METAVISUAL STRATEGY ASSISTING THE LEARNING OF INITIAL CONCEPTS OF ELECTROCHEMISTRY

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Abstract

This paper reports a metavisual strategy proposed for 11 high school students. The investigation consisted of ascertaining to what extent the metavisual strategy can be effective in rebuilding their previous ideas. The investigated topic consists in understanding concepts in electrochemistry involved in the initial interaction of copper (II) ions with iron atoms. For this activity was proposed to students to draw the microscopic representation of this chemical interaction and then compare their drawing with a representation presented in the study. This activity was videotaped; data were collected from their statements and transcribed for subsequent analysis. The findings seem to show that the metavisual strategy may enable the reconstruction of ideas by students, leading them to a better understanding of the phenomenon studied and could contribute towards improving learning in electrochemistry.
Key words: *electrochemistry, chemistry teaching, metacognition, metavisualization, metavisual strategy, teaching strategy.*

Introduction

Nowadays it is essential that the learner develop means that will allow the construction and reconstruction of their learning. In this work, starting point was the student's previous ideas with respect to initial concepts of electrochemistry, because studies indicate great difficulty in learning of this content in general. (Obomanu & Onuoha, 2012; Rosenthal & Sanger, 2012; Schmidt, Marohn & Harrison, 2007; Huddle & White, 2000). Huddle and White (2000) would even claim that the electrochemical, along with the concepts of mole, stoichiometry and chemical equilibrium, seem to be the most difficult of comprehension by the students, because these concepts are very abstract and new terms are still required for the student. Obomanu and Onuoha (2012) validated an instrument to identify these conceptual problems in electrochemistry. According to their findings, the students had difficulties in 84% of the test performed, showing great difficulty in understanding electrochemistry. One of the conclusions is that the electrode half-reactions seem to be the least understood and poorly generalized by 50% of students. From among various aspects mentioned by Schmidt, Marohn and Harrison (2007) and Huddle and White (2000), a misconception that electrons migrate through the solutions from one electrode to another. Additionally, the study by Rosenthal and Sanger (2012) was done with a group of 55 students, about the interaction between a solution of silver nitrate and copper metal using computer animations. Likewise, to other authors, the study also points toward learning difficulties in this topic. The students' task was to interpret and explain the animations that they were seeing about this interaction. Results indicated numerous misconceptions, the main ones being: confusion in the representations of water molecules and nitrate, the disappearance of the charges of the ions in solution, being neutral, the incorrect indication of the charges of the ions, incorrect proportion of copper that reacts and proportion nitrate/silver ions, not recognizing that the transfer of electrons changes the charge and size of the atoms or ions, not clarifying the explanation of the appearance of blue color and conflating the macroscopic properties of the particles and the chemical reaction. (Rosenthal & Sanger, 2012). Rahayu et al (2011) identified the key factor that hampers the comprehension of electrochemistry, as the understanding of how the interactions are processed at the microscopic level. Farther concluded that students analyzed had very poor knowledge in electrochemistry. Therefore, in this scenario the article aims to contribute to the improvement of education in electrochemistry, with the focus on the microscope, although it is important to understand the chemistry in the three representational levels – macroscopic, microscopic and symbolic – Santos and Arroio (2012) also required greater attention to microscopic, precisely because this is the most difficult for students. In this study, an activity was proposed to students for research purposes, in order to observe the interaction of prior knowledge with scientific knowledge presented and check, whether the student identifies similarities and differences between them and so, they change or not change their preconceptions. According to Mortimer (1996), there is now a belief that students' ideas may be transformed into scientific ideas, since a conflict is fostered so that the student may leave part of their ideas or modify them. Thereby, it will enable the occurrence of an evolution in the profile of students' conceptions in the classroom to achieve a scientific idea, and not properly a replacement for ideas (Mortimer, 1996). In this way, for this to occur, metacognition can be an ally to the extent that the student should make an evaluation of their previous ideas and interact with new, leading to a possible reconstruction of them (Mintzes, Wandersee & Novak, 2000). In a survey conducted by Hennesey (1993), she observed a change in the concepts of the propositions of the students in an activity with metacognitive perspective. Also according to the author, the interaction between ideas is necessary because it is not enough teachers show or explain scientific ideas, but may promote a learning environment in which students can realize their ideas and cognitive structures, highlighting the importance of the teacher in this conduct.

