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

CONCEPT MAP AND INTERACTIVE ANIMATION

Romero Tavares
Departamento de Física - Universidade Federal da Paraíba - BRASIL
romero@fisica.ufpb.br, www.fisica.ufpb.br/~romero

Abstract. We present a way to connect the simultaneously using of interactive animation and concept map at a learning event. Using a theory accepted by scientific community to explain certain phenomena, we can make available an animation that simulates the dynamics of reality using educative software. In this way, each concept of the map may be showed as an interactive animation. Concept map may act as a global knowledge framework of the matter we are studying and the interactive animation will deepen the contents that may be modelled. The interactive animation is characterized as an efficient advance organizer. Both components mentioned above joined with written text work as a support for the autonomous learning and also support distance learning through Internet. An example of a real situation may be considering a text formatted in HTML in a Web Page, a concept map an interactive animation constructed through the softwares CmapTools and Modellus respectively. In this work we suggest that an initial contact of the student with information will be through a pedagogical material done by specialists. In a second moment the learner will construct his/her knowledge in a lonely way or sharing meanings with colleagues in the Internet through CmapTools.

1 Introduction

Human being always has used symbols to share meanings with his/her similar. In a coarse attempt to communicate with others, people use gestures. Paintings are messages that survive without the presence of its authors, and can exist through the time. Later appears the written language that has been inspired in events of Nature. More lately have appeared various written languages that would be symbols without connection with daily events, and exist till now like diverse alphabets: Greek, Latin, Cyrillic, Sanskrit etc.

Using this various static symbols the human being succeeded in maintain relevant information through the time and spread it in other sites. Using written words, paintings and maps, the human knowledge have been preserved and spread. The mobility of the medium that preserves the information make possible an autonomous learning of people that could use these materials.

The possibility of a wide and autonomous learning came true in XIX century in USA through distance education courses that uses the regularity and reliability of communications at that time. The diffusion of information makes easy the scientific literacy, and by the way, makes easy the construction of a suitable knowledge according to scientific paradigms.

Nowadays the computer is used like an artifact that stores handle and diffuse information. However we are not using its complete potential as a pedagogical tool. To encourage the learning using computers is necessary to use systems adapted to human way of thinking and reasoning.

2 Meaningful learning

Meaningful learning imply the acquisition of new meanings, and is necessary three conditions to happen: the instructional material structured in a logical manner, the existence of knowledge in the cognitive structure of the learner relationable with the instructional material, and an explicit wish of the learner to make connections linking the new concepts with the previous ones. These existing previous concepts are called subsumers.

In Physics, for example, if the concepts of force and field already exists in the learner cognitive structure, they serve as subsumers for new information concerning a certain type of force field, e.g., the electromagnetic force and field. Thus, during meaningful learning, new information is associated with the existing relevant subsumers in cognitive structure. This association, in turn, results in further growth and modification of the existing subsumer. Thus, subsumers can be relatively large and well developed or they may be limited and poorly developed depending on the frequency that meaningful learning occurs in conjunction with a given subsumer (Moreira, 1977).

Actually the usual learning-teaching process is supported mainly in textbooks. These books are structured in such a way that their topics are chained in a logical sequence, and each topic has its own internal coherence. This material is called potentially meaningful when the learner is able to relate it with the previous knowledge existing in his/her cognitive structure. It is said that meaningful learning changes logical meanings to psychological meanings, in the sense that learner internalize the knowledge, transforming it in an idiosyncratic content. This is the way that takes place when one learns meaningfully, the way that new information is embodied in the cognitive structure of the learner using his peculiar way to do this. The previous knowledge will be changed with this incorporation, and the new knowledge will be modified by the specific way that the absorption takes place. When two persons learn meaningfully the same content, both share same meanings about the essence of this topic. However they have personal opinions about others aspects of the content, because the idiosyncratic construction of this knowledge.

