TEACHER'S EDUCATION AND THE USE OF VISUALIZATIONS IN CHEMISTRY INSTRUCTION

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Abstract

The accelerated development of information and communication technologies followed by several studies in the cognitive theory area, have promoted the construction of many visual tools (3D concrete models, statics or dynamics virtual 2D and 3D images, simulations, animations, interactive software's, etc) that have been placed to the disposition of instructors. When they introduce systematically these tools in there classes, with the purpose of getting better learning results, we verify a changing in the teacher's role. He is no longer the source nor the transmitter of knowledge, but the mediator between the source and the student. The class dynamic frequently changes without the perception of the teacher. The information was predominantly presented in the verbal and gestural modes, with some punctual introduction of graphics, tables and models, with the purpose of merely illustrating the teacher's verbal presentations. With the frequent use of these tools, images became the main vehicle of information, and if the learning impact is bigger so is the risk of misconceptions if the image's choice is inappropriate.
What pre-service educational training do teachers have to deal with learning/instruction processes strongly supported in visualization tools? What conceptions they have about visualization, representations and images, etc? These are the two questions that we are trying to answer throughout the development of this work. The research is qualitative. We applied a questionnaire with 12 open questions answered by 24 pre-service chemistry teachers. We concluded that their training course discusses these topics in some subjects but in superficial way. We also found that their conceptions are not solid, and sometimes even become misconceptions.
Keywords: *visualization, chemistry instructing, teacher's formation.*

Introduction

In the last years, four very different groups of people (computer software specialists, scientists, educationalists and cognitive scientists) have promoted the development, the discussion and the use of visual tools in sciences instruction (Gilbert, 2007). Therefore the traditional resistance to change, science instruction and more specifically chemistry teaching has suffered some progressive modifications, that go from small shifts in the traditional methods of teaching, strongly supported in the teacher, where in some punctual moments the students are allowed to built their own knowledge, to a complete change in the class dynamic, in teacher's role and consequently in the way of the students built there own knowledge.

Progressively educators began to recognize the value of the visual component on the chemical knowledge, which was until then, only attributed to the verbal and mathematical language; nevertheless the pictorial chemistry language is by itself a higher structured language (Ege, 1994). With Jonhstone (1991) the chemical knowledge was divided in three levels of representation (sub-microscopic, macroscopic and symbolic). For a student immerse into the macroscopic world, the reality, it becomes very difficult for them to understand the concepts and the processes located at the sub-microscopic level and represented in the symbolic language of chemistry. There is a stead growing body of research that suggests that the use of visual tools helps students' transition between these levels of representation and the student achievement in science is generally supported by direct access to multi-media modes of representation (Ardac & Akaygun, 2004). These studies refer that if models play important roles in science, it's also expected they are equally important in science education, both for students who may become scientists and for the majority who will need some level of 'scientific literacy' for later in life. We also found literature with some research (Rapp, 2007) that points out the importance of the construction of mental models by the students, without these models learning becomes very difficult, especially in chemistry. Gilbert says: '*All students of chemistry must have a mental model, of some kind of an 'atom" (Gilbert, 2007) (p.12)*

It is suggested that existing models play three key roles in learning:

- *First, they facilitate cognitive engagement by the learner with what is being taught;*
- *Second, in doing so, they enable each student to interact with the lesson as it progresses;*
- *Third, by being able to respond to a variety of mutually supportive media formats, they enable diverse types of information to be assimilated. (Gilbert, 2007, p. 2).*

As it was referred, all of this is performed with the aid of visualization. In a review of literature we find that there are three common academic usages of visualization in psychology and educational research (Gobert, 2007): external visualization, internal visualization and visualization as a type of spatial skill. In a simple way we can say that external visualizations in science refer to graphics, diagrams, models, simulations, etc, representations typically used in learning; internal visualizations is used to describe internal mental constructs, i.e., mental models; and visualization is also used to describe a type of spatial skill, the "ability to manipulate or transform the image or spatial patterns into other arrangements" (Ekstrom, French, Harman & Dermen, 1976). According to Gilbert (2007) this "spatial skill" that he called "metavisual capability" entail three complementary skills: being able to move fluently between two-dimensional and three-dimensional representations of a given model (translate); being able to mentally change the perspective from which a given three-dimensional representation is viewed (rotation); being able to operate on the representation itself, particularly in terms of taking mirror images of it (reflection and inversion). The development of these metacognitive skills is considered to be very important for several authors and include the reformulation of the school curriculum in general, general good practice in the use of representations by teachers and in text books and by specific cultivation of the skills involved. In the particular case of chemistry a necessary condition for a student to interpret specifics aspects of a model is that he has explicitly learned the conventions associated with the modes of representation, and apparently this is not done in a currently and systematic way.

