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USING CONCEPT MAPS AS A STRATEGY TO TEACH PHYSICS, IN PARTICULAR THE TOPIC OF ACOUSTICS

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Abstract This poster is the outcome of a thinking-acting research on teaching strategies developed in a constructivist learning environment in the classroom. The methodological work was done during Acoustics lessons in the subject of Physics and Chemistry in a Portuguese basic school. This poster refers ***only to a part of the overall research we developed***, involving concept mapping, the focus subject of this meeting. In this poster some general statements are made on constructivist learning environments in the classroom, particularly on the contribution that concept maps, as metacognitive tools, have for the improvement of "cooperative learning", which actually is one of the important features of the constructivist learning environments in the classroom. After that, we consider the analysis of some concept maps, which were one of the several tools used used by the students, and which were made by them during cooperative tasks, step by step, as the topic of Acoustics was being taught. The topic Acoustics was chosen because it is a relevant subject for an approach centred on the interaction STSE (Science – Technology – Society-Environments), and it has seldom been adequately handled by the teachers and the authors of schoolbooks in Portugal. We believe this is a subject that has become decisively important, particularly in a social perspective, and has influenced essential aspects such as the quality of life of human beings, their musical culture, and even the physiological knowledge of their own body. Nowadays it is known that the changes that are intended to be implemented in the educational system largely depend on the changes that will take place in the teachers' practice. For some authors, this change has to do with the building of constructivist and researching environments in the classroom, which will be able to lead the students into a meaningful learning by means, in this particular case, of Acoustics as the Physics topic.

1 Introduction

Teaching methods, being based on a careful consideration of constructivism in its epistemological, psychological and educational aspects, contrast with the traditional ones. The teachers who use the traditional method found their teaching almost exclusively on the presentation of the contents to be learned, with all the imperfections which Ausubel points to the expository teaching, which is used in schools (Ausubel, 2003, p. 7, 47), in which the teacher uses *"pure verbal techniques"* too early, presenting information very often in a tactful and arbitrary way, without realizing at all if the students have the necessary cognitive readiness, or if they can learn meaningfully.

Bell and Pearson (1992, mentioned in Gil-Pérez, 2002) say it is not possible to change this behaviour of the traditional teacher unless he changes his epistemology, his ideas about how scientific knowledge is built, and his viewpoints about science.

On the other hand, the science teacher will only change his behaviour in the classroom if he respects the theoretical ideas connected to the cognitive constructivist learning of different authors such as Vygotsky's (1991, 1994, Ausubel's (2003), Novak's (1981, 1999) and Gowin's (1990-1999), among others.

Knowledge is not piling the discovered facts, given to the students as a liquid in a siphon from one vase to another. You gain knowledge learning it in a very personal and idiosyncratic way, even though this process is very much influenced by the social interaction of learners, where the teacher's teaching, as a social process it is, becomes crucial.

As Novak and Gowin say, (1999, p. 36): "*Learning the meaning of a piece of knowledge requires dialog, exchange, sharing and sometimes compromise*." To share indeed, but not sharing learning. "*Learning is an activity which can't be shared; it is actually a question of individual responsibility. On the contrary, meanings can be shared, discussed, negotiated and are subject to a consensus*" (*idem*). Learning is therefore a personal construction in which the cultural agents are crucial for this construction.

The constructivist concept assumes teaching as a *"common, shared process, where the student, thanks to his teacher's help, can show himself progressively good and autonomous in problem solving, concept using, having certain attitudes and in many other questions"* (Solé and Coll, 2001, p. 22).

Thanks to the interaction and help from both his teacher and mates, each student can very successfully work or perform a task which he would not be able to do if he worked individually. By interacting and collaborating, students will be changing their knowledge schemes and heir meanings as they are reaching a greater and greater autonomy and the power to use their own thinking schemes in the face of new and more and more complex situations and tasks (Vygotsky, 1991).

2 Constructivist Learning Environments

A constructivist learning environment is, according to Wilson (1996, in Jonasen et al., 1999, p. 194), "a place where learners work together and support each other as they are using a variety of tools and sources of information, following the orientation of the learning purposes and the activities of problem solving." Building such an environment is not only the teacher's exclusive responsibility but it has a lot to do with the way the teacher faces teaching and learning. This must definitely be accepted as every student's personal and idiosyncratic activity and he must be given controlled freedom and shared responsibility to learn in a stimulating environment of dialogue and cooperation, in which the teacher is a supporting and facilitating agent, a fundamental mediator (Valadares, 2001, p. 12).