Sometimes the learners' subsumer is not sufficiently stable and differentiated to anchor adequately the new information, a new concept. In these circumstances Ausubel (2003) suggests the use of advance organizer. The principal function of the advance organizer is to bridge the gap between what the learner already knows and what he needs to know before he can successfully learn the task at hand. Considering its characteristics defined below, we can state (Tavares & Santos, 2003) certain types of interactive animation as advance organizer.

In Physics, models of reality are built using equations, whose solutions are functions that depend, usually, of position and time. A classical representation of the motion of an object can be obtained through Newton's Laws or Lagrange's Equations. In an interactive animation we show the motion of an object and at the same time we can construct graphs of temporal evolution of position, velocity and acceleration. When an object moves we have the focus on its motion and not to it causes, that is the forces which acting on it. In an interactive animation we can represent the forces that are acting as arrows above the object. When the object moves, it carries the arrow that will change accordingly to the change of the force it represents. Without loss of generality of the model, is possible to represent visually abstract details of the motion such force represented by vectors.

The main distinction between abstract and concrete items is in terms of its specificity or neighborhood of our concrete empirical experiences (Ausubel, 2003). The interactive animation makes possible this concrete experience. The interactive animation makes possible the visual perception of Physics functions (abstract or not), and in this way conduct to a level of abstraction of reality attained only by some few learners.

Rote learning occurs when relevant concepts or subsuming concepts do not exist in the individual's cognitive structure. In such case, new information must be arbitrarily stored in the cognitive structure, that is, it is not linked with existing concepts or, in other words, it is rotely learned. This does not mean that rote learning tasks are mastered in a cognitive vacuum. They are relatable to the cognitive structure but only in arbitrary fashion that does not result in acquisition of meanings. An obviously example of rote learning in Physics, is the rote memorization of formulas, but our previously example can be used again: if the general ideas of force and field were not available in the learner's cognitive structure, he could only rotely learn that an electric charge generates an electric field that exerts a force on a second charge placed in such a field (Moreira, 1977).

In deep, we are talking about the choice of to be or to have (Fromm, 1987). It is not necessary much waste of emotional energy to have something, it is only need to pay the price. However it is necessary much effort to be a certain kind of person and meaningful learning implies in a critical thinking. There are not needs of internal changes in a rote learning. The information is fixed literally, used in exams and then forgotten. The information does not change to knowledge, in the cognitive structure of the learner. Rote learning does not change the way that the learner sees his environment as meaningful learning does.

3 Concept map

Concept map is a concept structurer. It has been proposed by Novak (Novak et al, 2000) as a way to organize hierarchically the concepts and propositions of the students. Novak and his research group were interested to study the evolution of students learning through an audio-tutorial approach. Concept map has appeared as a natural way to measure the growth in a cognitive structure.

Measure and map the cognitive structure of a person is only one of the possible utility of this pedagogical tool. To analyze a concept map of a specialist is a nice way to begin the study of a domain, because it shows the relevant connections between important concepts, and a global sight of the whole content. Otherwise, when the beginner is constructing his map, at the same time he is explaining his knowledge about the content. In this process, per se, he will clarify his facilities and difficulties in the understanding of the concepts. At each moment he will have radiography of his understanding of the content, and can return to the sources of information to answer his questions in such a way to construct his own knowledge.

As the Internet appears it will be possible to explore enormously the possibility of sharing the construction of concept map (Cañas et al., 2001). In the literature, there are a certain number of works in order to examine the interaction patterns among participants, that is, how the participants use communication processes to accomplish the concept-mapping tasks (Chiu el al., 2000).

One of the most useful software tools available is CmapTools (Cañas et al., 2004), developed at the Institute for Human and Machine Cognition (IHMC). This software can be downloaded at no cost for school use at cmap.ihmc.us. Although there are a number of software programs that can be used to make concept maps, CmapTools has been explicitly designed to make concept mapping easy. CmapTools also provides some special features such as the ability to organize discussion groups, locally or at a distance, using the Internet, attachment of icons to concepts that can access pictures, videos, URLs, other concept maps, or any other resources that can be digitally stored in a local or remote computer or server (Novak, 2003). Through these icons in CmapTools we can execute another program with animations, for example Modellus (Teodoro et al - 2000).

