Chapter 17
Concept Maps and Conceptual Change in Physics

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ABSTRACT

The authors describe and discuss some recent applications of concept maps to physics teaching. They begin by reviewing the literature on applications of concept maps to science teaching, and argue for the usefulness of this resource in facilitating processes of conceptual change. They then describe two experiments on the collaborative use of concept maps to this end. The first was a study of how a team of teachers designed learning sequences using three-dimensional maps. In the second, concept maps were constructed and then collaboratively re-constructed by various groups of students. Finally, they discuss the preliminary results of these experiments on the processes of conceptual change, and suggest lines for further research.

CONCEPT MAPS AND CONCEPTUAL CHANGE: APPLICATIONS TO TEACHING AND LEARNING PHYSICS

From the mid 20th century onwards, researchers in various disciplines – philosophy, philology, artificial intelligence, and psychology – have developed systems for the graphical representation of declarative knowledge. The resulting diagrams consist of polygons and lines linking them to represent the underlying structure of the knowledge concerned. The polygons symbolize various kinds of nodes (objects, concepts, events, actions, etc.).

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The relationships represented by the links may be semantic (as in the classic associative networks of Quilliam), sequential (as in flowcharts), or functional (as in organigrams). A concept map is a type of diagram that represents semantic relationships between concepts in the form of a tree. The links connecting the concepts are labelled with words or phrases that indicate some property of one of the concepts. The overall diagram represents a hierarchical propositional structure of the body of knowledge.

Since their introduction by Novak in the 1960s, concept maps have grown into a powerful teaching tool with multiple applications because of their capacity to specify, design, and share knowledge. Their use has spread into many domains of learning. In science education in particular, several studies have demonstrated their usefulness as a strategy for evaluating, learning, and designing the teaching of scientific content.

Their primary use has been as a strategy for evaluation. Indeed, there is clear evidence for their effectiveness in assessing students' prior knowledge of scientific content and how it is organized (Anderson-Inman, Ditson, & Ditson, 1998; Caswell & Wendel, 1992), and the degree of understanding that students attain (Markham, Mintzes, & Jones, 1994; Novak, Gowin, & Johansen, 1983). The nature of the information that can be gathered in a map on students' learning depends, however, on the type of task asked of them. The more open procedures, such as creating a map of a single concept, provide very different information from more structured procedures, such as filling out an incomplete map or constructing one from a set list of concepts (see Ruiz-Primo, 2004).

Concept maps also constitute an interesting resource to support the learning processes of conceptual content, whether within a framework of autonomous learning activities or with the help of the teacher. Some studies, for example, have reported their usefulness for the students themselves to reconstruct strategically the knowledge they have acquired from various sources, and then to apply it to different learning tasks, i.e., to learn how to learn (Novak & Gowin, 1984). In a series of studies, Okebukola and Jegede have documented some of the main advantages of the use of concept maps as a strategy for learning science content, in particular, their positive influence on students' attitudes, strategic behaviour, and academic performance (Okebukola, 1990; Okebukola & Jegede, 1988, 1989). In this vein, McCrudden, Schraw, Lehman and Poliquin (2007) found that subjects who studied a scientific text accompanied by a diagram representing the semantic organization of the content understood it better than another group that spent the same amount of time in studying the text alone.

Concept maps have also been used as a teaching resource in contexts of joint teacher-student activities and to support students' collaborative learning at different stages of the teaching-learning process. In science education in particular, their utility has been studied as pre-organizers, i.e., as a means of presenting an initial overview of the content and connecting it with the students' prior knowledge (Montanero & Montanero, 1995). By comparing various methods of teaching a topic of science at the pre-university secondary education level, Hernández and Serio (2004) showed that the students' preparation of a concept map is especially useful as pre-organizer, whether it is presented by the teacher or the students themselves construct it, as long as the teacher explicitly helps them connect it with what has just been learnt. Other studies have also demonstrated their usefulness as a form of synthesizing the content studied during or at the end of a learning sequence (Horton, Mcconney, Gallo, Woods, Senn, & Hamelin, 1993; Pankratius, 1990).

Finally, concept maps provide a useful framework for representing knowledge in a form that can be taught or shared in a variety of contexts – scientific, educational, or professional (see Cañas, Hill, Carff, Suri, Lott, Eskridge, et al., 2004). In the educational context, the maps help to "unbundle" a teacher's expert knowledge in

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