SEVEN
publicações acadêmicas

Understanding the concept of density through investigative teaching and representations

Crossref doi
https://doi.org/10.56238/uniknowindevolp-148

Maria Luiza Silva Tupy Botelho
Doctor in Education
Federal University of Minas Gerais
E-mail: marialuiza.botelho@gmail.com

Ana Luiza de Quadros
Postdoctoral Fellowship in Education
Federal University of Minas Gerais
E-mail: aquadros@qui.ufmg.br

Giovana França Carneiro Fernandes
Specialist in Science Teaching by Research
Federal University of Minas Gerais
E-mail: giovanafcf@hotmail.com

Mariana Gonçalves Dias
Degree in Chemistry
Federal University of Minas Gerais
E-mail: marianagoncalves1@live.com

ABSTRACT
Associating teaching assumptions through investigations with the role of representations has been promising in terms of learning. We developed this work with students of the first year of High School with the objective of analyzing the contributions of science teaching by investigation in the involvement of students with the problem issue and with the use of representations as tools that facilitate conceptual understanding. The students were challenged to propose an experiment that would help them solve the problem and to communicate in pairs the path taken and the explanation for the phenomenon present in the experiment. We observed that the students were actively involved in explaining the phenomenon and, for that, they appropriated representations that helped both in organizing their own ideas and in communicating with peers.

Keywords: Science teaching through research, Representations, Density.

1 INTRODUCTION

Constructivist assumptions helped us to understand that transmitting information does not guarantee the understanding of what is being transmitted and that knowledge is more easily constructed by the active participation of students. Although constructivism has generated numerous currents, there are at least two main characteristics that are shared by the different currents and by researchers around Science Teaching: learning takes place through the active involvement of students in the construction of knowledge, and students' previous ideas play an important role in the learning process. The teaching and learning process, from these perspectives, requires activities that challenge students' previous conceptions and are related to their experiences, so that they can use their informal knowledge to interact with scientific knowledge and, from this interaction, build understandings involving the learning object (DRIVER *et al*., 1999).

To enable the process of teaching and learning Science to foster an understanding of the material world and the physical phenomena that occur around us, providing learning that makes sense and has value for students, some trends have come to be more valued in literature, generally called contemporary trends in teaching and learning. They represent, therefore, the focus of current discussion around teaching and learning, especially in the field of Natural Sciences. Although there are numerous trends under discussion, we will highlight, in this work, the role of research and representations in science teaching.

The development of investigative activities in science classes is not intended for students to think and act like scientists during the activities, but to understand the bases of knowledge production. There is a consensus among researchers in the field of education that these young people do not have the age, specific knowledge, and scientific tools to act as scientists (CARVALHO, 2013). The intention of the researchers and educators involved with teaching by inquiry is much simpler: the creation of an investigative environment in science classes, so that students can be led in a simplified process of scientific work. As a result, there is an expectation that they will gradually expand their scientific culture, improving their ability to communicate and use, in communication, the specific symbology of the area, and also becoming scientifically literate (SASSERON; CARVALHO, 2008).

Carvalho (2018) states that, in teaching by inquiry, the teacher creates some basic conditions in his classes, which lead the student to: think, considering the structure of knowledge; speak, evidencing their arguments and constructed knowledge; reading, critically understanding the content read; writing, showing authorship and clarity in the ideas exposed. Munford and Lima (2007) state that "there are multiple perspectives on the role and place of science teaching by inquiry in the education of students in Basic Education" (p. 109) and, in this sense, they argue that, when teaching science, it is necessary to "promote a more interactive, dialogical teaching based on activities capable of persuading students to admit scientific explanations beyond authoritarian discourses, prescriptive and dogmatic" (p. 110).

In the case of Chemistry teaching, we associate investigative teaching with the preponderant role of representations. We know that the production of knowledge, which takes place in universities and research centers, makes use of representations as a way of organizing ideas and communicating findings (KOZMA, 2003). Usually, in communication, the researcher combines verbal text with mathematical expressions, graphs, tables, diagrams, maps, drawings, and photographs. Representations, however, are also used by scientists to organize their own thinking (GOODING, 2004; 2006; 2010). In an attempt to bring the teaching and learning of Science closer to authentic scientific practices, the teaching approach based on research and the construction and interpretation of representations is relevant.

Over the last few decades, we have seen an increase in the number of publications on the role of language in the teaching and learning processes of Science, especially with regard to the discursive interactions between subjects in the classroom and the exercise of argumentation (HALLIDAY, 1978). More recently, research in the area of language has expanded, seeking to understand language in multimodal texts (HAND, MCDERMOTT and PRAIN, 2016), that is, in texts – written or spoken – that use various semiotic modes.

