Concept Maps: Theory, Methodology, Technology
Proc. of the First Int. Conference on Concept Mapping
A. J. Cañas, J. D. Novak, F. M. González, Eds.
Pamplona, Spain 2004

USING CONCEPTUAL MAPS IN PHYSICS CLASSES

Valadares, J.[(1)] *; Fonseca, F.*[(2)] *e Soares, M. T.*[(3)]
[(1)]*Universidade Aberta-Lisboa, jorgevaladares@netcabo.pt*
[(2)]*E.S.S.João do Estoril, FedoraFonseca@mail.pt*
[(3)] *E.S.M.Torga, mtms@mail.pt*
Centro de Estudos de Ciências e Matemáticas para o Ensino da Universidade Aberta

Abstract. This Poster follows, on the one hand, from the long-term use of concept maps in classes by one of the authors, and her reflection upon this use; it follows, on the other hand, from the fact that the declared theme is an important subject in the research being carried out by the other two authors. We begin with a necessarily-brief introduction to meaningful learning and its mechanisms, following Ausubel's and Novak's meaningful learning theory; we then refer generically to the concept maps, showing how we have both introduced them to pupils and used them in classrooms, and we conclude by presenting two examples (from the many that we could present) to illustrate not only the use that we have made of them, but also their usefulness. Basically, we will present some ideas that we have elaborated and discussed, and which are applicable in what concerns concept maps, and consequently submit them to discussion with the teachers and researchers present in this meeting.

1 Introduction

There are many authors nowadays who contend that classroom learning in can be improved if we understand how human beings create and value knowledge, as well as the psychological processes through which they understand it (Ausubel, 1980, 2003, Gowin, 1981, Novak and Gowin, 1999, Moreira, 1999, Valadares and Graça, 1998, Valadares, 2001). These and other authors give much importance to a constructivist theory, very parsimonious and attractive, which is the meaningful learning theory (MLT). Subjacent to MLT, in its present form, is the idea that each individual builds her/his own meanings in a certain subject on the basis of the interaction between her/his previous ideas on the subject, her/his idiosyncrasies, which include her/his own affectivity (feelings, emotions, etc.) and her/his interaction with the outside world. What an individual knows, in the broadest sense of the word – her/his complex *cognitive structure* – influences extraordinarily the way she/he will learns other knowledge (*Idem*). When powerful and relevant anchoring ideas, whether they are images, symbols, concepts, or relation between concepts, are incorporated in her/his cognitive structure (Ausubel calls these "subsumers") and she/he has an affective commitment to relate new knowledge to prior learning, she/he transforms the logical meaning of new knowledge into psychological meaning, learning meaningfully. That is: there is a non-arbitrary, non-verbatim, substantive incorporation of new knowledge into cognitive structure; what is incorporated in the cognitive structure is the substance of the new knowledge, of the new ideas, and not simply the words used to express them (Moreira, 1998). The new knowledge is thus interiorized, becoming part of the cognitive structure and also changing the concepts to which they related. In the learning materials, in textbooks, for example, the ideas are exposed in a linear way, but we admit that they will be interiorized by the pupil in such a way as to build a conceptual network in his mind, with a certain contextual hierarchy.

2 Concept maps and the Teaching of Physics

A concept map made by a pupil corresponds to a representation of the hierarchical organization of her/his cognitive structure (Wandersee, 1990), allowing the exteriorization of the singularities of that structure, which is very important in the day-to-day functioning of the classroom. In fact, the conceptions with which the pupil begins a learning task become more explicit, it reveals his more or less intuitive and erroneous thought, and when it is again constructed by the same pupil it allows him/her to schematically illustrate what was learnt, how it was learnt and to what extension the pupil's concepts were enriched.

The disclosure of the pupil "secrets of the mind", that "externalization" of her/his cognitive structure with the concept map, allows the teacher to make sense of the pupil misconceptions, how he/she establishes the hierarchy of the concepts, and how differentiates, relates, discriminates and integrates them. Therefore, "the construction of concept maps is a way of helping learners and educators penetrate the structure and meaning of the knowledge that they are trying to understand." (Novak and Gowin, 1991, p.1)

To reveal that the pupil's mind produced a good progressive differentiation of the concepts, her/his concept map must reveal a hierarchy of concepts, that is the more general and inclusive concepts should come on top of the map, and the more specific and less-inclusive concepts should be placed progressively below. A map should also show many cross-links between the concepts that cross it from one side to the other, in order to clarify a good integrative reconciliation of concepts in the cognitive structure of the learner who produces it.