Several researchers, amongst them Jonassen, 1994, Savery and Duffy, 1996, Brooks and Brooks, 1993, 1997, 1999, Solé and Coll, 2001, Valadares, 2001, 2005, have made clear that the good environments in the classroom can significantly improve the students' learning. Brooks and Brooks (1993, 1997, 1999) have described these environments, comparing them with the ones of the traditional learning.

Traditional Learning Environment	Constructivist Learning Environment
- the curriculum, as a whole, is presented in parts, clearly showing basic skills; - the curriculum is strictly followed and overvalued; - curricular activities are essentially based on texts from the school book, its instructions and workbooks; - students are considered like tabulae rasae, where the teachers' information is written down; - in general terms, teachers confine themselves to spread knowledge among students; - teachers only look for the students' correct answers to validate learning, undervaluing and wasting the answers which show their mind patterns; - evaluating learning is seen separate from teaching, it is episodic, with sumative concerns and made essentially with tests; -students work essentially alone.	- the curriculum is presented as a whole and only afterwards is it divided into parts, showing the principal concepts; - questioning and listening to students is considered important; - curricular activities are essentially based on primary data and information sources and manipulative materials; - students are considered like thinkers who have personal representations of the world they live in; - generically, teachers interact with their students, worrying about their learning environment; - teachers look for their students' viewpoints with the purpose of understanding their conceptions to explore them in their learning; - evaluating learning is diversified and a part of teaching and is based on observing the students' activity systematically and the work they do; - students work essentially in groups.

Table 1. *A look into school environments (adapted from Brook and Brooks, 1993, 1997, 1999)*

One of the important requisites of constructivist environments is that students cooperate with each other for the solution of the tasks which are proposed to them and which should always be small, stimulating challenges for their learning and cognitive development. Having cooperative activities, when it takes place in an adequate environment, is enriching as it often leads to the students' meaningful learning. Several authors, such as Johnson, Johnson & Holubec (1994, 1999), Slavin (1995,1999) refer to researches made in this area which point to advantages of using them in the classroom.

3 The role of Concept Maps

A concept map is a graphic organizer which uses schematic representation to hierarchically organise a set of concepts, connected by means of words in order to build meaningful statements. Showing meaningful relationships between concepts in the shape of propositions, the concept map reveals each student's comprehension and knowledge structure (Novak and Gowin, 1991).

The negotiation of ideas among students, on the basis of the concept mapping individually and/or by groups, particularly when it finally is conveniently monitored by the teacher in the class-group, helps them deepen the meaning of the knowledge upon which the maps were built. This is what Novak and Gowin (1999, p. 1) tell us when they say, "*concept mapping is a way to help students and educators see the meanings of learning materials*."

The concept map made by a student shows his cognitive structure. It reveals the way in which he could/not, better or worse, assimilate the concept structure of the source of knowledge on which the map was made. When it is made and used in a working group and being shared by all students, the concept map "*allows to change ideas and stimulate the reflexive thought*" (Novak and Gowin, 1999) and it can become an excellent process of building knowledge in a social environment which is cooperative and constructivist. Besides, they are excellent to detect the students' early conceptions (they are a good tool for a formative evaluation), making the students recognise new relationships and new meanings (often stimulating their creativity).

To put it in a nutshell, concept maps are excellent tools for a cooperative activity that will lead to a very meaningful learning; they are also useful for a good evaluation at the service of this learning (Novak, 2000; Valadares, 1998).

4 Research Methodology

4.1 The Sample

The empirical part of the research took place in the school year of 2004/2005, in a school in Lisbon's neighbourhood, in two classes taught by the same teacher. Class A (N= 28) was the experimental goup and Class C (N= 27) was the control group. In the first class a constructivist and researching environment was created, while in the second one the chosen environment was traditional, with a purely expositive teaching and very few chances for the students to cooperate among themselves.

The characterising of both classes was made with collecting data about the students' personal identification, namely their age, gender, the composition and characterisation of their family members, occupation of extra-curricular time, their school progress and the previous year's grades. To these data we added the ones collected in the results quantitatives of a pre-test and in the analysis of concept maps made by the students before the teaching of Acoustics. All this collected information allowed to conclude that both groups were equivalent at the beginning, which was essential in the strategy we used: the quasi-experimental plan.