Using CmapTools, instructional mediation can be based on an expert's knowledge as shown in a simple concept map providing a kind of "conceptual scaffolding" that can serve as a starting point for a learner. Then the learners progress in their own idiosyncratic way to build their knowledge structures and represent them as a more complex, more elaborated maps (Novak - 2003).

To begin the construction of a concept map we have to choose the most inclusive concept of the content. Then we choose less inclusive concepts that will be connected to the first one by connective words or expressions. The nest stage will be done by putting in the map more specific concepts than the previous ones. We have a hierarchy root, beginning with more inclusive concepts, and through ramifications we go to less inclusive concepts. This structure follows what Ausubel (1980, 2003) said, that the most natural way to acquire knowledge is through progressive differentiation. However we can have lateral connections between concepts without a need of hierarchy, showing an integrative reconciliation of concepts. Novak (1999) said that this kind of connections is associated to original and creative cognitive constructions of human being.

4 Interactive animation

When something moves in front of us, our attention is awake by this event and we analyze what is happening. This kind of behavior does not exist only between human beings. It is interesting to note that inside the whole hereditary animal perceptions there exists a differentiated perception directed to velocity, and it is found specialized cells in frogs responsible to do this work (Piaget, 2002). We could justify this alert and deep perception to movements like a need for the survival of animals, in such a way to escape from its predators. And if we consider the question form the eyes of the predators there is a need to measure the possibility of capture of its prey. The human being maintains yet this specific behavior, signal from the tomes that we could be predators or preys. Pedagogical tools may strengthen this human being tendency to follow movements if it permits his intervention while the motion goes on. Modellus (Teodoro et al., 2000) is a pedagogical software suitable to do this job because it is friendly and beginners can do animations very easily with it.

Digital technologies make it possible to examine the physical world at an increasingly fine scale, both in space and time. They also make it possible to simulate the world in more lifelike ways, for example, in modeling the complexity of natural systems such as climate. Researchers have direct access to increasingly sophisticated instruments, and to the archived data from those and other instruments.

In fact, many researchers speak of computation as the "third modality" of scientific investigation, on a par with theory and experimentation. For many years computers have been used to simulate natural phenomena, through statistical methods—such as the Monte Carlo codes used to analyze the transport of neutrons in fission chain reactions—or deterministic solutions of the equations of motion for complex systems—such as the molecules comprising a physical system or the stars contained in a galaxy. Today the extraordinary power of advanced scientific computers enables predictive simulation of complex phenomena directly from fundamental microscopic principles. Numerical simulations may tend to draw more closely together modelers, theoreticians, and experimentalists, because their tools (digital sensors, simulations, networks, and databases) are increasingly related. Digital tools enhance our understanding of natural phenomena. They do not reduce the importance of reliable experimental and theoretical analyses (Duderstadt, 2003)

Animation offers two perceptual attributes beyond those of smile visuals: motion and trajectory. Therefore, animated visuals should be most effective when these two attributes are congruent to the demands of the instructional task, such as is frequently found in physics instruction. Activities such as these are largely self-regulated by students, appear transferable to other learning tasks, and help create mental "anchors" on which subsequent instruction can build (Rieber, 1990). When such simulations are used in a classroom setting, the student can become more actively involved in the interrogative process.

Because the relevant elements of mechanical systems are perceptually available for causal inspection, people find it a natural task to be asked to reason about their dynamics in an informal context. Simple problems in mechanics lend themselves to the study of intuitive understandings: understanding in the domains of classical mechanics can, in principle, be based on perceptual experiences (Kaiser et al., 1992).

For whom is a picture worth a thousand words? First, students who possess domain specific knowledge may not need visual aids with text because they generate their own familiar analogical representation as they read or listen to an explanation of a system. Therefore, mainly unexperienced students - such as those in our studies - benefit from pictures being coordinated with words (Mayer et al., 1994).

