MEDIA LITERACY AND SCIENTIFIC EDUCATION: THE STUDENTS' PROTAGONISM

Agnaldo Arroio
University of São Paulo, Brazil
E-mail: *agnaldoarroio@yahoo.com*

Tânia Cristina Vargas Sana
Colégio Saint Claire, São Paulo, Brazil

Luiz Guilherme Basílio Novaes
State Secretary for Education, Diadema, São Paulo, Brazil

Daisy de Brito Rezende
University of São Paulo, Brazil
E-mail: *dbrezend@iq.usp.br*

Abstract

Currently, a discursive resource widely used is images, whose use can facilitate the explanation of concepts, constituting essential support for the communication of scientific ideas. This article reports the results of a study on the perception of 107 students of two High Schools located in São Paulo (Brazil) concerning representations of the physical state change processes at a sub-microscopic domain. After the development of a teaching-learning sequence (TLS) about the properties of matter, discussions were conducted both in small groups and with the whole class. At this point, students were asked to draw up images that represent their understanding of the phenomena of physical changes at the sub-microscopic level. In the second phase of the TLS, after some discussion about the drawings previously produced, each group of students was asked to create an audiovisual object (AO) concerning the phenomena. It was possible to perceive both the evolution of their expressed mental representations that present scientific features more consistently and the students' more coherent and secure speech. These results suggest that the multimodal approach promotes opportunities both for the building of models by the students, and their expression is essential to chemistry language learning.

Keywords: *multimodal approach, media literacy, sub-microscopic domain, science education.*

Introduction

Nowadays, a significant number of science teachers, both in Brazil and around the world, seek to improve the learning of their students by using videos, software or other digital resources to improve their classes, making them a more immersive experience. Considering that these technologies currently permeate the lives of young students, this type of approach can motivate, arouse curiosity and stimulate fruitful discussions.

With regard more specifically to Scientific Education, the student needs to understand and articulate scientific theories, laws, formulas, and models, as well as to reason on graphs and tables. These competencies are essential to their understanding of the basic concepts underlying everyday socio-political issues, as well as to the understanding of variables analysis and the reading of charts and tables that facilitate the interpretation of several themes that permeate everyday life, such as electoral surveys or data on economic variations. In short, appropriating the language of the Natural Sciences and Mathematics enables a better reading of the world.

More specifically, concerning the learning of Chemistry, one can consider that, to understand the concepts involved, it is necessary to take a language different from the one used in everyday communication. The difficulty involved resembles that of learning any foreign language, as one can readily deduce from the models that represent the dimensions of chemical knowledge. This proposition is in line with Lemke's ideas (1997), which contribute to the hypotheses that guided this study:

Science is not made; it is not communicated only through verbal language. It cannot be. The "concepts" of science are not verbal concepts, although they have verbal components. They are semiotic hybrids, simultaneously and essentially, typological-verbal and mathematical-graphic-operational-topological. The textual genres of action, conversation and writing of science are historical and current multimedia genres, fundamentally and irreducibly, multimedia genres. For one to do science, to talk about science, to read and write science, it is necessary to juggle verbal discourse, mathematical expressions, graphic-visual representations, and motor operations in the "natural" world (including human-like-Natural). (Lemke, 1997, p.4, our translation).

Among other possible models for chemical knowledge, the one proposed by Johnstone (2000, 1991, 1982) is widely accepted among researchers in the field of chemistry teaching. Johnstone proposes an explanatory model to articulate the three dimensions of chemical knowledge, showing its correlation, as exemplified in Figure 1, where this model is illustrated for the phenomenon of effervescence of an analgesic tablet.

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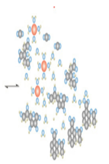
Representation of phenomenon	Dimension
	**macroscopic**
	**sub-microscopic**
$Na_2CO_{3(aq)} + C_9O_4H_{8(s)} + C_6O_6H_{8(s)} + C_6O_7H_{8(aq)} + H_2O_{(l)}$ $Na^+ + C_9O_4H^-_{7\,(aq)} + C_6O_7H^{2-}_{6\,(aq)} + C_6O_6H_{8(aq)} + 2H^+_{(aq)} + CO_{2(g)})$	**symbolic**

Figure 1. Example of a phenomenon represented in the three dimensions of chemical knowledge.