4.2 Data gathering for concept mapping

Collecting data in our research was based upon the combination of a qualitative method, consisting of a participating observation, distant and direct, with a quantitative method, based on a quasi-experimental plan. ***Although different tools for collecting data have been used, we will only mention the ones that concern the concept mapping.***

In Table 1 we show the various moments of concept mapping, the methodology we used, as well as the total number of maps made by the students in both classes:

Moments	Methodology	Experimental Class	Control Class
Before teaching Acoustics	Individual	28 maps	27 maps
While teaching Acoustic	Cooperative work	30 maps	----------
After teaching Acoustics	Individual	28 maps	27 maps

Table 2 *– Concept mapping by the students*

The same preparation for concept mapping was made in both classes before the research. The students of the two classes built the same number of concept maps about the same physics subjects with the same teacher, before the Acoustics teaching.

While the empirical work was being done, only the students of the experimental class worked in group and cooperated, while they were performing the tasks that had been assigned about the topic Acoustics.

This topic was divided into various blocks: production of sound, propagation of sound, sound phenomena, sound properties and audibility of sound, which includes aspects connected with sound pollution.

At the end of teaching each block, the students in each group made a concept map with the main concepts of each topic group. After that, the map was first analysed by the teacher and only afterwards was it discussed in each work group. During this discussion we made sure to confirm with the students the meaning they gave to the concepts, in order to get a concept improvement in relation to them. The students' maps were being progressively self-corrected as the result of the discussion that took place among students and with the teacher and, besides, they were enlarged with new concepts as they went to a new sub-section – *progressive mapping* – in a process of structuring and re-structuring each student's knowledge.

5 Results and conclusions obtained with concept mapping

The analysis made in each concept map was essentially qualitative and based on indications of authors such as Novak (1988), Moreira and Buchweitz (1993), Valadares and Graça (1998), Novak and Gowin (1999) and Mintzes, Wandersee & Novak (2000), as it is described in the figure 2.

	Before teaching Acoustics						After teaching Acoustics					
Avaliation	Weak		Acceptable		Good		Weak		Acceptable		Good	
Features	TE	TC	TE	TC	TE	TC	TE	TC	TE	TC	TE	TC
Hierarchising of concepts	✓	✓						✓	✓			
Linear structure versus ramified			✓	✓							✓	✓
Relative number of concepts adequate connected	✓	✓						✓	✓			
Links words	✓	✓						✓	✓			
Cross links	✓	✓					✓	✓				

Table 3- Qualitative evaluation of the concept maps organized by the students in individual work.

Based on the analysis of the students' concept maps, we could observe a concept evolution in experimental class (TE). However, this analysis showed some aspects where the students met a few difficulties. One of them was in establishing cross-links between concepts. It is not strange, since for students of this age it is not easy the integrative reconciliation of concepts, not only because their experience in using concept maps is short, but also due to the fact that not enough super-organised concepts exist in this field of knowledge at such an early stage. Another fact was the difficulty the students showed while discriminating some Acoustics concepts, such as, for example, the intensity of sound and the amplitude of sound waves, which they had studied in the sound properties. What concerns to the scientific accuracy of the links between concepts, we conclude that, in general terms, they were fairly acceptable.

