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REVIEW

Teaching for Conceptual Change

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ABSTRACT *Conceptual change has proven to be a popular and fruitful area of science education research in the past forty years. Three meta-analyses published in the past two years have shown that intervention studies on conceptual change are most successful when they utilize cognitive conflict as the remediation strategy. This review draws on the meta-analyses to argue that conceptual change interventions remain essential for improving student learning.*

KEYWORDS Conceptual change, misconceptions, u-learning

There has been continued interest in the generative learning model since late 1970s. This model influenced the conceptual change theory of learning, and to an extent, constructivism. According to this model, learning is seen to be the result of the interaction between what is taught and students' current ideas and concepts (Poster et al, 1982). The generative learning model assumes that the students already possess a comprehensive conceptual framework about natural phenomena that had been developed through personal and common sense. Research indicates that these alternative frameworks vary widely from the accepted scientific conceptions (Watts, 1985, Djanette & Fouad, 2014).

Further, these alternative concepts and/or misconceptions are found to be highly resistant to change. Instructional programmes which ignore these misconceptions are unlikely to be effective in bringing about the desired changes in student thinking. Cosgrove and Osborne (1985) argue that a successful teaching strategy should help students to restructure and modify the pre-existing conceptions. Thus, learning science is best viewed as the continual process of conceptual change (Hewson & Hewson, 1988).

Therefore, as a first step towards improving science teaching, knowledge of the common misconceptions of students is needed. A number of the research efforts in the past 40 years were focussed on identifying and describing children's misconceptions in different subjects (Aleknaviciute, 2023). In all domains of physical science, be it physics, chemistry or biology, a large number of common misconceptions across several geographical locations have been discovered and catalogued. With the identification of the misconceptions came efforts to remediate them. Given that these misconceptions are resistant to change, a special approach or strategy is required to address them. For example, Djanette and Fouad (2014) found that even among university freshmen, the misconception that color is

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specific to the object or the object has color or contain color is quite common. Further, they found that a significant number of students held onto this view even after instruction. Researchers have proposed an explanation for the resistance to change. Unlike radioactivity or electrostatics, light is a phenomenon children experience from birth. Very early on, they tend to form their own ideas about light unaided by scientific instruction. By the time they learn light at school, children have comparatively well-developed misconceptions about light that they believe firmly. Incidentally, this makes light a harder topic to teach than, say radioactivity. Students understand information about radioactivity easily because it is a phenomenon they do not sense directly; they have very few preconceptions–hence misconceptions–about it. But light is an essential feature of everyday life and "unlearning" misconceptions strongly believed in for many years takes time and reason. Therefore, special teaching strategies are necessary to change erroneous conceptual frameworks and bring them to bring them closer to currently accepted scientific conceptions.

Soon after the studies on the discovery of misconceptions and their resilience to instruction were published, both science and mathematics educators proposed a number of theories and teaching methods to remediate the misconceptions. These methods are known as conceptual change approaches or strategies.

Conceptual Change Strategies

Potvin et al. (2020) reported a review of 245 articles on conceptual change and identified 86 slightly different approaches used in them for conceptual change. However, most studies used a few well-known strategies. For example, Pacaci et al. (2023) summarized the outcomes of 218 studies which utilized just three different strategies: cognitive conflict, cognitive bridging, and ontological category shift in science learning. Resbiantoro et al. (2022) reviewed 72 studies published in international journals of which 36% focused on remediation of misconceptions. Both Aleknavičiūtė (2023) and Pacaci et al. (2023) are comprehensive meta-analyses of intervention studies and both concluded that a large positive effect of conceptual change interventions when compared with traditional teaching.

The conceptual change interventions arise from the model of conceptual change proposed by Posner et al. (1982). This model comprises two aspects: the conditions that need to be satisfied in order for a person to experience conceptual change and the conceptual ecology that provides the context in which conceptual change occurs. The subsumption of a new concept depends on the features of the conceptual ecology such as the inadequacy of existing concepts to explain new experiences. Anomalies provide cognitive conflict or dissonance that prepares the students' conceptual ecology for accommodation of the scientific concept.

According to Posner et al. (1982) four important conditions must be met before accommodation can take place: (1) there must be dissatisfaction with the existing conception (or misconception) from a number of experiences that cannot be explained using the existing conception; (2) a new conception must be understandable to the student; (3) a new conception must appear to be plausible to solve the accumulated unexplainable experiences; and (4) a new conception should be fruitful in that it would lead to new discoveries. Once these conditions are met then the student may mentally reorganize existing conceptions leading to accommodation. The model of conceptual change by Posner et al (1982) spawned many studies on remediation. Pacaci et al. (2023) found that the effect size is greatest for conceptual change strategy for the 218 studies he reviewed. Within conceptual change, Resbiantoro et al. (2022) who analyzed 18 studies regarding the remediation of physics misconceptions, found that most used conceptual change as a teaching strategy.

Teaching for Conceptual Change

The strategies to be adopted when teaching for conceptual change have been delineated by several researchers (Eaton et al., 1983; Rice & Feher, 1988; Watts, 1985). All researchers are in agreement that the misconceptions must be addressed explicitly. A synthesis of their work enables one to identify the key areas where emphasis must be placed when teaching for conceptual change. For conceptual change to occur, it is necessary to:

(1) be able to diagnose student misconceptions in the topic under discussion by using probing questions or pretests based on misconception research. Traditional questioning techniques which sought only correction answers must be abandoned. Incorrect answers often yield more information about the misconceptions.

(2) provide opportunities for students to clarify their own thoughts through individual work or in group discussion. It is necessary that such conceptual change discussions take place in an environment which supports the acceptance of a plethora of views and questioning or exploration of those views. Discussions may involve experimental testing of alternative conceptions.

(3) ensure that there is a direction contrast between students' conception and the scientific conception, either by presenting the desired conception or by it emerging from the class. Students "shed" their misconceptions only when they become dissatisfied with them (Posner et al,, 1982; Hameed et al., 1993; Aleknaviciute, 2023).

(4) give immediate opportunities for students to apply the newly acquired understanding to novel settings. This helps students to see that their new conception is fruitful in explaining related phenomena.

The application of this new conception of teaching should entail the production of better curriculum materials. Current textbooks do not adequately emphasize certain scientific conceptions about which students carry a lot of misconceptions. For example, many textbooks do not explicitly mention that an opaque object is seen because of the light it reflects into the observer's eyes. This omission subtly reinforced the common misconception that bodies are seen because light brightens them.

Conclusion

Research in the area of misconceptions has produced valuable insights into inadequacies of the traditional method of teaching that assumes no preconceptions.

The ineffectiveness of the traditional method has led to the formulation of strategies to counter misconceptions and urge students to forsake them in favour of the scientific view. However, much work still remains to be done.

In the past 40 years, educators have made a concerted effort to uncover common misconceptions in all areas of physical science. What remains now is to utilize this knowledge of misconceptions in writing textbooks, and teacher guides so that students can improve their learning.

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