As we can see teachers play a new and important role in instruction, especially in chemistry where the number of articles (where visualization term is used in context of chemistry) published between 2000 and 2008 has increased eighteen times (Bilbokaitė, 2008), which is a good indicative of the importance of the visualization in our classes. Therefore it's urgent to find out if the programs of pre-service chemistry teachers are supporting sensitive teachers for the impact of the apprenticeship strongly based in visualization tools (3D concrete models, statics or dynamics virtual 2D and 3D images, simulations, animations, interactive software's, etc). It's also important to know what conceptions about visualization, use of representations and images they have.

Methodology of Research

We adopted a qualitative research in our study, applying a questionnaire to a class of 24 pre-service chemistry teachers course from University of São Paulo (USP), São Paulo, Brazil. These students had a range of academic backgrounds, but the most important is that 8 of them had no experience in teaching, but the other 16 had already some teaching experience. We applied an inquiry with 12 open questions seeking to know what conceptions about visualization, use of representations, images they have, and at the same time what was the contribution of their graduated course on this issue. We also want to know if they feel that they are prepared to teach in this new teaching environment.

Results of Research

The first question of the inquiry was "Do you use visualizations in chemistry teaching classes?" As we said before 16 pre-service chemistry teachers had already some experience in teaching. They answered as teachers to the questions the other answered as students of a graduation course. When we analyzed all the answers, we found that only one of the 16 students that has some teaching's experience said "No", all the others said "Yes", and when questioned (second question) about the frequency (seldom, often, very often), the majority answered "often".

To the third question "What kind of visual tools do you usually use in your classes (3D concrete models, virtual 2D and 3D images, statics or dynamics, simulations, animations, videos, etc)?", the most of them said that they use virtual 2D statics images and 3D concrete models and a few of them said that they also use simulations, animations and videos on their classes. To the fourth question "Why do you use visualizations in your classrooms?", we found two different opinions, a large group said that it was to make the learning easier - *The visualizations help students on the more abstract concept* - and others said that was to increase the motivation – "*break the monotony*"- , and few said that it helps to make connections with the quotidian of the students.

To the next question" What do you perceive by visualization?" the large group answered - *Visual tools* – others said – *The use of images, models and videos* - and some said watching and making connections.

To the sixth question "Do you think that students need some special skills to learn using visualizations?", the large majority answered "No", a few of them said "Yes", but without specifying any skill, and one student said - *The students will need lesser skills, than in a class without the use of images, because they make easier the apprenticeship*.

To the next question (seventh)"How you define image?" we achieved several different kinds of answers. Some graduates answered only –*"representations"* , but others said -*"figures"*- or " *a way of communication*"- , -"*something concrete*"- , -"*photos*"-, -"*illustrations*"- and we have also a few graduates that tried to relate image to something that is built by our brain or a way to express ideas and thoughts. One graduate said that it was everything different from text.

To the eighth question" Do you find any special reason to the frequently use of models in chemistry instruction?" most of the them said that the use of models help student's comprehension of the abstract concepts that we find in chemistry, some of them said that it's usage increases the class dynamic, and one graduate said – *"Chemistry science is full of models, so when we learn chemistry we must use models"*.

The ninth question was "Did you ever read something about the issue visualization? What? Only four graduates said "Yes" but they don't remember what it was, the other twenty graduates said "No" or that they don't remember.

To the tenth question "How do you define visual capability?", when we analyzed all the answers we found that a large number of graduates didn't give any type of answer, and some said that –*"Visual capability is to be able of interpret or understand an image*".

The eleventh question "Do you think that your educational training allows you to be sensible to this issues related with instruction strongly supported on computers and visualization tools?" The majority of the graduates said "Yes", but most of them also said that it was necessary another deep approach, they talked about this superficially in some disciplines. The rest of the graduates said "No", some of them, just said that they never talked about this issue, others referred that - "*With what we discuss in our formation we won't have conditions to work properly with this kind of instruction.*"

Finally to the last question "Throughout your educational training has this issue been discussed? Do you believe that in the specific case of chemistry instruction this issue is fundamental in the teaching process (to the teacher) and learning process (for the student)?" According to the eleventh question the most part of the graduates said that they had discussed a little bit this issue, and they believe that is very important for the chemistry instruction. The other graduates said that they never discuss this matter in their graduation, but they thought that it is important to have some training in this area.

Conclusions and Discussion

As we can see by our results only one of the 24 pre-service chemistry teachers said that he never used visualizations as a teacher or a student. The result obtained in this sample is coherent with several studies that emphasize that the ready availability of powerful computers made this visualization tools very popular, and now it is very difficult to find novice students, expert students or even teachers in exercise that have never had any contact with this tools.

