Information and communication technology (ICT) as a metacognitive strategy for reconstructing science concepts

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Abstract: It is essential to consider different strategies to help students rebuild chemical concepts in the classroom. This research was done with undergraduates from a public university in São Paulo (Brazil), in which google forms - an ICT tool - was used to mediate the interaction between students and teacher. The objective of the class was to externalize the students' previous knowledge about the subject of heat and energy that would be the basis for the continuation of studies in thermochemistry. Based on an article evidencing alternative conceptions of these concepts, three questions were elaborated in which the students had to answer before the beginning of the lesson. During the class, the teacher was projecting the results, which were automatically expressed in graphs and thus the discussions surrounding the questions were being processed, enabling the deconstruction and reconstruction of previous ideas and the correct construction of scientific concepts. The results indicate that the metacognitive strategy using ICT was efficient, since the students could externalize and reconstruct their concepts collectively - metacognitive exercise. In addition, the results were positive in terms of behavior, motivation and the acquisition of technological attitudes and skills, since many students were unaware of the tool. Therefore, using metacognitive strategies in the teaching of science is recommended, as it allows the possibility to reconstruct scientific concepts, and the use of ICT can be a facilitator to know students' previous conceptions and to bring them to light for collective discussion.

Keywords: chemistry education, higher education, ICT, metacognition, metacognitive strategy

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1 Introduction

Currently, information and communication technology (ICT) is fundamental in supporting teaching and learning of Chemistry (Pernaa, 2016), being the computer its most important tool (Martinho & Pombo, 2009). The use of animations, simulations, videos or other technological tools has become an important element in learning chemistry (Pekdag, 2010). Specifically with respect to the cell phone, people have incorporated its use into their routines and this could be a possibility of using this fact to enhance students' learning. Aina (2013) has pointed out that science education aims to teach scientific concepts from alternative conceptions brought and demonstrated by students. This is due to the fact that the students arrive in the classrooms with previous knowledge or beliefs about the contents to be developed (Duit & Treagust, 2003). With respect to this, in a reflection on conceptual change, Duit and Treagust (2003) have revealed the importance of teachers improving their teaching, incorporating strategies that facilitate students' learning in their routines. Thus, these alternative conceptions about scientific concepts need to be externalized and reconstructed, in some cases, even deconstructed for later construction.

In this sense, the proposal of this research was to use the ICT allied to a metacognitive strategy that allowed this reconstruction of scientific concepts, specifically, those related to the beginning of the study in thermochemistry - energy and heat - as well as its transfer between bodies. Through metacognition, concepts could be reconstructed, where the individual will have the chance to monitor and self-regulate his or her cognitive process (Flavell, 1976).

2 Theoretical background

ICT – Information, communication and technology

According to Freitas and Chassot (2016), ICTs can be understood as "a set of technological resources, used in an integrated way, with a common goal". Some authors associate the term affordances that ICT can provide. Webb (2005) has analyzed several works on the relation between the use of the ICT and the learning of sciences and listed four of these opportunities:

> The affordances that I have identified support learning through four main effects: promoting cognitive acceleration; enabling a wider range of experience so that students can relate science to their own and other real-world experiences; increasing students' self-management; and facilitating data collection and presentation (p.705).

In this present study, there is a special interest in the last two, since the use of ICT can be structured in a metacognitive strategy, helping the student to self-regulate and improve their understanding of scientific concepts.

Pernaa (2016) has added two more possibilities that are directly related to this study, which are “ICT creates new opportunities in carrying out social interaction” and “ICT releases teaching and learning from time and place, if necessary” (Pernaa, 2016, p.1). The first possibility becomes especially interesting in the context in which this research was carried out. It was a large group (99 students), causing a limitation in the interaction of the teacher with the students, and the use of the ICT could help, facilitating this social interaction. The second possibility may allow the student to be involved with the topics covered in the discipline for a longer time, not limited to the classroom, which is also highly desirable.

However, there are barriers to be overcome and faced by educators. Barak (2007) analyzed ten university chemistry professors concerning the application of ICT in the classroom and revealed that they showed negative feelings regarding this use, being the main obstacles the lack of knowledge in using the resource and the absence itself of resources.

