didactic actions towards a better learning experience to students. Results described by Tovar-Gálvez (2008) show that applying the principles of metacognition enables this connection between students' cognitive aspects and didactic actions.

After defining these correlations between what the teachers have been doing with the ideas discussed at the meeting, the researcher asked them about possible changes in their teaching practices:

> RESEARCHER: So, look at that. You have just analyzed the activities you have conducted, so now I have to add: Would you change anything about what you have been doing, or what you did, considering what we discussed today? If so, what are the new strategies to be adopted? And if you don't think you would change anything, why not?

This provocation is intended to elicit metacognitive experiences in the face of the cognitive development established throughout the meeting, i.e., to enable the outlining of the subject's cognitive process when faced with tasks, processing the information related to them. For Efklides (2009), this prompting may be classified as an estimate of correction of different solutions, seeking to reinforce the interface between person and task.

All changes pointed out by the teachers concern the degree of intellectual freedom given to students when working with research-based teaching. For them, the metacognitive estimate is to reach level 3:

> TEACHER 1: I would like to work at level 3. To just go to my students and say: "ok, guys, go ahead and research whatever you're interested in". I mean, I'd like to give them this 03rd degree of freedom from the start, just to see what some students would come up with, and to inspire others. But, to this day, I never entered the class and told them "What would you like to research? Let's research it and discuss all these matters that you mentioned. I would like them to reach this level. I am working, more or less, between the 01st and 02nd degree, and this 03rd degree is my ideal goal.

> TEACHER 2: **I would like to change by letting the students work closer to level 2 or 3.** I've been holding them back at level 1, slowly approaching 2. But I think I've just managed to come up with some strategies to increase their degree of freedom.

These results are close to what Flavell (1979, p. 908) stated about metacognitive experiences:

> These are especially likely to occur in situations that stimulate a lot of careful, highly conscious thinking: in a job or school task that expressly demands that kind of thinking; in novel roles or situations, where every major step you take requires planning beforehand and evaluation afterwards; where decisions and actions are at once weighty and risky.

This means that, as much as the teachers want to change the degree of freedom given to students, this progress provides many opportunities to think and reflect on their own knowledge. Therefore, there is a need for quality control, which metacognitive experiences can help provide.

These results are examples of metacognitive feelings, which combine a sense of knowledge (appropriate during the meeting) and difficulty (upon rejecting well-known, well-structured didactic modules), but, at the same time, there is also a sense of satisfaction (by giving students more autonomy and freedom to learn). This is in line with the notion of metacognitive thinking, described in the works of Rosa and Alves Filho (2012), according to which teachers must reckon and promote the proper orientation to their students, in view of the tasks to be carried out in the didactic scenarios they may present.

To complement the previous questioning, the researcher then directed the monitoring dialogue to another concept relevant to research-based teaching, the elaboration of activities:

> RESEARCHER: And what about the way you elaborate activities, what do you think? Would you change anything?

> TEACHER 1: In regard to class activities, I would try to move away from pre-defined procedures.
>
> RESEARCHER: Would you prefer to bring up a problem and let the students propose ways to address it?
>
> TEACHER 1: But I can tell that not all students can keep up. I still would try to instigate them, bringing problems, but not a script. **They could develop their own script.**
>
> TEACHER 3: In our oil-recycling project, students were not just given a sheet of paper. They were given a bowl full of water, where they poured the oil, preferably used oil, to make it all really complicated, and then they had to really think it through before coming up with a solution. So, what did I do? I tried to approach it as a mystery, how should we address this? I don't know, let's see. They had space to breath. Only after that, I could interfere, once they had done their part, and their curiosity was aroused. A group of students tried to use a vacuum cleaner, and I didn't say anything at first. But how could we apply this to a whole river, man? Meanwhile, others came up with much simpler solutions, but there is also that one student who does not even want to be there, there's always that unruly student who has no solution to offer.

It is noticeable that Teacher 3 already elaborates their activities without a pre-written script, and likes to explore the creation of problems, unlike Teacher 1. However, their statements converge in the sense that some students cannot follow the activities without well-defined guidelines on what to do.

In general, problems provide students with “conditions to solve and explain the phenomena presented to them”; “Conditions for the hypotheses brought up by the students themselves to be used in order to determine all concerned variables”; and “conditions for students to relate what they have learned to the world in which they live” (CARVALHO, 2018, p. 772). However, not all students are used to this, given how this type of proposition is not frequent in class.

