Misconceptions in Biology Education and Conceptual Change Strategies

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Abstract

One of the factors that affects the learning and student performance is misconceptions. The purposes of this study are to; (*i*) define misconception and give information about the related constructs, (*ii*) reveal how misconceptions can be formed, (*iii*) expose some research findings about misconceptions in the field of biology and, (*iv*) propose some conceptual change techniques (e.g., word association, structural communication, diagnostic tree, concept maps, clinical interview, conceptual change texts, analogy, prediction- observation, and explanation) that can be used in the diagnosis and remedy of misconceptions. The importance of misconceptions regarding biology and science education is discussed and suggestions are proposed.

Key Words

Misconception, Conceptual Change Strategy, Biology.

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There are several factors that affect learning and student performance in educational settings. These can be classified as factors related to teachers (e.g., adequacy in professional knowledge, teaching style, attitude, sympathy, language skill, etc.), students (e.g., ability, attitude, need, learning styles, working memory capacity, and motivational styles, etc.), and others such as physical situation, assessment methods, and socio-cultural factors. Misconception is also an important factor that affects learning. It can be acquired prior to enrolling in any school program or it can be triggered at any stage of the formal education.

Misconceptions: Definition and Related Constructs

In broad terms, misconceptions correspond to the concepts that have peculiar interpretations and meanings in students' articulations that are not scientifically accurate. In the literature, misconceptions are also referred to as naive beliefs (Caramazza, McCloskey & Green, 1981), erroneous ideas (Fisher, 1985), preconceptions (Hashweh, 1988), multiple private versions of science (McClelland, 1984), underlying sources of error (Fisher & Lipson, 1986), personal models of reality (Champagne, Gunstone & Klopfer, 1983), spontaneous reasoning (Viennot, 1979), persistent pitfalls (Meyer, 1987), common sense concepts (Haloun & Hestenes, 1985), spontaneous knowledge (Pines & West, 1986), alternative frameworks (Driver & Easley, 1978), and children science (Gilbert, Watt & Osborne, 1982). Although the term *misconception* is dominant in the literature, some researchers (e.g., Abimbola, 1988; Gilbert & Swift, 1985; Wandersee, Mintzes & Novak, 1994) now prefer the term *alternative conception*. These researchers indicate that the later refers to experience-based explanations constructed by a learner to make a range of natural phenomena and objects intelligible. Also, it confers intellectual respect on the learner who holds those ideas.

In conclusion, it is important to use the term *misconception* rather than the alternatives in order not to create a concept-confusion because of the following reasons: (*i*) it is still commonly used by many researchers, (*ii*) the term already has familiarity in the public, and (*iii*) it easily conveys the message that a concept might have contradictory connotations with the current scientific thought in science education.

Knowledge claims

The term *knowledge claims* was proposed by Novak and Gowin (1984) and indicates the claims about what we think the answer to our question should be. They are the products of the inquiry. In this secti-

on of the review, knowledge claims related to alternative conceptions were proposed (Wandersee, Mintzes & Novak). However, because of the reasons stated before, instead of the term *alternative conceptions*, the term *misconceptions* was used in all claims. Under the headings of each knowledge claims, the related national as well as international findings in the field of biology education was given. The eight knowledge claims regarding misconceptions can be summarised as follows (Wandersee, Mintzes & Novak, 1994):

1. *Students come to formal science instruction with a diverse set of misconceptions concerning natural objects and events.*
2. *The misconceptions that students bring to formal science instruction go beyond age, ability, gender, and cultural boundaries.*
3. *Misconceptions are tenacious and resistant to extinction by conventional teaching strategies.*
4. *Misconceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.*
5. *Misconceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers' explanations and instructional materials.*
6. *Teachers often subscribe to the same misconceptions as their students.*
7. *Students' prior knowledge interacts with the knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.*
8. *Instructional approaches that facilitate conceptual change can be effective classroom tools.*

Conceptual Change Strategies

Cognitive structure is a hypothetical construct referring to the organisation of concepts or the pattern of relationships in memory (Kempa & Nicholls, 1983). Several strategies and techniques are used for externalising ideas and modifying misconceptions in students' cognitive structure. These strategies can be called as *conceptual change strategies* (Wandersee, Mintzes & Novak, 1994). Some of these are *word association tests, structural communication grid, clinical interview, interviews about instances and events, prediction-observation and explanation, concept maps, related diagrammatics, classroom discussions, computer simulations, diagnostic tree, journal writing, conceptual change texts, discussion web,* and *analogy.* Brief information about some of these techniques is given below.

