Teaching for Conceptual Change in Science Laboratory

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Abstract. *In this paper, I will present a conceptual change instructional model in laboratory settings based largely on the conceptual change model initially proposed by Posner, Strike, Hewson and Gertzog in 1982 and also incorporating fundamental tenets of Vygotsky's constructivism and Papert's constructionism.*

Keywords. Conceptual change, conceptual change model, Vygotsky's constructivism, Papert's constructionism.

1. The theoretical origins of the conceptual change model

The conceptual change model is based on the Student-As-Scientist metaphor, on Thomas Kuhn's description of scientific revolution [7] as well as on Piaget's notions of adaptation and organization.

1.1. The Student-As-Scientist metaphor

According to the Student-As-Scientist metaphor, students have strong similarities with the scientists.

Students possess alternative frameworks that often differ from those of scientists and that are coherent, robust and difficult to extinguish. *"The term "alternative frameworks" indicate that students have developed autonomous frameworks for conceptualizing their experience of the physical world"* [2].

The Student-As-Scientist (SAS) metaphor reject a type of cognitive development that has been characterized as "global restructuring", that is, changes in the structure of thought brought about by child's logical capabilities (e.g. Piaget's stage theory). The Students-As-Scientist metaphor accept that *" there are no across-the-board changes in the nature of children's thinking"* [4].

The SAS metaphor is compatible with Carey's domain-specific theory of cognitive development *" According to this view children begin with a few theory-like conceptual structures (e.g. a naïve psychology and a naïve physics) that, though restructuring, give rise to new theories (e.g. biology, economics, a theory of mechanics, of heat, etc.). This type of restructuring is conceptualized as a product of the child's increased knowledge of a domain (brought about by the child's experience and/or by instruction), rather than as the result of child's logical capabilities per se)"* [12].

1.2. Thomas Kuhn's description of scientific revolution

Kuhn divides scientific activity into two distinct categories: normal science and science revolution.

According to Kuhn, normal science means research firmly based upon on a dominant paradigm that some particular scientific community acknowledges for a time as suppling the theoretical framework for further practice.

Science revolution occurs when the scientific community puts away the existing dominant paradigm and adopts another one. According to Kuhn, a science revolution is very likely to take place when two condititions coexist. First, a dominant scientific paradigm fails to provide solutions or explanations to significant problems identified by the scientific community. Second, an alternative paradigm with the potential to solve these problems is available.

1.3. Piaget's notions of adaptation and organization.

Piaget believed that people have an innate need to be at a state of cognitive balance or equilibrium between their understanding of the world and their experiences.

1.3.1. Organization

In response to this need of equilibrium humans have the natural tendency to organize their experience into related, interconnected structures. The most basic structure is the scheme. Schemes are the building blocks of thinking [5]. Organization is the process of forming these schemes.

1.3.2. Cognitive conflict

We say that humans are in cognitive conflict when their understanding of the world can't explain their experiences.

1.3.3. Adaptation

Humans maintain equilibrium through the adaptation process. Accommodation and assimilation are both part of the process of adaptation. Accommodation and assimilation function together and are complementary to one another.

Accommodation is a form of adaptation in which the existing mental structures are modified and new are created when new experiences does not fit into existing schemes.

Assimilation is a form of adaptation in which new experiences are incorporated into previously existing schemes.

2. The conceptual change model

2.1. The analogy

According to Vosniadou [13], *"Posner, Strike, Hewson and Gertzog drew an analogy between Piaget's concepts of assimilation and accommodation and the concepts of "normal science" and "science revolution" offered by philosophers of science as Kuhn and derived from this analogy and instructional theory to promote "accommodation" in students' learning of science"*.

2.2. Four conditions of conceptual change

These researchers derived from this analogy the following conditions that need to be fulfilled before conceptual change can happen:

(i) There must be dissatisfaction with a currently held conception.
(ii) The alternative conception must be intelligible.
(iii) The alternative conception must appear plausible.
(iv) The alternative conception must appear fruitful.

2.3. Central concepts of the model

The central concepts of the model are status and conceptual ecology.

The status that a conception has for a person is determined by its intelligibility, plausibility and fruitfulness to that person. Thus, the more intelligible, plausible, and fruitful an idea, the higher the status.

Conceptual ecology comprises all knowledge and beliefs that a learner possesses.

2.4. Critisisms of the model

According to Vosniadou [13], the conceptual change model described above *"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"*.