In summary, each of the dimensions of chemical knowledge can be defined as follows:

- macrochemical (also called macroscopic), related to tangible, concrete and measurable processes from the perspective of human sensory devices (even if enhanced by sophisticated instrumentation);

- submicrochemical (or sub-microscopic), is related to molecular, atomic and kinetic models proposed from the experimental evidence;

- representational (or symbolic), referring to the symbols, equations and chemical formulas.

The learning of Chemistry involves not only understanding the articulation between these three dimensions, but also knowing how to move between them. A number of studies indicate that students, especially from the Basic School, have difficulty on interpret and represent the sub-microscopic level (Chittleborough, Treagust, 2007, Chandrasegaran et al, 2007, Cook, 2006, Jansoon et al. 2009, Jaber & Boujaoude, 2011; Scalco, 2014). Instructional activities that emphasize the sub-microscopic level can facilitate the students' learning, so it is necessary to develop teaching activities that allow the establishment of interactions between the different levels of the chemical knowledge.

Multimodal approaches that promote the active participation of students can facilitate the learning of Chemistry because this approach promotes the involvement of many cognitive processes. In addition to digital integration, students can use visual resources to communicate their knowledge and thus share their ideas and productions with other students and with the teacher, facilitating the teaching-learning processes both by making them protagonists of their learning and by facilitating the expression of their mental representations.

Research Methodology

In this context, the present work reports the results of an investigation related to audiovisual productions on chemical and physical transformations, of High School students of a public and a private school located in the metropolitan region of São Paulo (Brazil). The data were obtained during the implementation of a teaching-learning sequence (TLS) referring to the transformation of materials, whose main aspects are presented in Table 1, for the public school, located in Diadema, São Paulo, Brazil. This sequence was developed in the regular classes of the discipline of the second and third years of High School.

The sequence developed in the private school in the counterpart of regular classes, with High School students from three years, who volunteered, is similar to the one just described, with some modifications in the sense of shortening it, maintaining the instructional objectives.

The primary goal of both sequences is that students could express themselves through different discursive genres, including the production of images and audiovisual objects (AO). The images, animated or not, allow the expression of the students' mental models and their socialization, facilitating the perception of conceptual misunderstandings and their collective resignification.

Table 1. Sequence of teaching activities developed.

	Key objectives	Teaching activities
1	Historical context of chemical knowledge with the text: "Chemistry is old"	Discussion and collective reading
2	List of students' common sense knowledge about the term "TRANSFORMATION"	Construction and discussion of individual and collective tables
3	Study of the processes of physical and chemical transformations	Execution of experiments and preliminary interpretation of the evidences
4	Addition of the "physical" and "chemical" qualifiers to the term Transformation	Discussion and correlation between the tables produced
5	Macroscopic observation of boiling water and a mixture of water plus glycerine	Execution and interpretation of experiments
6	Observation of the mixing experiments Water + alcohol (1) and Diffusion of dye in water (2) to subsidize the discussions in the sub-microscopic scope of the chemical knowledge	Execution and joint interpretation of the experiments
7	Design of the sub-microscopic model and drawings of it on paperboard	Collective discussion of the images presented on paperboard
8	Construction of audiovisual objects (AO)	Collective discussion of audiovisual productions
9	Conclusion	Closing

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Results and Discussions

In this article, we present examples of the materials produced by the students during the steps 7 and 8 mentioned in Table 1, to show how resources that carry more information facilitate the students' mental model expression if compared with written records. In this perspective, the informative content of the AO is more significant because they are multimodal, allowing the better expression of the attributes of the model, which enriches the collective discussion about them, in comparison with what is possible to express employing just static images.

The design of the TLS is in a spiral, to favour several semiosis during the execution of the activities related to each type of record (written record, static drawing, and AO). Each and more specific attributes make the concept of transformation less inclusive, that is, more specialized, moving towards the meaning of chemical transformations, in an approach inspired by Ausubel's considerations on learning.

The didactic sequence culminated in the production of images on the sub-microscopic domain, in paperboard, and in the elaboration of audiovisual objects, steps 7 and 8, which should contribute to the explication of the sub-microscopic models of the students.