There is a consensus among researchers who investigate multimodality in the teaching and learning process that it is important for teachers to induce students to use multiple modes in an exercise of interpretation/questioning of scientific texts and phenomena. In order to develop a quality science teaching, it is recommended that students understand the function of the various modes that circulate in scientific texts and are able to incorporate these modes in their school practice and in other social contexts (HAND and PRAIN, 1995; LEMKE, 2004).

In this scenario, we highlight the use of multiple representations in science teaching, as defended by Prain and Waldrip (2006) and Prain *et al.* (2009). They argue that learning is favored when students have contact with different types of representations and use these representations in order to understand/explain a given phenomenon.

Kozma and Russell (2005, p. 129-130) state that students learn science in a meaningful way when they participate in activities "in which representations are used in the formulation and evaluation of conjectures, examples, applications, hypotheses, evidence, conclusions, and arguments."

In this work, we analyze an experience of teaching Chemistry with students of the first year of High School in which the teacher encouraged the investigation based on a problem brought in the classroom by a student. Our objective was to analyze the contribution of teaching by inquiry and representations in the involvement of students with the problem issue.

2 METHODOLOGY

The experience we share through this work took place in a first-year high school class during the second semester of 2019. This class was made up of 32 students who, in various activities during the school year, worked in groups.

In a class in which the concept of density was resumed, a student reports a fact that she described as "curious": a mixture of coffee and milk in two phases, that is, coffee and milk had not mixed. She also informed that the justification given for this phenomenon was density, but that she was not able to understand this justification. This report of the student became the problem question that motivated the next class.

In the next class, the teacher challenges the students to make a mixture of two miscible liquids, in order to leave them in two phases, providing the students with only water and table salt and the common laboratory glassware. In groups, they should propose this mixture and explain the results, considering the density mentioned by their colleague in the previous class.

The students met in a group and used a time of about 30 minutes to meet the challenge they received. After this time, the teacher invited the groups to report the result and explain what had happened. We selected one of these groups because the debate around their experiment was more effective and the students in the group used the representations to explain how the difference in density formed a mixture of two phases.

This lecture was videotaped for easy analysis. The video was watched by the researchers and the fragment of the class in which the students presented the experiments, explained the phenomenon and, with that, promoted a small debate was selected and transcribed in full. In this transcription, the students were given fictitious names to comply with the legal procedures of research. The analysis took place in the way the students solved the problem and in the semiotic modes they used to explain the phenomenon.

3 EXPERIENCE REPORT

During the 30-minute time available to the students, they took to their groups the material they thought was necessary and planned what they would do, raising hypotheses in relation to the results they could obtain. We observed that in the first 10 minutes the teacher was called in all groups because, in a way, they believed that two liquids were needed to make the mixture and had received only water and table salt. Since the students couldn't think of a possible path, the teacher informed them that they could come up with two solutions using only the material they had been given. From this "tip", the groups came up with new hypotheses and carried out tests.

To give an idea of the paths chosen by the groups, we selected one of them who, in addition to the materials available, asked the teacher to release a ball of mothballs (material that they had already used and that they knew they had available in the classroom). The teacher asked the groups, when presenting their results, to go to the front of the room (next to the blackboard). The group selected for this analysis took advantage of the presentation of the previous group and has already used part of the blackboard to make the drawings they would use in the presentation.

This group brought, for the presentation, a beaker with the mixture already made and explained, initially, what it was about. However, looking at the bottle, there was liquid in a single phase. They then threw the mothball, which went down to almost half of the liquid and was "parked" at that point, in the middle of the two solutions they had used. Figure 1 shows the experimental apparatus used to test and create the hypotheses necessary to solve the proposed problem, i.e., the beaker with the liquids and the mothballs added later.

Figure 1. Cylinder with both solutions and mothballs

The group then informed their colleagues that they had made a solution with water and table salt and that the other liquid used was tap water. Believing that the density of the solution would be greater than that of tap water, they informed their colleagues that they initially added the water + salt solution and then added tap water by slowly dripping it down the walls of the beaker. The mothballs demarcated the space occupied by the solutions, between the solution of water and salt and the tap water. Below is an excerpt from the transcript referring to the explanation provided by the group, given by one of the students in the group:

> Student Luana: We had a container with water and salt, and it was very concentrated. The first thing we did was fill 50 mL of water with salt, then we measured 50 mL of water, and put it very slowly, letting it run down the corner of the beaker, to prevent the two solutions *from mixing*, and we put the mothball inside. Because of the care we took when putting the water, the ball was in the middle. The density of salted water is higher than that of unsalted water, and mothballs, it has the ideal density, to the point of being lower than that of salted water, and higher than that of water.