Though simulation can never replace practical experiments in science education, it does offer some distinct advantages. It allows learners to control complex systems, manipulate variables, run experiments, take measurements, etc., in ways, which would be difficult or impossible to achieve with real world systems. In addition, simulations could turn some abstract concepts and relationships into manipulate objects and phenomena and thus facilitate learners' understanding (Li et al., 1996).

The unique properties of simulations, their ability to offer direct and dynamic manipulation and feedback, have another consequence: simulations offer a safe environment in which to practice making real-world decisions. This means that simulations allow us to set tasks in accordance with situated learning principles when it would not otherwise be safe to do so. In using a simulation, students can practice making decisions which closely resemble those practitioners in their field must make (Pilkington et al., 1996)

How can students be helped to understand scientific explanations of cause-and-effect systems, such as how a pump works, how the human respiratory system works, or how lightning storms develop? What can be done to help students learn mathematical procedures, such as how to add and subtract signed numbers, in ways that allow them to use what they have learned to solve new problems?

When instructional messages are presented in pictorial form the learner selects relevant features to pay attention to, thereby forming a series of mental visual images such as the steps in the lightning process. He or she then organizes the images into a coherent structure such as a visual mental model of the causal chain for lightning formation.

Constructivist learning occurs when the learner engages in each of these cognitive processes selecting relevant images and sounds, organizing them into respective visual and verbal mental models, and integrating them with each other and with existing knowledge. Our research is concerned with designing multimedia messages so that they prime these processes (Mayer, 1999).

5 Texts, maps and animations

A pedagogical content may be structured using various strategies, exploring the specific potential of each strategy. Written text is yet the medium best used when wish to expose in details a specific content.

The triad written text, concept map and interactive animation has intended to make easy the autonomous learning, using a computer. The medium used to support the written text will be the computer monitor through HTML files.

Part of pedagogical material will be composed by concept map and interactive animation done by specialists. The student will choose the way his/her first contact with the content: written texts or concept map. Using key words in the written text he/she will execute the interactive animation related with those concepts. In other way, if he/she choose to begin the learning using concept map through CmapTools software, it will be possible to execute the interactive animation pressing the convenient icon in the map, related to the respective concept.

Concept map may be used as global structurer of the knowledge that is being studied, and the animation will examine each topic (or concept) of the content that is possible to be modeled. In this way we will have a transversal organization f the knowledge through the map and a deepen of each concept through the use of interactive animation.

In a first moment, the student will have a contact with the pedagogical material worked by specialists. In a second moment he will do his own concept maps and interactive animations. It will be suggested to him to do maps that reflect a new sight to the content or, otherwise, maps that deepen the knowledge of the concepts of the specialists map. In each case it will be suggested the construction of an interactive animation supported by pertinent scientific theory. The construction of all this knowledge also may be done in a shared way between nearest students, or through softwares that permits the connection via Internet.

6 Conclusions

Teachers can encourage meaningful learning by using tasks that actively engage the learner in searching for relationships between her/his existing knowledge and the new knowledge and by using assessment strategies that reward meaningful learning It is not possible for the learner to reach high levels of meaningful learning until some prior relevant knowledge structures are built, and thus learning must be an iterative process over time to build expertise in any domain of knowledge (Novak, 2003).

Interactive animation turn easier the understanding when makes possible to the learner to see in the screen the mathematical representation of a model of Nature: this is the transformation of a equation in a moving image that intends to reflect the Nature itself, and through the interaction it may be possible to change the logical content into psychological content. When the learner interacts with the information, he is constructing his knowledge, and he is making important connections between meanings.

It is important to note that interactive animation strengthens the powerfulness of the conceptual map when insert a ludic component in the process of learning, and a tool that deepen conceptual items of the map.