The purpose of inserting step 7 in the TLS is to obtain representations materialized in images about the transformations. Therefore, to analyze the images, in the multimodal perspective, Bell (2001) clarifies that the content analysis is suitable for analyzing "visual" materials.

In his words, *"content analysis is an objective and empirical (observational) procedure for quantifying recorded" audiovisual "representations (including the verbal part) using reliable and explicitly defined categories*." Thus, we decided to analyze this material from the perspective of Social Semiotics - which understands images and visual language as constructions directly linked to the individual's social and cultural history.

Specifically, the analysis was made based on the works of Kress and Van Leeuwen (2006), who, in their vast literature, propose a theoretical, taxonomic and descriptive basis of how images can be used to express and construct meanings. The categories proposed by these authors derive from the discussions of the Systemic-Functional Grammar, therefore, they are structured from the notion of language as a social practice and derive from three aspects of meaning that converge throughout the communications:

1) inferences about the representation of objects and their relations in a world outside the representation system, that is, human experiences and their contexts;

2) the need to relate, indirectly, the subjects involved in communication through representation, that is, the intended relationship between what is represented and the reader;

3) perception of what elements and characteristics of the text were used by the author to correctly express their representation.

Considering the above aspects, it is important to emphasize that these types of representation encode the ideas experienced by the students in the execution of the experiments and in the observation of the macroscopic evidences concerning the system that precede the process of image representation. Therefore, the representations are impregnated with characteristics that were negotiated collectively during its construction, whose origin is previous to that particular school experience and can add complexity to it.

After the transcription of the audio, we selected the extracts from AO related to the expression of the phenomenon represented. Therefore, it was possible to obtain "images" in sequence, called frames, in conjunction with the students' speech, as shown in the following example.

The water + alcohol mixture

The AO denominated "*Water + alcohol mixture*" represents the effect of decreasing the final volume of a distilled water and 96 ° GL ethanol mixture , compared to the expected value for the sum of the volumes of the individual components. In general, the experiment consists of mixing 50 mL of each of the two materials.

Asked about the possible final volume, students suggest that 100 mL will be measured but, in practice, there is a reduction of about 20% in the volume of the mixture, in relation to the expected one from the sum of the individual volumes. The sub-microscopic model suggests that the distance between the molecules decreases, due to the intermolecular attraction forces resulting from the hydrogen bonds between the particles of the materials, more intense in the case of intermolecular interactions with water (a more intense dipole). When there is only ethanol, the interparticle attraction is smaller, because the alcohol molecules present a less intense dipole moment than water. This is the explanatory model, at the level of the constituent particles of the materials, for the fact that the macroscopic volume measured for the final blend is smaller than the assumed one. In a teaching situation, this experimental observation, a macroscopic evidence, suggests to the students that the material is discontinuous in its sub-microscopic dimension and that the explanatory model considers the structure of the constituent particles of the materials.

The transcription of the AO corresponding to the above remarks is recorded in Table 1, followed by a discussion of the modes present in the selected frames of the same representation.

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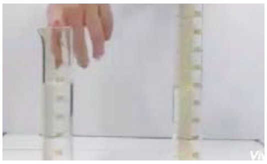
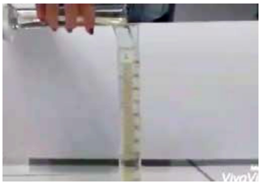
Table 1. Audiovisual object audio transcription.

Audiovisual object 1 - Mixture of water + alcohol   Duration: 2min29s
Student (girl): Our experiment is about mixing water and alcohol. The goal is to show you why does not happen what was expected, which would be the addition of the two, which in the case of 50 mL of alcohol and 50 mL of water should give 100 mL. Now, the junction of the two. In the case, I will put 50 mL of water, which would be [she points to one of the test tubes], and 50 mL of alcohol, which would be [she points to another test tube and pour the contents to the test tube]. As you can see, I had 50 mL here and 50 mL here [pointing to the two beakers]. It just did not give 100 mL.
Student (boy): Well, now I'm going to explain to you why the 50 mL of water together with the 50 mL of alcohol did not give 100 mL. This happened because the empty particles of water, which is a simpler substance, the particles of it that are empty, are grouped together to the particles of alcohol. Consequently, this caused the volume of water and alcohol together to decrease, so the final result was 96 mL [pointing to the value recorded on the blackboard]. So here is the representation of the particles. Here is a very mystical representation of what happens to the particles of water and alcohol. Here, you can see the particle of alcohol, fitting into the particle of water. Then you see the whole process until they are nestled together, grouped together. Once that happens, we will have, consequently, a volume a little lower than expected, which was to have. Then, after that happens, the volume goes down and the end result is 96 mL.

