Strategies for Facilitating Conceptual Change in School Physics

Abdul Gafoor K.**
&
Akhilesh, P.T.**

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*Associate Professor, Department of Education, University of Calicut
**Senior Research Fellow, Department of Education, University of Calicut

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Dr. K.Abdul Gafoor*
Akhilesh, P.T.**

Abstract: Learning occurs through various processes. Among these processes, conceptual change has a pivotal part. This article discusses briefly conceptual change in physics. Anchoring on Kuhn's original explanation of theory change in science, this article elaborates especially on the influence of children's science concepts in general, and pre-conceptions and misconceptions in learning process in particular on conceptual change in the science classrooms. Key teaching strategies that build on pupils existing ideas as well as cognitive conflict approaches, to facilitate conceptual change process in school physics are summarized.

Physics is richer its own concepts, ideas, and laws as well as interdisciplinary concepts that it shares with other science disciplines. Concept formation and conceptual change in physics require reconsidering the nature of physics concepts. Majority of the learners construct their physics concepts by the help of their rich mental environment. This environment is made up of familiar experiences and knowledge, interests and stories and their own ideas of what counts as evidence and knowledge. The extent to which a new concept fits this mental environment determine its fit, whether it is accepted, modified or rejected.

Children's science

Research studies have shown that children have beliefs about how things happen and expectations that enable them to predict future events (Clement 1977; Nussbaum & Novak 2006; Driver & Easley, 1978). Based on their everyday experiences of the world, they hold these beliefs and expectations very strongly. Moreover, children have clear meanings for words that are used both in everyday language and in formal science (Gilbert, Watts &Osborne 1980). Such views of the word and meanings for words, held by children are not simply isolated ideas (Champagne, Klopfer & Anderson 1979) but rather they are part of conceptual structures that provide sensible and coherent understanding of the world from the child's point of view. These structures may be termed children's science. Ideas of children's science may become stepping-stones as well as barriers in the physics learning process. So children's science concepts must be addressed with due consideration while planning teaching strategies for physics class room learning.

Role of Pre-conceptions and Misconceptions in learning process

Even young students have well developed ideas of how the world works. These pre-conceptions can hinder their learning in science. Five decades ago, Ausubel (1968) pointed out that these preconceptions are amazingly tenacious and resilient to extinction. Later on, it was found that student preconceptions are so strong that, in some cases they are preserved in the face of obvious and contradictory evidence (Osborne & Freyberg, 1985). Some students accept the teachers' science for the duration of the topic being studied and revert to their intuitive ideas following instruction. In other instances students construct separate schema to accommodate the lesson content without altering their preconceived views. Both preconceptions and learned misconceptions resist conceptual change (Nussbaum & Novick, 1982). Some teachers find this as worrying. However, the strength of student conceptions means that acceptable conceptions, once learned, are robust and lasting. As learned misconceptions and preconceptions may arise as barriers in learning, replacing them with scientific ones is possible only through conceptual change.

Conceptual change

The root of conceptual change approach to learning can be found in Thomas Kuhn's works on 'Theory change in the philosophy and history of science' (1962). Kuhn proposed that normal science operates within set of shared beliefs, assumptions, commitments and practices that constitute paradigms. Over time, discoveries emerge that cannot be accommodated within the existing paradigms. When those anomalies accumulate, science enters a period of crisis that is eventually resolved by revolutionary change in paradigms. A paradigm shift happens. According to Kuhn, different paradigms are incommensurable; scientific knowledge grows as we move from one to another paradigm, but it is no longer possible to imagine the results of scientific revolutions as a cumulative linear progression. Kuhn claimed that concepts are embedded in theoretical frame works –i.e., paradigms- from which they obtain their meaning. When there is a paradigm shift, there is conceptual change. That is, the meanings of concepts in the new paradigm, even when they keep the name they had in the old paradigm are markedly different from the old ones. Such conceptual changes are part of evolution and development of science as a whole. Adopting an evolutionary and genetic epistemological stance, such paradigmatic shifts are part of development of concepts in individual learners as well.

Conceptual change in the science classrooms

Learning in science classrooms can occur under at least three different conditions of prior knowledge. In first condition, a student may have no prior knowledge or information about the 'to be learned concepts', although they may have some related knowledge. In this case, prior knowledge is missing, and learning consists of adding new knowledge. In second condition, a student may have some correct prior knowledge about to be learned concepts, but that knowledge is incomplete. In this case, learning can be conceived of as gap filling. In both missing and incomplete knowledge conditions, knowledge acquisition is of the enriching kind (Carey, 1991). In a third condition, a student may have acquired ideas, either in school or from everyday experience that are in conflict with to be learned concepts (Vosniadou, 2004). Knowledge acquisition in this third case is of conceptual change kind. It is assumed that the prior knowledge is incorrect or misconceived and to be learned information is correct. Thus, learning in this third condition is not adding new knowledge or gap filling incomplete knowledge. Rather, learning is changing prior misconceived knowledge to correct knowledge. This is termed as conceptual change or process of conceptual change.