Interestingly, this doesn't only happen in learning chemistry, but many studies strongly indicate the importance of metacognition in learning the various areas of knowledge (Feyzioglu & Ergin, 2012; Soliveres et al, 2011, Cooper, Sandi-Urena; & Stevens, 2008, Anderson; Nashon & Thomas, 2007; González & Escudero, 2007; Mintzes, Wandersee & Novak, 2000; Rickey & Stacy, 2000, Locatelli & Arroio, 2013). Since the student can monitor and self-regulate their learning process, he will have autonomy in learning, known as "learning to learn". For this, he needs to have; first, awareness of this process and the teacher will be able to use metacognitive strategies in the classroom, to help him in this task. More specifically, this process while referring to views is called metavisualization (Gilbert, 2005), being very important in the construction and reconstruction of models (Locatelli & Arroio, 2011), especially the study of sciences (Justi, Gilbert & Ferreira, 2009). A student may have an image stored in its memory, and from it, he may, for example, reach a construction best suited for a particular concept. For this, he can retrieve that image, confront each other and rebuild a third (which may be a mixture of the previous two in different proportions, or even may have occurred a conceptual change), but it will happen provided it is meaningful to him. Moreover, that is the purpose for the activity presented to students. From their previous ideas on an initial concept in electrochemistry, the intention is that students do modeling until they reach an adequate conception. According to Aguilar, Maturano and Nunes (2007) working with images will enable answers that reflect the students' ideas more accurately than traditional questionnaires, because the images are facing the phenomenon and its representations directly. Locatelli, Ferreira and Arroio (2010) highlight the importance of visualization in the sense that chemistry is understood through models; thereby students becoming metacognitive regarding visualization is fundamental in the process of acquiring knowledge.

For this purpose, it was proposed in this research, a change in strategy known as POE (predict-observe-explain) that can be considered metacognitive (Rickey & Stacy, 2000; Mintzes, Wandersee & Novak, 2000). This strategy may be used to explore the ideas of students to start a topic, or during this study and finally to increase final understanding (Mintzes, Wandersee & Novak, 2000). It consists of three major stages:

1. Prediction: Given an event, the student will be encouraged to predict what will happen. The following will produce an explanation for your hypothesis based on your previous knowledge about the subject.
2. Observation: In this phase, the student will have the opportunity to observe the phenomenon, that is, what actually occurs.
3. Explanation: In this last phase, the student will have to re-examine their ideas because he will have to reconcile their previous ideas with the observed culminating in accepting the scientific concept, which is the main goal.

   The amendments (4 and 5) occur at this time, the student will confront this explanation (3), with an external visualization, in case a figure that will bring models with scientific concepts more adequately:
4. Metavisual Observation: Students will compare the figure they proposed with the figure presented. Locatelli and Arroio (2013, p. 25) pointed that "the previous ideas can become a facilitator or an epistemological obstacle", so in order to further assist these students were also provided some information about the observed phenomenon to aid students in the reconstruction of their ideas. According to Mortimer (1996), sometimes the student does not rebuild because not enough information for it.
5. Re-explain: Now, from this it will again redraw their ideas.

Following this sequence proposed for the research, the student will work with his dual or trio, later; the matter will be taken up in the classroom with the teacher in order to discuss the ideas that emerged, the divergent points, and the reappointment process. Highlighting what Locatelli and Arroio (2013) identified as important: the mediating position of the teacher in this building.

It is also worth to note that on the topic visualization, which, according Teruya et al (2013) there are more articles with more qualitative than quantitative analysis. However, this latter type of methodology (qualitative) allows a better comprehension to understand how mental models are constructed by the students, which is the case, so the choice of the recording and analysis of the process later.

Purpose of the Study

Investigate to what extent the metavisual strategy may assist students to (re) build correctly the initial concepts in electrochemistry. Comparing their design with presented, they can perceive differences and / or similarities? Why? From this, the extent to which they rebuild? Why?

Methodology of Research

Five groups participated in the activity, divided into four pairs and one trio, being eight girls and three boys (11 students) aged between 16 and 17 years. “A” designated the girls and “B” for the boys:

Table 1. Groups of students and their components.

Groups	Components
1	A1 and A2
2	A3 and A4
3	A5 and A6
4	A7, A8 and B1
5	B2 and B3

It was proposed to carry out an activity in which students, in groups, have begun the construction of the fundamental concepts for learning in electrochemistry. For it meta-visual strategy was used, in which the student suggested a representation in the form of design and confronted with a more adequate scientific representation, as this would enable the thinking and rethinking about its own construction. Students were divided into groups of 2 or 3 components, were filmed doing the activity described in the sequence in which designed and discussed their hypotheses of chemical interaction between steel wool and copper (II) ions. The instruction given was to speak aloud whatever was thinking technique known as think aloud. Subsequently, the film was transcribed for analysis. In addition, the researcher interviewed them to clarify some points of the research.