Therefore, realizing the difficulties that students may face when carrying out different activities with less guidance, without a pre-defined script, for instance, is a metacognitive experience that evokes both cognitive and metacognitive elements. There are cognitive factors because teachers already know the obstacles that may arise, and metacognitive aspects because they are quite aware of this and intend to change their practices to assist students adjust to these research activities.

What we have here is a ME arising from a judgment of learning, in view of prior activities carried out by the teachers themselves. Additionally, there are specific knowledge-based tasks, aiming to clarify all matters discussed at the meeting and allow them to be aware of how to approach these situations.

According to the results of Paris, Lipson and Wixson (1983), this metacognitive dimension fits into the declarative, procedural and conditional knowledge triad. This is because teachers know causing factors (declarative knowledge), they know how to propose changes (procedural knowledge) and when these will be more effective in class (conditional knowledge). Meanwhile, in the results of Rosa and Vilagrá (2018), this triad involves all the didactic operationalization of which one can become aware when addressing metacognitive aspects.

CONCLUSIONS

Working with continuing education for teachers, under a metacognitive perspective, proved to be a promising choice. Firstly, because it makes those teachers more comfortable to report their expertise and teaching practices. Second, because it allows each one to personally reflect on what they are doing and how they could improve, without someone telling them what to do.

Regarding this second point, it should be noted that teachers have the metacognitive knowledge necessary to develop more research-based teaching activities (as they already do), with greater emphasis on providing the students with more autonomy, the freedom to act, propose solutions, build up arguments for their decisions, and solve problems. However, restricted experiments are still prominent.

In terms of metacognitive experiences, there is a wide variety of possibilities. From assessments (judgments) and projections (estimates) to achieve new didactic and learning goals, to different ways of activating cognitive and metacognitive knowledge and feelings. With regard to research-based teaching, teachers mainly emphasize their desire to increase the degree of freedom given to students in class (without scripts or pre-defined procedures), promoting activities for them to think, speak, read and write more.

Therefore, we understand that applying metacognitive approaches to continuing education and initial training allows, at first, the recording of well-established metacognitive knowledge; then, a proper reflection on the matter, with a view to planning new metacognitive experiences to be added to this metacognitive knowledge, expanding and improving it.

Future developments of this course will comprise debates on different methodologies for a research-based, investigative approach, initiated by both the researcher and the teachers, so that the proper metacognitive reflection may be applied to outline their knowledge and deepen their metacognitive experiences. It is noteworthy that this type of course may become recurrent, even in the scope of higher education, in order to encourage more discussions about teacher training.

Conhecimentos e experiências metacognitivas de professores de química sobre ensino por investigação: um foco na formação continuada

RESUMO

Percebe-se uma orientação ampla no ensino de Ciências de que a formação continuada deve focar nos anseios dos professores. Para isso, um dos caminhos é adotar uma perspectiva metacognitiva para possibilitar uma maior reflexão, criação de significados, reavaliação e redirecionamentos. Atendendo a esse panorama, o objetivo deste trabalho é apresentar uma discussão sobre quais os conhecimentos metacognitivos que professores possuem sobre o ensino por investigação e que experiências metacognitivas podem ser pensadas por eles para desenvolver um ensino (mais) investigativo em suas aulas. Assumindo essa tese e apoiando-se nos mecanismos da pesquisa-ação, foi realizado um curso de formação para professores em exercício entre os meses de agosto e dezembro de 2019 com a participação de seis professores de Química que lecionam no ensino público e integral do estado de Sergipe. Os resultados, obtidos a partir da gravação em áudio de uma primeira fase do curso, destacaram que os professores possuem conhecimentos metacognitivos adequados sobre o ensino por investigação, como dar maior autonomia para os estudantes para elaborar argumentos, propor soluções, tomar decisões e resolver problemas. Os debates no curso permitiram uma ampliação desses conhecimentos a partir de propostas que incluem diferentes tipos de experiências metacognitivas. Portanto, entende-se que assumir abordagens metacognitivas para formação continuada e também para a formação inicial possibilita: primeiramente o monitoramento dos conhecimentos metacognitivos já apropriados; e em seguida, a reflexão deles para o planejamento de novas experiências metacognitivas que serão adicionadas aos conhecimentos metacognitivos, ampliando-os e melhorando-os.

PALAVRAS-CHAVE: Formação continuada. Metacognição. Conhecimentos metacognitivos. Experiências metacognitivas.

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