Pintrich, Marx, and Boyle [8] argued the conceptual change model put too much emphasis on the rational and, neglected affective and social issues of conceptual change. Furthemore, it does not consider how other participants in the learning environment influence the pathways from students' pre-instructional conceptions to science conceptions.

Strike and Posner [10] suggested that affective and social issues affect conceptual change.

2.5. Success of conceptual change model in science education

According to Guzetti and Glasss [6], the research findings show that *"Despite recent self-criticism of their earlier positions (Strike & Posner, 1992), the genre of instructional strategies described earlier by Strike and Posner (1985) that produces dissatisfaction with current conceptions and shows the scientific conception as intelligible and applicable, has been effective"*.

3. Fundamental notions of Vygotsky's constructivism.

3.1. The More Knowledgeable Other (MKO)

The MKO refers to someone who knows more than the student, with respect to a particular task, process, or concept.

3.2. The Zone of Proximal Development (ZPD).

Vygotsky [14] defined the ZPD as *"the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers"*.

3.3. Scaffolding

The MKO and the ZPD form the basis of the scaffolding. Scaffolding is the process of guiding the student from what she already knowns to what is to be known

3.4. Piaget vs Vygotsky

According toThomas [11], some central problems to the cognitive development are the following
"(i) Are changes in cognitive ability domain-general or domain – specific?
(ii) Are there qualitatively different stages or is change gradual and smooth?
(iii) Is development just learning or does something change in the brain to make children cleverer.
(iv) Is development "genetically controlled"?"

Vygotsky and Piaget approach these central questions from a different point of view.

Piaget viewed cognitive development from biological perspective. Piaget's stages theory is a domain-general theory. He argued that development is affected by both environment and genetics and the stages of cognitive development are qualitatively different.

Vygotsky viewed cognitive development from historical and social perpective and *"does not deal with fixed stages of development but describes "leading activities" typical of certain age periods around which intellectual development is organised"* [11].

Unlike Piaget who maintained that children's development must necessarily precedes their learning, Vygotsky argued that effective learning is the learning that precedes development.

Vygotsky agree with Piaget learners must be active constructors of their knowledge and development is stimulated by cognitive conflict.

4. Papert's constructionism

According to Bruckman and Resnick [3], *"The term "constructionism," first coined by Seymour Papert , involves two types of construction. First, it asserts that learning is an active process, in which people actively construct knowledge from their experiences in the world. (This idea is based on the theories of Jean Piaget.) To this, constructionism adds the idea that people construct new knowledge with particular effectiveness when they are engaged in constructing personally-meaningful products. They might be constructing sand castles, computer programs, or virtual objects. What's important is that they are actively engaged in creating something that is meaningful to themselves and to others around them."*

5. A conceptual change instructional model in laboratory settings.

5.1. Describe the experiment

5.2. Probe students alternative frameworks with predict-observe-explain tasks

(i) Ask each student to record an individual prediction on the handout sheet.
(ii) Ask the class to engage in small group discussions in order to decide on a group prediction.
(iii) Ask each student to record a final prediction on the handout sheet.

5.3. Create a cognitive conflict

Students or the teacher carry out the experiment. Student must encounter a problem which she cannot easily solve by herself, but which, she can solve with carefully structured

help from the teacher or a more able peer (scaffolding) [1]. Student must reconcile any conflict between prediction and observation.
(i) Ask each student to record what she sees happen on the handout sheet.
(ii) Ask each student to record an individual explication on the handout sheet.
(iii) Ask the class to engage in small group discussions in order to decide on a group explication.

5.4. Encourage and guide restructuring

Teacher presents the scientific explication. He must show it is intelligible, plausible and fruitful. Students must construct their own knowledge. Conceptual change will occur only if the status of scientific conceptions is higher than the status of students' pre-instructional conceptions. The process from srudents' initial models to scientific models is gradual (through synthetic models [13]) and time consuming.

Students and teacher construct something that others will see, critique, and perhaps use (i.e. simulations, powerpoint presentations) to express their conceptions (constructionism).

5.5. Encourage metacognition

Metacognition means "thinking about your own thinking". Students must encourage to reflect how they explicated the experiment, what they found difficult about it, what sort of reasoning they used, what sort of help they needed, and how they sought help [1].

5.6. Encourage bridging

Discuss analogous physical situations. The sort of reasoning students developed in the laboratory context must be bridged to other contexts [1].

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