Classical approach of conceptual change

According to White and Gunstone in the 1970's researchers started paying greater attention to student's ideas and explanation of physical phenomena. They started to realize that students held various pre conceptions, misconceptions or alternative beliefs, some of which proved to be very persistent and robust (Viennot, 1979; Driver & Easley, 1978; McCloskey, 1983). In some cases, these misconceptions appeared be very similar to earlier theories in the history of science.

Based on the above, Posner et.al (1982) formed an analogy between the kinds of changes needed to be made by students learning in science and Kuhn's explanations of theory change in science. They claimed that students need to undergo radical conceptual change when it comes to understanding scientific concepts like force or heat energy. They need to replace their preconceptions or misconceptions with the new scientific concepts through instruction. Combining Kuhn's ideas with Piaget's, Posner et.al derived an instructional theory according to which there are four fundamental conditions that need to be fulfilled before can happen in science,

- There must be dissatisfaction with existing conceptions.
- There must be a new conception that is intelligible.
- The new conception must appear to be plausible.
- The new concept should suggest the possibility of a fruitful program.

This theoretical structure known as the classical approach to conceptual change became the leading paradigm that guides research and instructional practice in science education for many years. According to the classical conceptual change approach, the student is like a scientist, the process of (science) learning is a rational process of theory of replacement. Conceptual change is like a gestalt shift that happens over a short period. Accordingly, cognitive conflict is the major instructional strategy for promoting conceptual change.

One of the most controversial claims in Kuhn's (1962) original explanation of theory change in science, which was adopted by the classical approach, is that the change from one theoretical framework to the other is an abrupt and sudden change that takes place in a short period. It appears that Gestalt psychology influenced Kuhn and this shift in terms of the gestalt ideas of re-structuring is produced by insight. Although it is possible that such abrupt re-structuring may happen in individual cases during the learning process, this does not appear to be the usual road to conceptual change.

The empirical evidence so far has shown that the course of conceptual change is conservative and slow process. Even when researchers claim that radical conceptual changes are happening in the long run; these are usually the end-state of a slow and gradual process and not of a sudden and radical gestalt type of shift (Caravita & Hullden, 1994). Hence, teaching-learning processes have to be devised to facilitate conceptual changes in science.

Important Teaching strategies based on conceptual change process

Research findings in conceptual change have started using in instructional practice but there is a vast gap between our theoretical and empirical knowledge and classroom practices. Teachers are not well informed about conceptual issues and do not use the recommended instructional strategies for promoting conceptual change in the classroom (Duit, et.al, (2008)). Hewson and Hewson (1982) commented on traditional instruction as simply introducing new information without paying attention to students existing ways of making sense of ideas related to the concepts.

According to Scott et.al (1992) pedagogical decisions should be made at three levels while planning for conceptual change teaching. Firstly, teacher needs to foster a learning environment that will support conceptual change learning. This can be via providing opportunities for discussion and consideration of alternative viewpoints and arguments. A second level of decision-making involves the selection of teaching strategies. Lastly, consideration must be given to the choice of specific learning tasks. The learning task must address the demand of the particular science domain under consideration.

While selecting specific teaching strategies, four factors may need to be taken into consideration:

1. Students' prior conceptions and attitudes
2. The nature of intended learning outcomes
3. Cognitive level or intellectual demand of the learner
4. Possible teaching strategies

Two distinct groups of strategies promote conceptual change. The first group is based on cognitive conflict and resolution of conflicting perspectives. The second set of strategies bases on learners existing ideas.

Strategies based on cognitive conflict.

Cognitive conflict has been used as the base of developing a number of teaching strategies. Such strategies involve promoting situations where the students existing ideas about some phenomenon are made explicit and are then challenged to create cognitive conflict.

Strategy based on Piaget's theory of concept learning.

Nussbaum and Novick (1982) suggest a teaching sequence that draws upon the Piagetian notion of accommodation. It includes four main elements.

a. *Initial exposure of student preconceptions* through their responses to an exposing event
b. *Sharpening student awareness* of own and other students' frameworks
c. *Creating conceptual conflict* by attempting to explain a discrepant event
d. *Encouraging and guiding* accommodation and invention of a new conceptual model consistent with the accepted science view

Conflict between ideas

Stavy (1991) draw attention to two types of framing of conflict between ideas. They are,

a. A conflict between a child's cognitive structures related to a certain physical reality and the actual physical reality.
b. A conflict between two different cognitive structures related to the same reality. They made use of second type of conflict in developing teaching strategy.