Our experience with concept mapping and our awareness of the research on this subject (in our Center of Studies) permits us to state that they facilitate the construction of meanings from the contents of a school text, for example. We believe that the fact concept maps have their foundation in a constructivist vision of the production of knowledge, as well as in the Meaningful Learning Theory (MLT) make them very important tools to improve learning.

As teachers and researchers we have been using concept maps, one of us for about twenty years, mainly in the teaching of Physics. We could realize that they satisfy many useful targets in the teaching of that subject. With little space, we only can attach here two examples. The first one is a map constructed by an 11^{th} grade pupil in a subject called Physics Laboratorial Techniques. He was invited to construct this map after having performed an experimental activity in which he accurately determined the mechanical equivalent of heat, and after having elaborated a report on that experiment for which he was given a B mark. Witness the pupil's misconceptions, particularly the traditional confusion between heat and temperature. The second map was constructed by one of us in order to structure the planning of an 8^{th} grade curricular unit entitled 'Light and Vision'. This map was constructed according to the thematic sequence indicated in the National Curriculum for the Instruction of Physics and Chemistry.

3 Conclusions

Concept maps are metacognitive tools that allow the representation of knowledge structures in thematic fields and the disclosure of "secrets" in the cognitive structures of students of all ages. As a learning strategy, concept mapping stimulate learners' commitment and involvement in negotiation of ideas, which is very important to learn meaningfully. As a teaching support, concept maps are also helpful, as they permit the establishment of networks of concepts that progressively differentiate a central concept in a coherent, structured and integrated manner, guiding the sequence of teaching.

Our experience confirms the research results that point to concept mapping as an efficient strategy for meaningful learning. With them, we could help students to organize their knowledge and to overcome their difficulties. Concept mapping allowed us to operate at the knowledge reorganization level. In opposite to the curricular linear structures, our approaches conducted many times to coherent and structured networks in the pupils' cognitive structures, facilitating the store in their long-term memories. Our strategies based on concept maps support a pro-active formative assessment and strengthen its didactic role. Using this instrument means giving a new meaning to education, as well as a new meaning to the concepts of teaching, learning, and assessment of learning.

4 References

AUSUBEL, D. P. (1981). *Psicologia Educacional. (Tr.)* Rio de Janeiro, RJ: Interamericana.

AUSUBEL, D. P., NOVAK, J. D. e HANNESIAN, H. (1980). *Educacional Psychology: A cognitive view (2ª ed.).* Nova Iorque: Holt, Rinehgart and Winston.

AUSUBEL, D. P., (2003)**.** Aquisição e retenção de conhecimentos: Uma perspectiva cognitiva. Lisboa: Plátano: Edições Técnicas.

BIEEZUNSKI, M. (1997). *História da Física Moderna*. Lisboa: Instituto Piaget.

CONCEIÇÃO, L. ; VALADARES, J. (2002. Mapas conceptuais progressivos como suporte de uma estratégia construtivista de aprendizagem de conceitos mecânicos por alunos do 9º ano de escolaridade – que resultados e atitudes?. Comunicação oral no I Encuentro Ibericoamericano Sobre Investigación Básica da Educacion em Ciencias en Burgos.

CONTERAS, L. C. (1997). El uso de mapas conceptuales como herramienta educativa *en* el ámbito de los números racionales*. Enseñanza de las Ciencias,* 15 (1), pp.111-122.

FERNÁNDEZ, T. (2000). Los mapas conceptuales como estrategia de aprendizaje e evaluación. Comunicação oral no III Encontro Internacional sobre aprendizagem significativa, realizado em Peniche e organizado pela Universidade Aberta.

FERREIRA, J. A. e FRANCO, S. (1995) Conceitos Elementares de Óptica Geométrica e sua aplicação à Óptica da Visão, Gazeta da Física, 18 (29), 6-11.

FERREIRA, J. A., FRANCO, S., (1995). Conceitos Elementares de Óptica Geométrica e sua Aplicação à Óptica da Visão: Gazeta da Física, 18(2), 6-11.

GALAGOVSKY; L.R. (1993). Redes Conceptuales: base teórica e implicaciones para el proceso de enseñanza-aprendizaje de las ciencias. *Enseñanza de las Ciencias* 11, (3), 301-308.