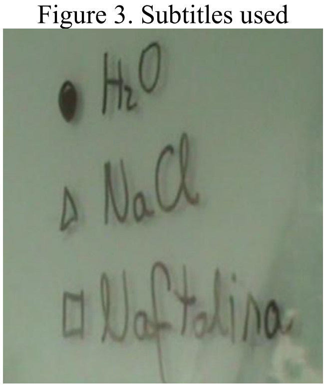
The students reported using the same amount of solution and tap water, but the colleagues observed that the mothballs stopped slightly below what would have been the expected demarcation. The teacher asks them to explain this result. They readily used miscibility, stating that during mixing a small part might have already miscebilized, displacing the mothballs a bit. Jessica, a member of the group, intervenes, explaining:

> Student Jessica: You can really see that the ball is not exactly in the middle, even though it is 50 mL of water and 50 mL of salt water. But that's because when it came to putting it on, our measurement wasn't perfect and we weren't one hundred percent careful either. So there is a layer of "mixture" of water with salt and water, where the solution became less dense, and by chance the ball, it must be denser than this layer of mixture.

The difference in density between the tap water and the solution, associated with the surface tension between the two liquids, was used as a justification to form the two phases. To this they added that, in one of the attempts, they stirred the system too much and the ball went all the way up. With this, they stated that the density of the "whole mixture" is greater than the density of mothballs.

To explain this phenomenon in terms of particles, they used the drawing they had already made on the blackboard. Figure 2 shows this drawing and Figure 3 shows the legend used by the group.

Figure 2. Representations drawn on the blackboard


Figure 3. Subtitles used


When explaining to their peers what had happened in their experiment, this group of students used the representations. In Figure 2 it is possible to see the representation, in the form of a drawing, of the mothballs between the two liquids, and in Figure 3 the legend for the constructed representation. The following is an excerpt from the transcription of the explanation that the student Luana elaborates for the constructed representation:

> Student Luana: Using the molecular kinetic model of particles, here it would be water (points to the circle filled with black), and here water with salt (points to the region of the drawing with circle filled with black and triangle). [...] Here, the mixture is denser (points to the region of the central design), which has 14 particles of water and salt and this other (points to the upper region) with 9 of water, in the same volume.

We can observe that they associated the representation of particles with the phenomenon and, therefore, stated that the greater amount of particles present in the solution gave it greater density when compared to tap water. The particulate model used by the group was intended to strengthen the explanation around the difference in density between the salt water solution and tap water. Mothballs would be, according to them, in an intermediate density. However, when explaining the representation of the particles, the student showed, in the caption, the representation used for the water particle, for mothballs and for NaCl, to which the teacher intervened, and the following dialogue occurred:

> Teacher: Did the solution of salt and water still have solid salt?
> Student Luana: No... It was all liquid.

Professor: But you said it was a NaCl particle!
Student Luana: Yes.
Professor: When NaCl is dissolved, how does it stay in the solution?
Student Luana: Oh yes! It's the ions... So I have to say that these particles are Na+ and Cl^-? (pointed to the particles represented by a triangle)
Teacher: What do you think? (looking at the whole class)

At this point there is a brief debate involving several students, with some suggesting two ways of representing (one for Na+ and one for Cl^-) and others saying that a single one is enough, as long as it shows that it represents both ions. Thus, it was possible to observe that the representation provided support to the students' explanation. They therefore used verbal modes, the experimental apparatus, and representation as semiotic modes of communication. However, we argue that these modes, especially the representation drawn on the blackboard, helped these students to organize their own ideas, as defended by Kozma (2003).

The teacher provided these students with the opportunity to think of a solution to the problem presented by a colleague in a previous class, to communicate the path taken to reach this solution, and to explain the "findings", debating with their peers, as defended by Carvalho (2018). In addition, they dealt with different semiotic modes and used the representation drawn on the blackboard to understand/explain the phenomenon, which favors learning, according to Prain and Waldrip (2006) and Prain *et al*. (2009).

4 EXPERIENCE ANALYSIS

During the presentation, this group of students was able to propose an experiment that dealt with the doubt that was being investigated, showed the appropriation of scientific concepts, by referring to density and concentration to explain the proposed experiment and used a representation of particles, drawing it on the blackboard. As pointed out by Sasseron and Carvalho (2008), this investigation promoted the expansion of the scientific culture of these students, improved their communicative capacity and made them appropriate the specific symbology present in the language of the area.

Whereas learning is also associated with activities with representation (KOZMA; RUSSEL, 2005) and that the representation for NaCl was questioned by colleagues who observed the group's explanation, we highlight the teacher's posture when socializing the doubt generated in the presenters, when she stated "What do you think?". With this, it further promotes research based on the representation used and transfers to students the responsibility of constructing coherent explanations.