Word association test is one of the most common and the oldest methods in the investigation of cognitive structure and has been used by several researchers (Bahar, Kempa & Nicholls, 1983; Johnstone & Moynihan, 1985; Johnstone & Sutcliffe, 1999; Shavelson, 1972,

1974). In this technique, a small number of, typically about ten, key (stimulus) words from the topic are selected and subjects are asked to write as many related terms as possible in a minute (or in 30 seconds) for each stimulus word (taken one at a time). The underlying assumption in this technique is that the order of the response retrieval from long-term memory reflects at least a significant part of the structure within and between concepts (Shavelson, 1972).

The Structural Communication Grids (SCG) technique is developed by Egan (1972) and has been used by several researchers (Johnstone, Bahar & Hansell, 2000; MacGuire & Johnstone, 1987). The SCG is a powerful assessment and diagnostic tool. In this technique, the data are presented in the form of a numbered grid and the questions are asked to students (*i*) to select the pieces (box numbers) needed to answer the grid and, (*ii*) to represent these numbers in a logical sequence to show their reasoning. The student does this for each question. Thus, he communicates with the teacher through the structures he has imposed on the random grid. This response shows the degree of completeness and interconnectedness in the student's knowledge in given topic.

Diagnostic tree testing (Johnstone, McAlpine & MacGuire, 1986) has a simple tree design. It consists of seven statements to which a true/false response is required. The route a student follows on the test gives an indication of where he has mislinkages, wrong strategies, or incorrect knowledge. Several research studies have the diagnostic tree testing (Bahar, 2001; Bahar, Cihangir & Gözün, 2002; Bahar, Öztürk & Ateş, 2002). The findings of these studies suggest that students show a positive attitude to these techniques and the results are promising in terms of effectiveness of these techniques as a diagnostic and evaluation tool (Bahar, 2001; Bahar, Öztürk & Ateş, 2002; Bahar, Cihangir & Gözün, 2002).

Concept map that was developed as an outgrowth of Ausubel's theory of learning concentrates mainly on the importance of prior knowledge and meaningful learning. It can serve as a vehicle for obtaining a graphic representation of information held in memory. It can therefore give an insight into ideas lodged in a student's cognitive structure. Concept maps might be the most popular technique (Bahar, 2002; Kulaberoğlu & Gürdal, 2001; Novak & Gowin, 1984; Ross & Munby, 1991; Sungur, 2000; Yılmaz, 1998). In some studies, concept maps and clinical interview were also used together (Brody, 1994; Songer & Mintzes, 1994).

Clinical interview that was used by Piaget (1929) and Osborne and Gilbert (1980) is a conversation of an expert with a student, focussed by initial questions about the situations represented in series of line diagrams to check the student's interpretation of natural phenomena or social occurrence (White & Gunstone, 1992).

Prediction-Observation and Explanation (POE) is primarily used to learn how to use the information students acquire to interpret events and experiences (White & Gunstone, 1992). In this technique, students need to do three tasks. First students must predict the outcome of some events and prediction must be justified; then they describe what they see happening; and finally students must reconcile any conflict between prediction and observation. This powerful technique should be used more commonly for externalising and modifying the misconceptions.

Conclusion

Anybody who had teaching experience at primary, secondary, or university level might have experience of seeing misconceptions in students' exam sheets even after formal instruction. We know that they are tenacious and resistant to extinction. Therefore, it is important to be aware of the misconception literature, knowledge claims by educators and teachers so that everything can be opened to discussions and remedies can be offered and be shared. In addition, the conceptual change strategies stated above should be used for diagnosing and modifying misconceptions.

There are numerous studies related to misconceptions that can be encountered in international journals such as International Journal of Science Education and the Journal of Research in Science Teaching. Although some important studies have been done recently in Turkey related to identifying misconceptions in scientific disciplines, more studies should be done at all levels including graduate level, not only for identifying but also for modifying misconceptions. Journals published in Turkey should pay more attention to this issue.

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