Juuti et al. (2009) has analyzed the use of three forms of communication related to the use of ICT in science teaching: "face-to-face interaction, mediated interaction, and mediated quasi-interaction" (p.103). The first one seemed to be more effective and was the strategy used in this work, since the students had to answer the questions in the classroom and the subject was taken up by the teacher through the students' own answers. Likewise Barak (2007), Juuti et al. (2009) has added some more problems related to the use of ICT in the classroom: the lack of time for teachers to learn new technologies; the possible need to go to another room to teach in this perspective; and "teachers' technophobic attitudes about ICT in Science teaching" (Juuti et al., 2009, p.104).

As a form of interaction between teachers and students, Aina (2013) has suggested that questions could be addressed to the students with feedback from the teacher, who could ask further questions from the answers given. As google forms were used in this research, it was possible to follow this recommendation, since as the students were responding, moments later we had the collective answers of all the students of the room and this data was designed to be discussed with them. Regarding chemistry teaching and periodicity, Pekdag (2010) has believed that incorporating the technological tool into the classroom is not only important, but should be done in the long term, as the learning benefits could be greater for students. Thus, changes in the curriculum could be incorporated for this purpose.

Metacognition and metacognitive strategies

Although metacognitive processes are quite old, the term metacognition arose in the mid-1970s with psychologist John Flavell. Despite the lack of consensus on the definition of metacognition in teaching, the definition proposed by Flavell (1976) still seems quite adequate for this purpose with some additions. Metacognition refers to one's knowledge concerning one's own cognitive process and products or anything related to them…" (Flavell, 1976, p.232). Later, in the same page of the text, he brings more two words: regulation and monitoring. Girash (2014) has also considered metacognitive knowledge in terms of stability and levels of consciousness. To sum up, metacognition refers to the ability to think about your own thinking, monitoring, managing and regulating the learning process as being conscious aware about the cognitive process.

Littrell-Baez and Caccamise (2017) has recommended some metacognitive activities that can assist in the construction and understanding of concepts in chemistry. They have indicated that in order to succeed in learning chemistry, students need to have the ability to assess and manage their own learning as they will confront information in many different ways, for example "text, class presentations, hands-on projects, and visual representations "(Littrell-Baez & Caccamise, 2017, p.31).

Although metacognitive approaches have proven to be efficient in the classroom, it is important to realize that the most benefited students are those who already have some metacognitive knowledge (Zohar & Barzilai, 2013). This has reinforced the idea that metacognitive strategies in the classroom should be implemented in the long term (Pekdag, 2010), so that all or most students have the possibility to develop this metacognitive skills. In order for students to become lifelong learners, then it becomes necessary for university professors to offer suitable conditions for such. The development of metacognitive skills in students has had the potential to make learning more efficient and effective, so the strategies chosen for teaching in the classroom should be intentionally metacognitive (Rao, Tarr & Varma-Nelson, 2017).

The individuals involved in this activity are entering the university and, thus, investing in the development of metacognitive autonomy of these students becomes an objective in the teaching-learning process. Locatelli and Alves (2018, p.80) have pointed out that "Although it is desirable that students enter higher education with a high degree of autonomy in the conduct of their studies, this does not always happen properly, and several factors contribute to this problem." The authors have suggested the use of portfolios as a metacognitive tool to help in the development of this metacognitive autonomy. Students need to be aware of their cognitive and metacognitive processes, as well as being able to rethink their concepts before, during and after school. Spaces are necessary for this to occur, specifically, during the cognitive process. Flavell (1979) has drawn attention to the metacognitive experiences that essentially occur during the process, such as the feeling that one does not understand the lesson or some concept developed in it, which is very important because the student can identify the your problems. In this way, it is assumed that school student's alternative conceptions can be retaken, re-thought and properly resignified during the learning process. Therefore, the use of a metacognitive strategy associated to ICT is a great option for the learning of these students.

3 Research question

Considering the importance of ICTs in chemistry teaching, as well as the regulatory processes of metacognition, this paper aimed to answer the following guiding question about ICTs: Is it possible to construct and reconstruct basic ideas about heat and energy using a metacognitive strategy involving ICTs?