When we talk about distance education we are referring to a distance that is more than simply a geographic separation of learners and teachers. It is a distance of understandings and perceptions, caused in part by the geographic distance, that has to be overcome by teachers, learners and educational organizations if effective, deliberate, planned learning is to occur. The transaction that we call distance education occurs between individuals who are teachers and learners, in an environment that has the special characteristic of separation of one from another, and a consequent set of special teaching and learning behaviors. It is the physical separation that leads to a psychological and communications gap, a space of potential misunderstanding between the inputs of instructor and those of the learner, and this is the transactional distance (Moore, 1991).

An educational event that includes conceptual maps and interactive animation working together, configures itself like the one with a small transactional distance.

7 References

Ausubel, D P (2003). Aquisição e retenção de conhecimentos: Uma perspectiva cognitiva. Editora Plátano.

Ausubel, D P; Novak, J D e Hanesian, H (1980). *Psicologia Educacional*. Editora Interamericana.

Cañas, A J, Ford, K M, Novak, J D, Hayes, P, Reichherzer, T R, Suri, N (2001). *Online concept maps: Enhancing collaborative learning by using technology with concept maps*. Science Teacher vol68, p49.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M., & Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology, Proceedings of the 1st International Conference on Concept Mapping*. Pamplona, Spain: Universidad Pública de Navarra.

Chiu, Chiung-Hui, Huang, Chun-Chieh, Chang, Wen-Tsung (2000). *The evaluation and influence of interaction in network supported collaborative concept mapping*. Computers & Education vol34, p17

Duderstadt, James J (2003). *Issues for Science and Engineering Researchers in the Digital Age*. National Academies Press - Washington - USA

Fromm, Erich (1987). *Ter ou Ser?.* Editora Guanabara. Portuguese translation of *"To have or to be?"*

Kaiser, Mary K; Proffit, Dennis R; Whelan, Susan M and Hecht, Heicho - 1992. *Influence of animation on dynamical judgements.* Journal of Experimental Psychology vol18, p669

Li, Yibing; Borne, Isabelle and O'Shea, Tim (1996). *A scenario design tool for helping students learn mechanics.* Computers and Education Vol26, p91

Mayer, Richard E (1999). *Multimedia aids to problem-solving transfer.* Int. Jnl. of Educ. Research Vol31 p611.

Mayer, Richard E and Sims, Valerie K (1994). *For whom is a picture worth a thousand words?.* Journal of Educational Psychology vol86, p389

Moore, Michael G (1991). *Distance Education Theory.* The American Journal of Distance Education, vol5, N3

Moreira, M A (1977), *An Ausubelian approach to Physics Instruction,* PhD Thesis, Cornell University

Novak, Joseph D and Gowin, D B (1999). Aprender a aprender. Plátano - Lisboa.

Novak, Joseph D ; Mintzes, J J e Wandersee, J H (2000). *Ensinando Ciência para a Compreensão.* Plátano - Lisboa. Portuguese translation of *"Teaching science for understanding".*

Novak, Joseph D (2003). The Promise of New Ideas and New Technology for Improving Teaching and Learning. Cell Biology Education Vol2, p122

Piaget, Jean (2002). *Epistemologia Genética.* Martins Fontes - São Paulo. Portuguese translation of *"L'épistemologie génetique".*

Pilkington, Rachel and Parker-Jones, Christine (1996). *Interacting with computer based simulation.* Computers and Education Vol27, p14

Rieber, LLoyd P. (1990). *Using Computer Animated Graphics in Science Instruction With Children.* Journal of Educational Psychology, vol82, p135

Tavares, R ; Santos, J N (2003). *Advance organizer and interactive animation.* IV Intenational Meeting on Meaningful Learning. Maragogi - BRASIL.

Teodoro, V D, Vieira, J P, D.; Clérigo, F C (2000). *Modellus 2.01: interactive modelling with mathematics.* Monte Caparica: Faculdade de Ciência e Tecnologia. Universidade Nova de Lisboa

Vygotsky, L S (2002). A Formação Social da Mente. Martins Fontes - São Paulo. Portuguese translation of "Mind in society - The development of higher psychological processes".