In the experience reported in this work, the teacher proposed an investigative activity, aiming at understanding the density of different solutions. The students related their explanations to the representations, taking the lead in the class. Thus, we realized that the explanations provided by the students were well constructed, resulting from their involvement with the challenge made by the teacher. They communicated their findings and listened to critiques from colleagues, which were used to consolidate the role of representation in that experiment and in the construction of knowledge.

As soon as the explanation of the experiment was finished, the group returned to the student's question - brought up in the previous class - and explained the difference between the density of coffee and milk in terms of particles dissolved in each of these materials.

5 FINAL THOUGHTS

In this work, we aimed to analyze the contribution of teaching by investigation associated with the use of representations in the explanation of a phenomenon. We observed that, when challenged, these students were actively involved in the search for a path that would allow them to allowed the creation of a new phenomenon, explaining it and associating it with the phenomenon reported in a previous lesson. The students used experimentation as a tool for the creation and testing of hypotheses and, with that, they came up with a result. To explain it, they anchored themselves in the representations, in the form of particle drawings, which they shared with their peers. When questioned, they rethought their own representation. As a limitation of these representations is the number of particles, which was far below what Science recommends, since the students performed this representation "inside the flask", associating the microscopic representation with the macroscopic one. Thus, the students may have remained with alternative conceptions in relation to particles, especially with regard to quantity, that is, the existence of a small amount of particles in a given container. However, it seems that this tends to be "corrected" by the teacher now she introduced the students to the content of the amount of material.

The investigative approach used by the teacher, in addition to engaging the student in the search for understanding a problem proposed or presented by a colleague, as in the case reported, allows to be the protagonist of stages of a scientific work. As advocated by Kozma and Russell (2005), these students actively participated in the activities and used the representations to formulate and evaluate conjectures, which is a strong indication that there was learning. This involvement of the students was favored by the fact that the activity was investigative.

REFERENCES

CARVALHO, A. M. P. Ensino de ciências por investigação: condições para implementação em sala de aula. São Paulo: Cengage Learning, 2013.

CARVALHO, A. M. P. Fundamentos Teóricos e Metodológicos do Ensino por Investigação. Revista Brasileira de Pesquisa em Educação em Ciências, v. 18, n. 3. p. 765-794, 2018.

DRIVER, R.; ASOKO, H.; LEACH, J.; MORTIMER, E. F.; SCOTT, P. Construindo conhecimento científico na sala de aula. Química Nova na Escola, São Paulo, n. 9, p. 31-40, 1999.

HALLIDAY, M. A. K. Language as Social Semiotic. London: Edward Arnold, 1978.

KOZMA, R. The material features of multiple representations and their cognitive and social affordances for science understanding. Learning and Instruction, v. 13, p. 205–226, 2003.

KOZMA, R.; RUSSELL, J. Students becoming chemists: Developing representational competence. In GILBERT J. (Ed.) Visualization in Science Education. Springer: Dordrech, 2005, p. 121-145.

GOODING, D. Visualization, inference and explanation in the Sciences. In: Malcolm, G. (Ed.) Studies in Multidisciplinarity, v. 2, Elsevier, p. 1-25, 2004.

GOODING, D. C. From phenomenology to field theory: Faraday's visual reasoning. Perspectives on Science, v. 14, p. 40-65, 2006.

GOODING, D. C. Visualizing scientific inference. Topics in Cognitive Science, v. 2, n. 1, p. 15-35, 2010.

HAND, B.; PRAIN, V. Teaching and learning in science: The constructivist classroom. Sydney: Harcourt Brace, 1995.

HAND, B.; MCDERMOTT, M.; PRAIN, V. Using multimodal representations to support learning in the Science classroom. Switzerland: Springer International Publishing, 2016.

LEMKE, J. The literacies of science. In SAUL, E. W. (Ed.) Crossing borders in literacy and science instruction: Perspectives in theory and practice. Newark: International Reading Association/National Science Teachers Association, 2004, p. 33-47

MUNFORD, D.; LIMA, M. E. C. C. Ensinar ciências por investigação: em quê estamos de acordo? Ensaio: pesquisa em Educação em Ciências, v. 9, n. 1, p.89-111, 2007.

PRAIN, V.; WALDRIP, B. An exploratory study of teachers' and students' use of multi-modal representations of concepts in primary Science. International Journal of Science Education, v. 28, n. 15, p. 1843-1866, 2006.

PRAIN, V.; TYTLER, R.; PETERSON, S. Multiple representation in learning about evaporation. International Journal of Science Education, v. 31, n. 6, p. 787-808, 2009.

SASSERON, L. H.; CARVALHO, A. M. P. Almejando a alfabetização científica no ensino fundamental: a proposição e a procura de indicadores do processo. Investigações em Ensino de Ciências, v. 13, n. 3, p. 333-352, 2008.