4 Methodology

Context of the study

During the course of a discipline of General Chemistry given at the Federal University of ABC (Brazil), 67 undergraduate students participated in the research of a total of 99. In this discipline are given general chemistry contents, such as: chemical phenomena, balancing of equations, stoichiometry, thermochemistry, kinetics and chemical equilibrium. The average age of the students is 19 years, being that they are in the beginning of the graduation course. The classroom was equipped with slide projects, computer and internet access. The students used their own mobile devices and the local Internet, and this is in line with what Savec (2017, p.19) has recommended regarding the use of ICTs: “Continuous care for the availability of up-to-date ICT devices in science classrooms, including possibilities for the use of students’ own devices”. This is indicated, since students have commonly used the cell phone for various personal activities, so integrating this use with an educational process can be seen as very productive. For the activity, they were asked to answer previously three questions related to the concept of heat and energy, made available through google forms. This is an online form, where the student can respond at any time he has available, in this case the proposal was that they had to respond at the beginning of the lesson. The goal was to identify their previous ideas to rethink and reconstruct them during the lesson.

Activity

Previously to the class, the students had to answer three basic questions related to the concept of heat, made available through google forms (table 1). Guidance was given that they should not consult any supplementary material.

Table 1. Questionnaire to be answered.

	Question	Alternatives
1. Heat	Heat (you can check more than one option)	a) is a substance. b) can be of two types: hot and cold. c) it is a form of energy. d) is directly proportional to the temperature.
2. Energy	Energy flows from body A to body B. Then:	a) A is at a higher temperature than B. b) A has more heat than B. c) The temperature of A and B can be the same.
3. System	One beaker and a test tube contain water in the liquid state (figure 1). As the system warms up, the water inside the beaker will boil. The water in the test tube:	a) will not boil. b) will boil at the same time as the water of the beaker c) will boil some time later.

For question 3, also was given the figure 1 that illustrates the phenomenon described:

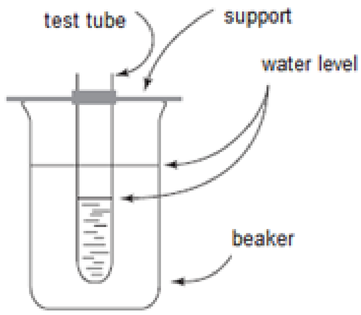

Figure 1. System containing water. Adapted from Mortimer & Amaral (1998, p.34)

Mortimer & Amaral (1998) has discussed students' conceptions of basic concepts related to heat and temperature, which are fundamental for moving to other topics in thermochemistry. Some points were chosen to be discussed in this work, and the questions that are in table 1 were proposed from the reading of the article (Mortimer & Amaral, 1998). The goal was to identify their previous ideas to rethink and reconstruct them during the lesson. After all students replied the questions, the teacher projected their answers by means of a projector. With this it was possible to visualize their responses (in percentage), but anonymously, question per question. The students were surprised by the results expressed by them. At this stage, students had the task of comparing his or her individual response with their colleagues and rethinking it - metacognitive stage. Thereafter, the results are presented.

5 Results

After completing google forms, graphs were generated automatically with the results expressed by the students. Some have been reshaped in this article for better visualization.

Question 1: Heat

The results on question 1 are expressed in figure 2, where the questions are set out in table 1:

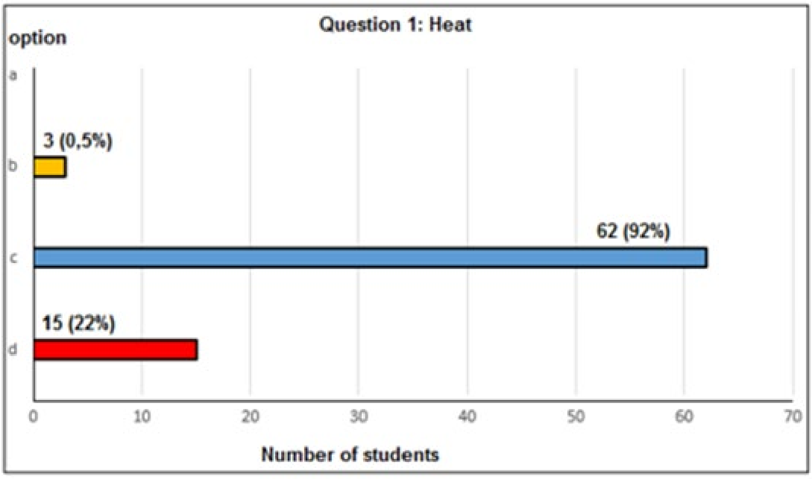

Figure 2. Student responses about question 1.