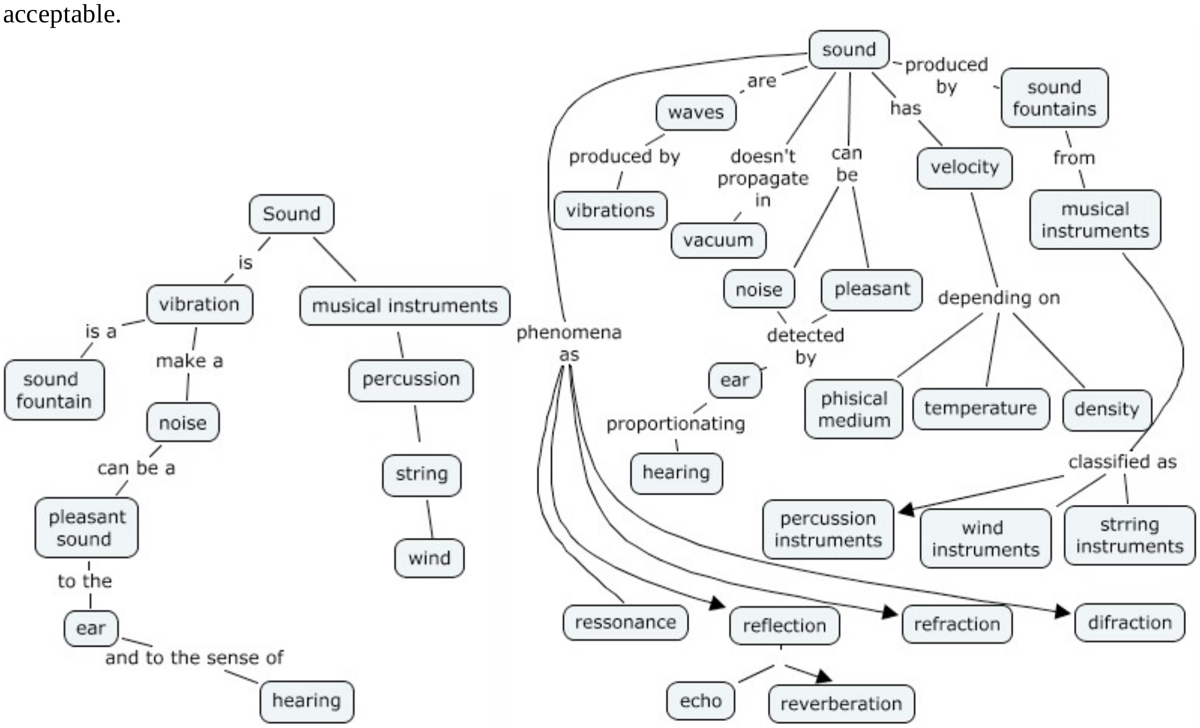

Figure 1. First and third map designed by the same group of students.

The results we obtained of the conceptual maps analysis before teaching Acoustic show the efficiency of concept mapping in the classroom, when the maps are made in a constructivist and investigative environment.

Obviously the generalisation of the obtained results is not legitimate, owing to the nature and the dimensions of the sample in this research; so a similar research with other students from other countries is desirable. We finished, as a mere example, with two concept maps made by the same work group of the experimental class during the teaching of Acoustics. The first map was made after learning the sub-topic production of sound, the second one after learning two other sub-topics, the propagation of sound and sound phenomena. We can verify some improvement in the reorganization of concepts, as well as the introduction of new concepts in a better map.

6 References

Ausubel D. P. (2003). Aquisição e Retenção de Conhecimentos: uma perspectiva cognitiva. Lisboa: Plátano: Edições Técnicas.

Brooks, J. G.; Brooks, M. G. (1997). Construtivismo em sala de aula. Porto Alegre: Artes Médicas.

Gowin, D.B. (1990,1999). Educating. Ithaca, N.I: Cornell University Press.

Johnson, D.W; Johnson, R.T.; Holubec, E.J. (1994, 1999). Los Nuevos Círculos del Aprendizaje: la cooperación en el aula y la escuela. Buenos Aires: Aique Grupo Editor S.A.

Jonassen, D.H. (1994). Thinking Technology: Toward a constructivist design model. Educational Technology, 34 (3), 34-37.

Novak, J. D. (1981). Uma teoria de educação. São Paulo: Pioneira.

Novak, J. D. (1988). Construtivismo humano:un consenso emergente. In Enseñanza de las Ciencias, 6 (3).

Novak, J. D. (1991). Ayudar a los alunos a aprender cómo aprender. La opinión de un professor-investigador. Enseñanza de las Ciencias, 9 (3), 215-228.

Novak, J. D. & Gowin, B. (1999). Aprender a aprender. Lisboa: Plátano Edições Técnicas.

Savery, J.R. & Duffy, T.M. (1996). Problem based learning: An instructional model and its constructivist framework. In Brent G. Wilson (Ed), Constructivist learning environments: case studies in instructional design. Englewood Cliffs, NJ: Educational Technology Publication.

Slavin, R. (1995, 1999). Aprendizaje Cooperativo, Teoría, Investigación y Práctica. Buenos Aires: Aique Grupo Editor S.A.

Solé, I. & Coll, C. (2001). Os professores e a concepção construtivista. In Coll, C.; Martín E.; Mauri, T.; Miras M.; Onrubia J.; Solé, I.; Zabala A., O construtivismo na sala de aula (p. 28-53). Lisboa: Edições Asa.

Valadares, J.; Graça, M. (1998). Avaliando . . . para melhorar a aprendizagem. Lisboa: Plátano Edições.

Valadares, J. (2001). Abordagens construtivistas e investigativas à actividade experimental . IV Encontro Nacional de Didácticas e Metodologias da Educação “Percursos e Desafios”. Évora: Universidade de Évora.

Valadares, J. (2005). Como facilitar a aprendizagem significativa e rigorosa da Física. Conferência do XVI Simpósio Nacional de Ensino de Física, organizado no Rio de Janeiro pela Sociedade Brasileira de Física.

Vygotsky, L. S.(1991) Aprendizagem e desenvolvimento intelectual na idade escolar. Lisboa: Editorial Estampa.

Vygotsky, L. S. (1994). A Formação Social da Mente. S. Paulo: Livraria Martins Fontes Editora, Lda.