AO allowed the addition of dynamicity to the representation in comparison with is shown on the paperboard poster. The representational action gesture in Event 1, as described in Table 2, permits to infer the dynamicity of the model that represents the process.

Table 2. Characterization of the audiovisual object 1 - part 1.

Event	Frame	Transcript of the excerpt	Remarks
1		*"Our experiment is about mixing water and alcohol. The goal is to show you why does not happens what is supposed to, what would be the addition of the two, in this case 50 mL of alcohol and 50 mL of water should give 100 mL* "	Drawing representing the mix and gesture with hands showing the join of the components.
2		*"Now, the junction of the two, in the case I will put 50 mL of water that would be this (she points to the bottle) and 50 mL of alcohol, which would be this (she points another bottle)."*	Classificatory conceptual representation
3		Absence of speech	The act of pouring the contents of one beaker into the other represents the mixing process

Then, in carrying out the experiment to demonstrate the phenomena of volume decrease, that is not expected, the student presents the materials (Event 2, Table 2, and uses deictic gestures to differentiate them). The image drawn on the blackboard makes no mention to this process and does not have elements that allow inferring about the action of mixing (vectors, symbol of sum or symbol).

This is an example of the possibility of transmitting more information content through this resource (AO) than through static representations. There are two tubes with transparent liquids, which at first suggest they are the same liquid. The act of pointing to the materials when speaking their names indicates that the physical gestures classify and distinguish the materials for the viewer. As she describes the materials, the student pours the contents of one beaker into another (Event 3, Table 2). The act of performing the experiment and then explaining it reinforces the description of the macroscopic evidence expressed in the introductory part of AO. In presenting the phenomenon, the student exposes her inquiry, even though no word is verbalized during the action.

Events 4 to 7 of this same AO are presented in Tables 3 to 6. In these events, students use deictic gestures when pointing to two different entities in the representation that have the same meaning; the first one (shown in Table 3) is the graduation of the beaker indicating the final volume of the mixture, i.e. the macroscopic evidence that raises the reason for obtaining a different volume than the expected one. The second entity refers to the volume value recorded on the slate to sketch the mixing process (event 5, Table 4).

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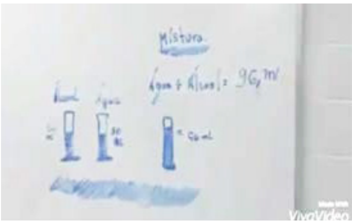
The purpose of this record is to inform the narrative sequence of the process. However, no vectors are represented to indicate or highlight the mixture, the volume decrease and the value of the final measure. These aspects are presented orally, taking the drawing as the background of the narration. Considering the person's speech in event 5 of AO (see Table 4), it is important to note that the students who developed it were in the second semester of the second year of secondary education, that is, they were about to finish the High School.

Table 3. Characterization of the audiovisual object - event 4.

Frame	Transcription of the excerpt	Remarks
	"*In this case, as you can see, I had 50 mL here and 50 mL here, but, in this case, I did not get 100 ml*."	The student points to the graduation of the test tube indicating that the expected 100 mL was not obtained.

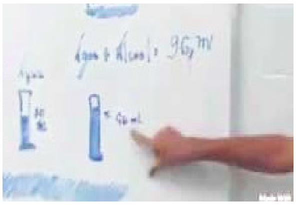
Table 4. Characterization of the audiovisual object - event 5

Frame	Transcription of the excerpt	Remarks
	"*Well, now I will explain to you why the 50 mL of water together with the 50 mL of alcohol together did not give 100 mL. This happened because the particles of water, which is a simpler substance, the particles of it, which are empty, have clustered to the particles of alcohol.* "	The scheme drawn on the board has no vectors and the author explains the process of the expected final volume decreasing.

