Conceptual Change Research and the Teaching of Science

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Abstract

In this paper, I will try to define the conceptual change approach to the learning of science, as it has been developed over the years, on the basis of cognitive/developmental research. An effort will be made to differentiate this approach from the naive empiricism adopted by many science educators as well as from the Piagetian framework. It will be argued that the conceptual change approach can explain the phenomena observed in the acquisition of science concepts better than other approaches. At the end of the paper implications of this approach for teaching of science will be drawn.

What is the Conceptual Change Approach?

Many science educators adopt an empiricist approach to describe the process of learning science. According to this approach, there is little or no predisposition for learning. Knowledge acquisition is based on experience and proceeds in a continuous manner, enriching existing conceptual structures. Science learning depends on increased experiences, that, at the beginning give rise to concrete ideas but that later, these ideas, become more abstract and more widely applicable. Instruction should provide children with more experiences and opportunities to understand the process of doing science.

The development of science concepts has been interpreted differently by Piaget (1970). Piaget has also given a great deal of attention to experience but he claimed that the process of developing more abstract conceptual structures depends on the constructive activity of the learner. He chose to provide a structural account of the intellect in terms of a mathematical model. According to this model, the process of intellectual development proceeds through a series of stages, each of which is characterized by a different psychological structure. In infancy, intellectual structures take the form of concrete action schemas. During the pre-school years these structures acquire representational status and later develop into concrete operational structures (described in terms of groupings based on the mathematical notion of sets and their combinations). The last stage of intellectual development,
formal operational thought, is characterized by the ability to engage in propositional reasoning, to entertain and systematically evaluate hypotheses, etc.

The process of cognitive development described by Piaget has been characterized as "global restructuring" (Carey, 1985) and is considered to be the product of the natural, spontaneous process of intellectual development and not of explicit learning. The implications of this approach for instruction is that we should encourage the constructive ability of learners and provide them with experiences that may be interpreted differently at different stages but which, by the time students reach adolescence, will be transformed into scientific learning and understanding.

The conceptual change approach, which will be described here, differs significantly from the Piagetian and empiricist approaches. It focuses on knowledge acquisition in specific subject-matter areas and describes the learning of science concepts as a process that requires significant reorganization of existing knowledge structures and not just their enrichment.

The proposal that the learning of science involves "conceptual change" has its roots in the work of science educators like Novak (1977), Driver and Easley (1978), and Viennot (1979) who were among the first to pay attention to the fact that students bring task alternative frameworks, preconceptions, or misconceptions to the science learning, that are robust and difficult to extinguish through teaching. Posner, Strike, Hewson and Gertzog (1982) drew an analogy between Piaget's concepts of assimilation and accommodation and the concepts of "normal science" and "scientific revolution" offered by philosophers of science such as Kuhn (1970) and derived from this analogy an instructional theory to promote "accommodation" in students' learning of science. The work of Posner et al. (1982) became the leading paradigm that guided research and practice in science education for many years but also became subject to a number of criticisms that have not yet been answered (e.g. Caravita & Halden, 1994).

In my view, the instructional questions that Posner et al. (1982) tried to answer cannot be adequately approached until we have a better understanding of how students learn science. The conceptual change approach described here is based on cognitive/developmental research and attempts to provide a description of the process of learning science and the mechanisms that bring it about. The implications of this approach for instruction are described later. More specifically, the following arguments are being made:

1) The human mind has developed, through evolution, specialized mechanisms to pick up information from the physical and social world. This results in very quick and efficient learning which starts immediately after birth. Some kinds of things are easy to learn, not because they are less complex, but because human beings are prepared through evolution for this kind of learning. This seems to apply to the learning of language and to intuitive physics. Intuitive physics is the knowledge about the physical world that develops early in infancy and allows children to function in the physical environment.

2) Learning which is acquired early in life and which is not subject to conscious awareness and hypothesis testing can stand in the way of learning science. This happens because scientific explanations of physical phenomena often violate

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2 This type of knowledge reorganization is also known in the literature as "domain-specific restructuring" as opposed to Piaget's "global restructuring" (Carey, 1985).