The percentages add up to more than 100, since students could point to more than one alternative. The only correct and expected option for students to respond was (c), which was pointed out by most of them, 92%, in which heat is conceived as a form of energy. The other options (a), (b) and (d) were alternative conceptions, conceptually incorrect and needed to be retaken if they were demonstrated by students. No student pointed to alternative (a), which brought heat as a substance. Regarding option (b), only 3 students (0.5%) pointed out and believed that there were two types of heat: hot and cold. Finally, 22% of students believed that heat was directly proportional to temperature.

Question 2: Energy

Concerning question 2, the data are expressed in figure 3:

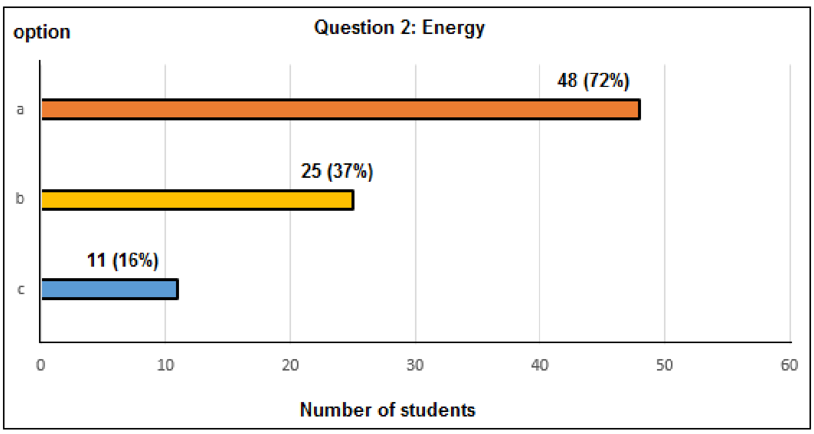

Figure 3. Student responses about question 2.

The only correct alternative was (a) where the heat flows from the body, which is at a higher temperature for the body, which is at a lower temperature. The correct choice was noted by 72% of the students. Once again, alternatives (b) and (c) were alternative conceptions often demonstrated by students, where in this research options were indicated by 37% and 16% respectively, indicating that these concepts needed to be retaken. The alternative (b) was to consider that a body can have heat, showing a confusion of the concepts of energy and heat, and finally, the student who indicated alternative (c) did not consider that there should be a temperature difference between two bodies, so that the heat flows from the body, which presents greater to the lesser heat.

Question 3: System

In figure 4, the data for question 3:

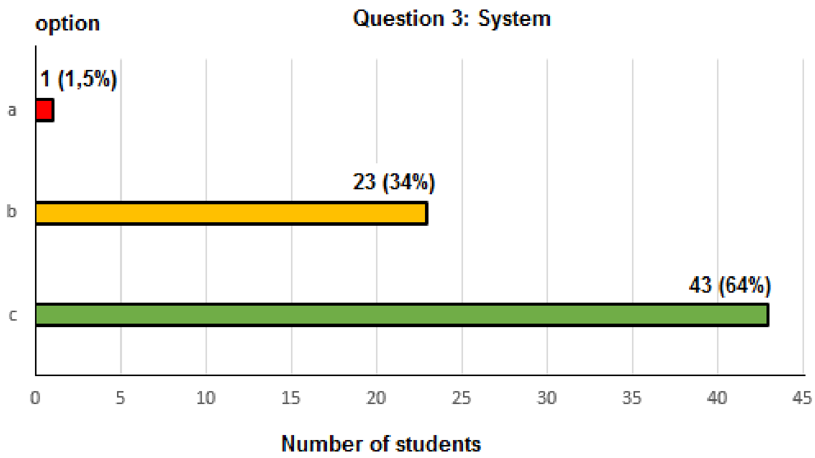

Figure 4. Answers from students about question 3.

Only one student indicated the correct alternative (a) and all others were surprised by the correct answer. The other students concluded that the water from the test tube would also boil, however 34% thought it would be at the same time as the water of the beaker and 64% concluded that it would be after some time. The teacher was conducting the class, dialoguing with the students to understand the scientific concepts involved.