Description of Proposed Activity for Data Collection

Guideline given to students: when starting the activity, begin filming. Speak aloud everything you are thinking and discussing. No need to write anything, just make the proposed design.

Part 1: Predicting – Note the following materials: an aqueous solution of copper II) sulphatee ($CuSO_4$) and steel wool (Fe):

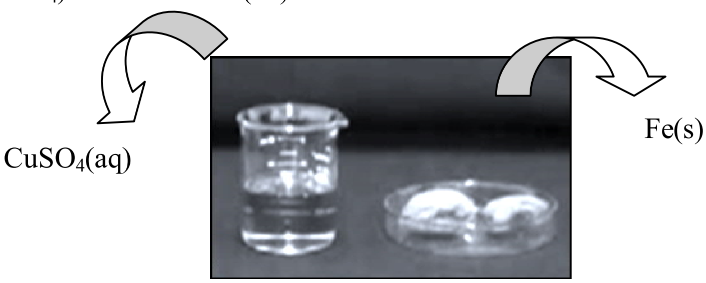


Figure 1: Aqueous solution of copper (II) sulphate and steel wool.

What do you think will happen when the piece of steel wool (Fe) is added to the solution of copper (II) sulphate? Why?

Part 2: Observing – Let's rebuild or deepen your idea. Note the chemical interaction. Freely discuss your impressions.

Part 3: Explaining – Consider the interaction between the metal (Fe) and ion (Cu^{2+}) that you have just observed. The iron (Fe) transfers two electrons to the copper (II) ion (Cu^{2+}). The blue color is given by the copper (II) ions (Cu^{2+}). Using the model of balls, build a better microscopic representation of the beginning of the reaction (reactants) and the final state (products), placing the label.

INITIAL STATE:	**FINAL STATE:**	**LABEL:**

Figure 2: Place of registration of drawings.

Part 4: Metavisual Observation – Below is a possibility representative model of the phenomenon under investigation. Carefully observe the figure and the information for a few minutes and try to think about what you had planned and designed and / or explained.

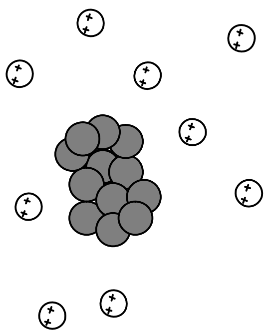
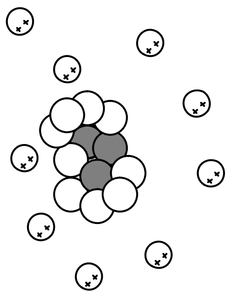
INITIAL STATE:	**FINAL STATE:**	**LABEL:**	
			Cu
			Cu^{2+}
			Fe
			Fe^{2+}

Figure 3: Given representation of the observed interaction.
Note: the water molecules were not represented.

See that each atom of iron (Fe) loses two electrons to an ion (Cu^{2+}) and then occurs the formation of iron (II) ion (Fe^{2+}) and metallic copper (Cu). Have you noticed the size of the particles? The neutral atom loses electrons from the last layer and becomes a cation (positive ion). The cation loses the last layer becoming smaller than the neutral atom:

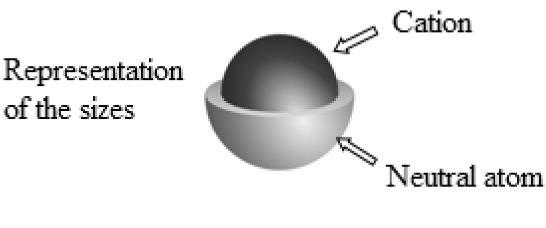


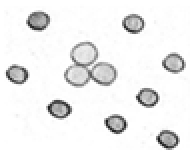
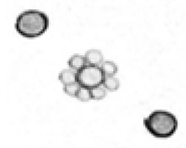
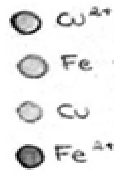
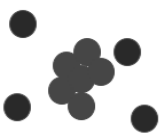
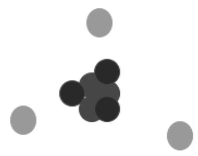
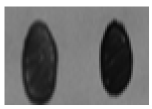
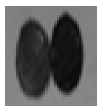
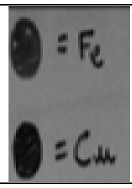
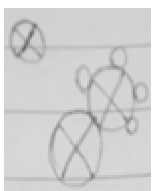
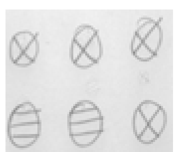
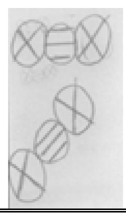
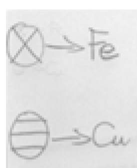
Figure 4: The size of the neutral atom and its corresponding cation.