In this speech, some excerpts that suggest the importance of favouring the expression of the students' representations throughout their learning path (which does not appear to have happened in the case of these students) were emphasized. It can be seen from all the underlined sections that the student does not have adequately internalized the idea of the discontinuity of matter, that is, that all matter is discontinuous because it would be formed of moving particles and huge spaces between them (the so-called discontinuity of matter).

There are misconceptions in the student use of the terms particles and void, suggesting that he has not been able to assign the proper meanings to this terminology until this moment. In the discontinuity model of the matter, spaces are between particles in constant motion, there being no empty particles or the possible aggregation of particles until there is practically no space between them.

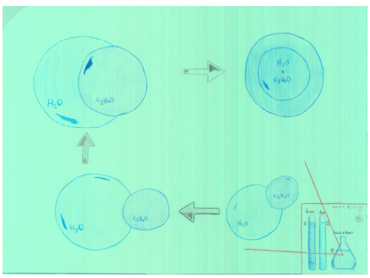
Table 5. Characterization of the audiovisual object - event 6.

Frame	Transcription of the excerpt	Remarks
	*"(...) this caused the volume of water and alcohol together to decrease, so the final result was 96 mL."*	Emphasis on the value of the volume found at the end of the experiment, using a pointing gesture.

Regarding AO Event 6 (presented in Table 5), our results suggest that the communicative modes in a science class blend and complement, although Piccinini and Martins (2004), when analyzing several of these modes, in a situation of teaching, have stressed that the gestural and imagery modes are subordinate to verbal language. There is, in our view, an inter-dependence between modes, which facilitates the students´ attribution of a signification to the action of mixing materials only when the verbal mode and the slate image are expressed together.

If activities such as the one proposed in this TLS had been implemented earlier and continuously during the schooling of these students, the students´ expression of their mental model would have led to collective discussions with their colleagues and the teacher. These opportunities would probably lead to the reformulation of their model due to the negotiation of meanings in the group. Finally, the students used the drawing they had done in paperboard (Table 6) to complement the discussion of the phenomena.

Table 6. Characterization of the audiovisual object - event 7.

Frame	Transcription of the excerpt	Remarks
	*"So, here is the representation of the particles. Here, is a very mystical representation of what happens to the particles of water and alcohol. Here, you can see the particle of alcohol fitting into the particle of water. Then you see the whole process until they are nestled together, grouped together. Once that happens, we're going to have a slightly smaller volume than expected, which is what it was. Then, after that happens, the volume goes down and the end result is 96 mL."*	The beginning of the turn of the explanation at particle level use the same image of the cardboard and narrates the process complementing the image. The representation of the image suggests that the particles "eclipse", but the verbal content is that one fits the other.

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It is interesting to note that the paperboard presents vectors that represent the movement of one particle eclipsing another. When the student explains the representation, he says that the particles fit together. Therefore, the audiovisual object, in this case, assigned another meaning to the movement of the entities, corroborating the expression of the dynamic aspects of the set of particles, even using an explanatory model alternative to the scientifically accepted one. The use of different tools in the teaching and learning processes, as proposed in the literature (Mayer, 2003), should favour the construction of knowledge connected to the production of models.

Conclusions

Semiotic hybrids (image, voice, and gestures), as highlighted by Lemke (2000), show a significance that surpasses oral explanation and isolated images. The observation of the visual representation of the paperboard, reused in the audiovisual object, evidences this synergy. The change of meanings between image and AO - eclipse versus docking - reinforces the assumptions that audiovisual media supports more informational content than written or visual-only media (Van Leeuwen & Jewitt, 2005; Sousa et al., 2013), because it involves more elements for the expression of information.

According to the results, it is essential to employ diverse communicative genres to favour the students´ expression of their mental model, facilitating the development of scientific language by the students that perform an enriching form of knowledge creation. The gestural performance of the students, when using deictic gestures to classify the representative materials and gestures related to the mixing process, denote an emphasis on what stands out for the students in their representation.

Another point worth mentioning is the construction of representations for the particles. Excluding the question of scientific validity, by selecting specific signs (circles, arrows and chemical formulas) collectively negotiated between them, the representation was sufficient to express their theoretical proposition for the macroscopic evidence they had observed.

Media literacy could also be able to prepare citizens for many competencies that are needed to promote the individual’s right to communicate, express, seek, receive and impart information and ideas concerning this fundamental human right (Arroio, 2017).

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