The results of the second and third questions reinforce these notions, the use of these tools is increasing in number and frequency, the classroom dynamics is changing, and the information is being displayed in many forms. Textual and visual information sources are at least competing side by side. These sources differ in the fact that, textual information presents information in a linear sequence, whereas visual information sources provide all the information to the learner simultaneously (Thorndyke & Stasz, 1980; Larkin & Simon, 1987). When we have a textual display, the cognitive processing is directed by the structure of the text, but when we have visual display the processing of information is directed by the learner, so additional attentional processes for acquiring information from scientific visual information is needed (Gobert, 2007). Thus, teachers must be aware of these demands and find knowledge acquisition strategies for acquiring information from complex visualizations in chemistry.

Continuing to analyze our inquiry results we can conclude that there is a group of teachers that still use the visualization as an entertainment, *to break the monotony*, to make classroom more interesting for students, but they don't valorize in terms of model-based teaching and learning, many times the student are not engaged with the visualizations. But, we also found a large group of teachers that are beginning to realize the potential of visualization tools; they have the perception, sometimes through their own experience or by reading some studies that they can get better learning results with the aid of visualizations, even thought, as we could see in several answers, they don't have theorical knowledge in this area.

This is completely confirmed in the answers to the direct question "What do you perceive by visualization?" all the graduates related the tool or type of display with the definition and nature of visualization. We think that probably this is the most common situation; teachers aren't yet sensible to the nature of the processes that underlie this learning, which is very depending of the visual perception of the learner. In this type of learning the construction of the knowledge is supported by how the brain deals with external visualizations and builds their own *internal model*.

Following the answers to the inquiry we can be more certain that there is a lack of training in this area, revising the sixth question "Do you think that students need some special skills to learn using visualizations?" this graduates show that they don't make distinctions between learn from textual displays and learn from visual displays. Even those who said yes to this question couldn't specify what kind of skills students must have to learn from visualizations. First they don't show any particular understanding that is necessary to improve metavisual competence on the students and that they must know previously the codes of representation, the conventions that underlie the visualizations, and second it seems that some of them begin to believe that visualizations could be a panacea for teaching some difficult scientific topics. These situations can lead students to build misconceptions or complete failures in the learning process. A poorly designed and implemented visualization is no better than a poorly designed lecture, an incoherent textbook explanation, or a rambling conversation, without the use of appropriate cues, colors, designs and organizations, students are less likely to know what to attend to, and what is being conveyed by the visualization (Rapp, 2007).

When we asked them to define images, they show some reasonable understand, like we mentioned before most of the graders write "representations", "figures". They show that in most cases they make the distinction between object and images, but we found also some incomplete ideas about this issue that, they never considerer the existence of mental images.

On the eighth question we found again that is some missing training in this area, even they have the perception that using models helps students understanding the complex and abstract concepts of chemistry; they don't show any theoretical background that supports that perception.

Empirically, by their own experience as students or as teachers, or by readings they know that visualizations can lead to enhanced learning beyond traditional teaching techniques. Only one graduate related the importance of models in science with their role in science education. Chemistry science is full of scientific models that can function as a bridge between scientific theory and the world-as-experience, as simplified depictions of a reality as observed, produced for specific purposes, to which the abstractions of theory are then applied, or be idealizations of a reality as imagined, based on the abstractions of theory, produced so that comparisons with reality as observed can then me made (Gilbert, 2007), so it's expected that these models are important in science education.

Analyzing our inquiry outcomes we also found that only four graduates said that they had read something about this issue but they don't remember specifically what. Once again this confirms that their chemistry course may not introduce these novel tools with effectiveness.

To the question "How do you define visual capability?", as we referred before most of the pre-service chemistry teachers simply didn't give any answer, it show that they feel uncomfortable with this issues. Literature in learning theory present an emergent field of research that is focused in the importance and development of "visual capability", "metavisual capability" (Gilbert, 2007) and "representational competence" (Kozma & Russell, 2007). The first two terms are related with internal representations of information and experiences from the outside world, the process of mental models construction and the skills needed for these operations, the last term is related to the skills and practices that is needed to a person build and use a variety of representations or external visualizations, to think about, to communicate with their peers, etc.

The last two questions of the inquiry address the opinion of the graduates about their training in this area in their graduation course and the degree of importance they attributed to this new field. As we referred earlier most of them said that they discussed these topics in a superficial way, and they feel that they aren't prepared to work properly with this type of teaching. Almost all of the graduates think that it is important to have some training in this area that allows them to apply these new teaching strategies in a useful way.

As a final conclusion we can say through this sample that is necessary to improve the educational training of our future chemistry teachers and supply them with all the theoretical background necessary for them to apply this new tools with effectiveness in chemistry teaching.

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