Part 5: Rebuilding – Now resuming your hypothesis, rethink and discuss freely with your colleague, discussing. Show WITH DETAILS what is different and similar between the explanations, including drawings (what you did and what was presented). What do you conclude? Have you had done properly or not? Try to explain why. Try to find your mistakes, differences, exposing your doubts, explaining.

Results of Research

In the following table, the designs made by the groups were arranged representing the initial states, and the respective end label:

Table 2. Representations proposed by students.

Group (Students)	Drawing		
	Initial State	Final State	Label
1 (A1 and A2)			
2 (A3 and A4)			
3 (A5 and A6)			
4 (B1, A7 and A8)			
5 (B2 and B3)			

Five categories were created (table 3), according to the presenting drawings and speeches of students. This may represent misconceptions exposed by students. The 3rd column (table 3) has been completed in accordance with the perception that the design is suggesting or not students have thought correctly. Already in the 4th column (table 3) is the perception of the students after metavisual exercise. The word yes or partial present in this 4th column indicates that the student was able to reformulate their ideas.

Table 3. Some considerations on the drawings made by the students.

	Group	Column 3 – Does the design of the students suggest that they have managed to think properly? (Beginning)	Column 4 – Perception of the group after comparison with the figure and proposed explanations: Does the evidence suggest that they were able to rebuild? (After)
1. Stoichiometric ratio in the reaction: 1:1	1	No	No
	2	Yes	---
	3	Yes	---
	4	Yes	---
	5	No	**Yes**
2. Different size of atoms and ions.	1	No	**Yes**
	2	No	**Yes**
	3	No	**Yes**
	4	No	No
	5	No	No
3. Difference between an atom and an ion	1	Yes	---
	2	No	**Yes**
	3	No	**Yes**
	4	Yes	---
	5	No	**Yes**
4. Understand the chemical interaction.	1	Yes	---
	2	No	**Yes**
	3	No	**Yes**
	4	No	**Partial** (the student demonstrates to understand that iron undergoes oxidation, but he does not seem to understand very well that copper reduces.)
	5	No	**Partial (**the student understood the oxidation-reduction reaction, but did not consider such a reaction.)
5. In the solid particles are together, the aqueous separated.	1	Yes	---
	2	Yes	---
	3	No	**Yes**
	4	No	**Yes**
	5	No	**Yes**

Based on table 3, the percentage of correct or incorrect assumptions may be expressed, considering the beginning (figure 5) and after the metavisual process (Figure 6):

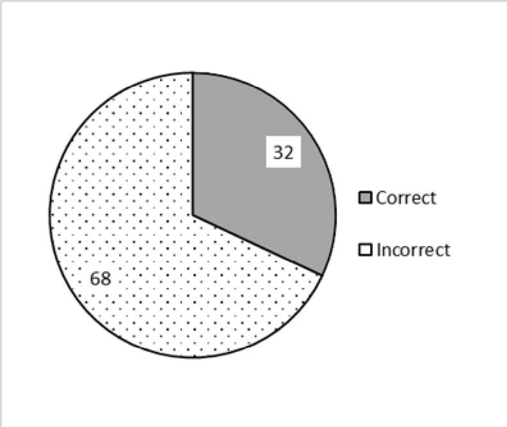


Figure 5: Percentage of correct or incorrect assumptions in the beginning. 3rd column

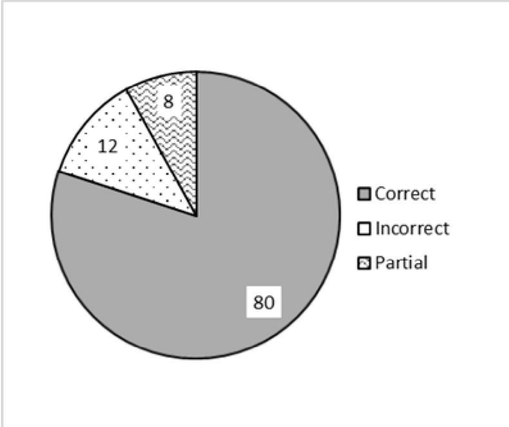


Figure 6: Percentage of correct, partial or incorrect assumptions after the metavisual exercise.