Generative learning model

Generative learning model of teaching (Cosgrove and Osborne, 1985) has the following four steps.

a. *Preliminary phase*: teacher needs to understand the scientists view, the children's view, his or her own view.
b. *Focus phase*: opportunity for pupils to explore the content of the concept, preferably within a real everyday situation such that learners to engage in clarification of own views
c. *Challenging phase*: learners debate the pros and cons of their current views with each other and the teacher introduces the science view
d. *Application phase*: opportunities for application of new ideas across a range of contexts

Dialogue based strategy

Dialogue based strategy (Champagne, Gunstone and Klopfer, 1985) otherwise described as ideational confrontation is specifically designed to alter student's declarative knowledge with in a particular domain. It involves following steps.

a. *Students make explicit the notions* they use to explain, or make predictions about a common physical situations
b. Each *student develops an analysis* that supports his or her predictions and presents it to the class
c. Students' attempt to *convince each other of the validity* of their ideas, discussions and argument result in each student becoming explicitly aware of his or her ideas in that content

d. The *instructor demonstrates* the physical situation and presents a theoretical explanation using science concepts
e. Further discussions allow *students to compare their analyses with the scientific one*

Resolution between ideas

Rowell and Dawson (1985) propose a strategy in which resolution between students' prior ideas and new conceptions occurs after new conceptions have been introduced. The strategy that draws upon a perspective from the history and philosophy of science and equilibration theory (Piaget, 1977) is based upon the following two premises. 1) A theory is only replaced by a better theory and not discarded based on contradictory evidences, and 2) The construction of a better theory need not involve an immediate confrontation with the knowledge that an individual spontaneously considers relevant.

Although cognitive change involves both strategic and meta-strategic knowledge (Kuhn, 1983) they need not be constructed together. The teaching approach involves six steps.

a. *The ideas which student consider* relevant to the problem situation are established.
b. *Discussion and their ideas are retained in a 'paper memory'* for subsequent consideration.
c. *Students are told that a theory is introduced* to them which may solve the problem and that their help will be required both in its construction and later in its evaluation against the alternatives they have proposed
d. *The new theory is prese*nted by linking it to basic knowledge already available to the class
e. *Students apply the new theory* to problem solution, in order to indicate its construction by individuals. Written work must a part of this procedure to provide a second paper memory for each student.
f. *Each student compares the memories from step 1 and step 5* and the quality of the ideas is examined

Teaching strategies build on pupils existing ideas

Analogy based teaching strategy.

Analogical teaching strategy (Clement, Brown, & Zietsman, 1989) constitutes four steps.

a. The student's *misconceptio*n relating to the topic under consideration is made *explicit by using a target question*
b. The instructor suggests a case which he or she views as analogous and which will appeal to the students intuitions. This case is termed as *anchoring example* or simply an anchor.

c. The instructor asks the student to make an *explicit comparison between the anchor and target cases* in an attempt to establish the analogy relation
d. If the student does not accept the analogy, the instructor then attempts to find a *bridging analogy* or a series of bridging analogies

Method which scientist's use

Niedderer (1987) put forwarded an approach based on the philosophy of science outlined by Brown (1977). It aims not to replace students' theories by scientific theory but allow them to arrive at a conscious knowledge of both. Solomon (1983) also has suggested learning scientific concepts by difference.

The strategy consists of six steps:

a. *Preparation:* The teaching process that precedes the intervention, and may contain tools and concepts that may be drawn on.
b. *Initiation*: an open-ended problem is posed
c. *Performance* in following sequence. formulating questions or hypothesis, planning and performing experiments, making observations, theoretical discussions, and formulation of findings
d. *Discussion of findings*: in a class forum
e. *Comparison with science*: class findings are compared with similar historical theories or modern ideas. Differences are stated and possible reasons for those differences are discussed
f. *Reflection*: students are encouraged to look back on the process of performance and to consider particular questions or difficulties which a have arisen.

Keeping pupils alternative frame works in mind Driver suggested three points to be considered while planning classroom practice. 1) Curriculum development in physics needs to pay as much attention to the structure of thought of the child as it has recently paid to the structure of the discipline in organizing learning experiments. Currently scientist's concerns for the structure of thought of the child have been focused on Piagetian operations. It is argued that the content as much as the process of thought requires our attention. 2) Teaching programs need to be structured in keeping with the developmental path in understanding important scientific ideas. The logical order of teaching a topic may not correspond with the psychological order in learning .This is a word of caution for those who are enthusiastic about structured learning programmes that involve such hierarchies. 3) Activities in physics may need to include those that enable pupils to disprove alternative interpretations as well as affirm accepted ones.

Conclusion

Both primary and secondary teachers need to be made aware equally of children's science and of scientist's science, and to clarify where their own views lie with respect to these views. Further, teachers have to provide excellent opportunities for students to clarify their own ideas to provide them with a sound orientation on which to base good science. Teaching practical work by itself is not enough. Pupil need time to think and talk through the implications and possible explanations of what they are observing. And, this may take time, more time than teachers usually allow in classrooms.

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