GONZALEZ G. (1992). Los mapas conceptuales de J.D. Novak como instrumentos para la investigación en didáctica de las ciencias experimentales. *Enseñanza de las Ciencias* 10, (2), 148-158.

HANKS, A., HANKS, T. (1995). *Óptica Básica.* Manual de instruções e Guia Experimental para o Modelo OS-8515 da Pasco Scientific, Roseville.

HECHT, E., (1991). *Óptica*. Lisboa: Fundação Calouste Gulbenkian**.**

JENKINS, F.A., WHITE, H. E. (1982). *Fundamentals of Optics*. New York: Fundamentals of Optics.

MOREIRA, M. A. e BUCHWEITZ; B. (1993). *Novas Estratégias de Ensino Aprendizagem*. Lisboa: Plátano Edições Técnicas.

MOREIRA, M. A. (1999). *Aprendizagem Significativa.* Brasília: Editora Universidade de Brasília.

NOVAK, J. (1977). *A Theory of Education*, Cornell Univers. Press, Ithaca.

NOVAK, J. (1990). *Human Construtivism***:** A Unifification of Psychological and Epistemological Phenomena in Meaning Making, A paper presented at Frourth North American Conference on Personal Construct Psychology, San Antonio, Texas, july 18-21.

NOVAK, J. D. (1977/1981). *Uma teoria de educação*. São Paulo, SP: Livraria Pioneira Editora.

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.

ONTORIA, A. e BALLESTEROS, A. e CULVA, C e GIRALDO, L. e GOMEZ, J. P. e MARTIN, I. e MOLINA, A. e RODRIGUEZ, A. e VELEZ, U. (2000). *Mapas conceptuais, uma técnica para aprender*. Rio Tinto: Edições Asa.

SANSÃO, M. (1997). *A aprendizagem em Física com recurso a mapas de conceitos*. Tese de mestrado. Lisboa: Universidade de Lisboa – Faculdade de Ciências.

SEQUEIRA, e FREITAS, M. (1989). *Os mapas de conceitos e o ensino aprendizagem das ciências.* Revista Portuguesa de Educação, 2 (3), 107-116.

VALADARES, J. e GRAÇA, M. (1998). *Avaliando para melhorar a aprendizagem*. Lisboa: Plátano Edições Técnicas.

VALADARES, J (2001). *Abordagens Construtivistas e Investigativas à Actividade Experimental*- Comunicação Oral no IV Encontro Nacional de Didácticas e Metodologias da Educação- Percurso e Desafios Universidade de Évora.

WANDERSE, J. H. (1990). Concept mapping and cartography of cognition. Journal of Research in Science Teaching, 27(10), 923-936.

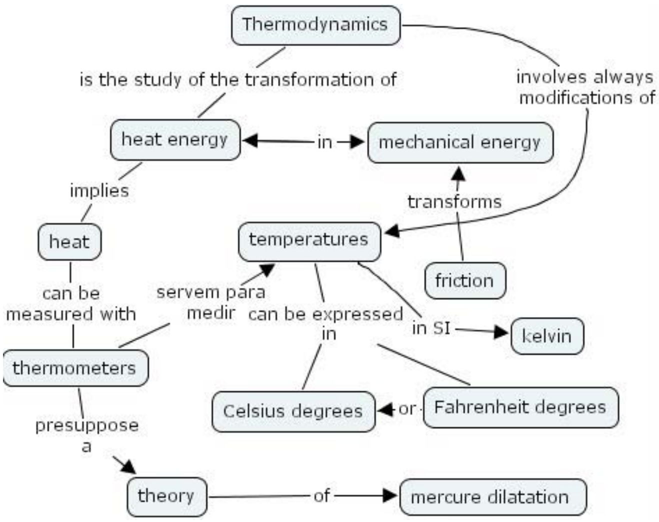

Fig 1. Concept map constructed by an 11th grade pupil, in a Physics Laboratorial Techniques classroom, after having performed a good report on an experimental activity in which he accurately determined the mechanical equivalent of heat. The map revealed that the student had the traditional confusion between heat and temperature and the wrong idea that there is a variation in the bodies' temperature involved in all thermodynamic phenomena. Questioned about one of the statements of the map, "calorific energy implies heat", he revealed also a substantialistic conception of heat. This changed completely the didactic strategic with other students that made the same experimental work after him and implied some decisions concerning the conceptual difficulties of that student.