In the interview with the students, all signaled that they confront their drawings with other design scientifically more correct is beneficial. In this way, they might be thinking about what they had produced, helping them find their mistakes, albeit partially:

Group 1: Yeah… the fact that we compare… you know… our hypothesis with a given representation… well… this… helped us better visualize the interaction between the particles…. From this…we could rethink…and so… identify our mistakes and formulate…others conclusions.

Group 4: The exercise helped us... Because we compare right with wrong… Now… we are gonna have the right ideas in mind… be sure!

Discussion

For this group of students was also possible to identify some misconceptions already pointed out by other researchers in their investigations in electrochemistry. Obomanu and Onuoha (2012) and Rosenthal and Sanger (2012) pointed out many difficulties, including, the understanding of this type of interaction (item 4, Table 3). In the beginning, 20% of the groups (1/5) understand the phenomenon, and after metavisual exercise, there was a significant improvement, for only 40% of the groups (2/5) still seemed to demonstrate partial understanding of chemical interaction and still others 60% (3/5) appeared to demonstrate comprehension.

Still signaled by Rosenthal and Sanger (2012) many other difficulties in understanding electrochemical could be verified in this study (items 1, 2 and 3) of Table 3. Lastly, the difficulties highlighted by Rahayu et al (2011) on the microscopic representation, which was the object of study in which students tried through a drawing representing microscopically and showed, at least, all the difficulties researched in this study and presented in Table 3 (items 1-5 in Table 3). The items 1 to 5 of Table 3, 32% (8/25) of the students' responses suggest that perhaps they had already achieved thinking correctly (before), as may be seen in figure 5. After metavisual exercise, this number seems to increase considerably to 88% (22/25) of the students' responses suggest that they were thinking correctly, or at least in parts (figure 6). It seems metavisual exercise may have been a factor that helped students to rebuild their thoughts.

Likewise, seems to give visibility to the process started is still under construction, namely, it is still necessary to improve and rebuild some concepts with the students, since 20% (12% incorrect and 8% partial) still need investment to get a closer scientific concept.

The groups 4 and 5 presented a partial understanding of the final process. Group 4 seems to show understanding that iron oxidation suffered, but did not seem to understand very well that copper reduces, signalling the difficulty in identifying the electron transfer reactions. The group 5, seemed to understand the oxidation and reduction, the electron exchange, but did not consider it as a chemical interaction. By speeches, in both cases, it seems that lacked the theoretical framework to advance this construction. According to Mortimer (1996, p. 24) "often in the process of building a new idea, the lack of information to interpret the results of an experiment is that the biggest obstacle conflict between students' ideas and results." What which again seems to suggest that the process is still under construction.

Concluding the discussion, members of five groups seemed to recognize that metavisual exercise was important because they could, even partially, locate, and correct their errors autonomously. They felt better prepared for collective discussion. According to Santos and Arroio (2012, p. 7) “the utilization of visual tools in teaching chemistry is required to promote visualization capacities and understanding of the representations”.

Conclusions

Returning to the research questions, the results seem to indicate that the metavisual strategy used for this group of students was important in the reconstruction of their ideas, and the number correct answers went up 32% to 88%, which seems to have enabled students to build a concept appropriate. Nevertheless, it was observed that students do not always recognize their errors (total or partial), which happened in 20% of cases (incorrect and partially correct).

There were several factors involved in the realization of the proposed activity in this group of students and that might contribute or not in favour of rebuilding their ideas. Both groups (4 and 5) seem to have realized the conflict, but failed to advance what may be suggestive of a lack of theoretical reference. Students also reported that the proposed design was the most important factor for them to rethink, because when they looked at the drawing, immediately began to rethink their designs and find the errors. It seems to indicate the important role of external visualizations in the teaching of chemistry.

One issue that is worth pointing out was that all students seem to have comprehended, even partially, the observed chemical interaction between copper (II) ions and iron atoms.

Ultimately, the metavisual strategy can be recommended to start the construction of concepts, which can be an important ally mostly in microscopic understanding, it seems to be more difficult for students. Furthermore, one should take into account that the previous ideas that students bring are strong, then beyond the proposal it seems that the role of the teacher as a mediator is crucial, since it enables the modeling may continue in the classroom, in a way shared and collective, until reaching the scientific concept. The research in question, suggests further studies to clarify how students transform their knowledge from external visualizations.

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