6 Analysis of results and discussion

The objective of the metacognitive strategy using ICT was to promote the deconstruction and reconstruction of alternative conceptions for the correct construction of scientific concepts related to the concepts of heat and energy. In this sense, with respect to the three questions proposed, the alternative conceptions were demonstrated in all cases, varying the level and depth in which this occurred.

With respect to question 1, the conceptualization of what is heat is resumed. An important concept for understanding thermochemistry, a subject that would be dealt with later in this introductory class. Mortimer and Amaral (1998) have researched the literature and summarized the main alternative conceptions about heat demonstrated by students: “heat is a substance; there are two types of heat: the hot and the cold and the heat is directly proportional to the temperature "(p.31). Most of the students did not demonstrate any of these conceptions, however 22% of them believed that the heat was directly proportional to the temperature. Mortimer and Amaral (1998) have credited this way of thinking, since students refer to their daily life, in which expressions such as "it is very hot" in which people refer to a place where the temperature is high. This differs from the scientific concept, because the student comes to believe that heat and temperature have the same meaning.

Question 2 was about the flow and concept of energy and heat. Mortimer and Amaral (1998) have conceptualized temperature as a property of the system whose function is to indicate the direction of the energy flow. In the case of the question, the energy (heat) will flow from the body, which is at a higher temperature to the body of lower temperature. In the case of the 16% of students who indicated alternative (c) as correct, this did not seem to be clear to them. Finally, 37% of them confused the concepts of heat and energy, as they pointed to alternative (b), considering heat as an attribute of the substance, Mortimer and Amaral (1998) have attributed this idea because the student may consider that the body may contain heat or cold, which is scientifically incorrect and needs to be resumed.

Finally, question 3 was the most difficult for the students, evidencing deficiencies in the understanding of some concepts related to heat transfer and to the physical transformation involved. With the exception of one student, the other ones thought that the water in the test tube would also boil, and the question would be just how long it might take. Mortimer and Amaral (1998) have proposed this experiment with the objective that the student perceive that in order to have heat transfer, a temperature difference between the systems is required. The systems (water in the beaker and water in the test tube) reach the same temperature. In this way, there is no heat transfer to the system (water and test tube) to break up the hydrogen bonds between the water molecules, so the water does not boil inside the test tube (Mortimer & Amaral, 1998). For students to understand better, it is important to relate this fact to everyday examples, such as to make a condensed milk pudding, the water bath is used, precisely not to burn the pudding mass.

The use of "google forms" - an ICT tool - played a very important role in the possible reconstruction of scientific concepts, since the results referring to the questions answered by them (figures 2, 3 and 4) were designed and the concepts were discussed with the students and with the teacher's mediation, enabled the metacognitive exercise with the re-signification of the concepts. The discussion was intense, with several questions from students about the subject. The tool consisted of a monitoring and self-regulation instrument (Flavell, 1976), in which the students could perceive that the concept demonstrated by them had scientific inconsistency and the consequent regulation of this. This also develops in students the aspect related to awareness (Girash, 2014), emphasizing here that it is a long-term process, this activity being one among several for the student to develop their metacognitive autonomy, in which they can monitor themselves, self-regulate, once he or she is aware of these cognitive and metacognitive processes.The mediating and regulatory role played by the teacher was fundamental for the systematization of the concepts, especially in the third question that was considered a challenge by the students.

7 Conclusions

Returning to the guiding question of this research: Is it possible to construct and reconstruct basic ideas about heat, using a metacognitive strategy involving ICTs?

The students begin their studies in higher education with many alternative conceptions about science as the results demonstrated, and thus, university professors must propose dynamic classes that can make possible the exteriorization of them for later reconstruction towards the scientific concept with the mediation of these educators. This is because alternative conceptions could be summarized and renegotiated collectively with the class, in an intense metacognitive exercise, which was actively observed in this research.

On the other hand, the observations and results were positive in terms of behavior, motivation, use and acquisition of technological and attitudinal competences. Therefore, using metacognitive strategies in the teaching of science is recommended, as it allows the possibility to reconstruct scientific concepts and still the development of a metacognitive autonomy. Finally, the use of ICT can be a facilitator to know students' prior knowledge bringing them to light for collective discussion, and the use of the students' cell phones for pedagogical purposes was efficient.

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