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USING CONCEPT MAPS TO ENHANCE MEANINGFUL CHEMISTRY LEARNING

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Research has demonstrated that students at all levels come to science classes with preconceptions (or misconceptions) about various aspects of the physical world around them, and that these misconceptions are rather resistant to formal instruction. Numerous studies have also shown that students can produce correct answers to various kinds of problems, but their understanding of the underlying science concepts was lacking. This state of affairs has been attributed to superficial or rote learning, which is contrasted with meaningful or deep learning. This paper highlights the use of concept maps as a tool for enhancing of meaningful learning or deep learning among chemistry students.

INTRODUCTION AND BACKGROUND

Meaning of Meaningful Learning

Meaningful learning is contrasted with rote learning (Ausubel, 1963, 1968). In rote learning new knowledge may be acquired simply by verbatim memorization and arbitrarily incorporated into a person's knowledge structure without interacting with what is already there. Hence rote learning is surface or superficial learning and the result is easily forgotten. In contrast, meaningful learning involves the appropriate interaction of new knowledge (new concepts) with the learner's existing or prior knowledge and is long-lasting. Ausubel stresses that the distinction between rote learning and meaningful learning is not a dichotomy, but a continuum.

Importance of Enhancing Meaningful Learning Among Students

Research has demonstrated that students at all levels come to science with alternative conceptions already formed as a result of their interactions with the world. These alternative conceptions influence how they interpret and construct new conceptions in science lessons. These alternative conceptions are highly resistant to change, at least by traditional teaching methods. Much research has been directed at describing students' alternative conceptions in different aspects of science (e.g. Boo, 1996, 1998; Boo & Watson, 2001; Carmichael, Driver, Holding, Phillips, Twigger, & Watts, 1991; Pfundt & Duit, 1998). Numerous studies have also shown that students can produce correct answers to various kinds of problems, but their understanding of the underlying science concepts was lacking (e.g. Gabel & Sherwood, 1983; Lythcott, 1990). It appears that often students' school learning is like a veneer. On the surface student are able to perform the required operations but there is little depth of understanding (Krajcik, 1991).

This state of affairs is put succinctly by Gardner (1991:2): "Research shows that even students who have been well-trained and exhibit all the overt signs of success - faithful attendance at good schools, high grades, high test scores, accolades from teachers - typically do not display an adequate understanding of material and concepts with which they have been working."

One of the key factors contributing to the low level of conceptual understanding and large number of misconceptions among students is that the existence of students' prior knowledge is either ignore or not recognized. In particular, when science is taught as if the students had no prior experiences and knowledge relative to the topic being studied. Thus teaching methods employed do not seek to diagnose or engage students' prior knowledge and the mode of instruction tends to be didactic which encourage passive learning on the part of students (Boo, 1995).

From another perspective, the didactic or traditional mode of instruction is associated with an empiricist or logical-positivist view of science, in which science tends to be seen as a body of knowledge, predominantly a collection of facts which are derived from observations and experiments (Boo & Toh, 1998; Reiss, 1993). The teacher's role is typically seen as that of a dispenser of scientific knowledge.

Subsumed in the empiricist or logical-positivist view of science, is the belief that the process of observation is objective and independent of the prior knowledge or beliefs or feelings or values or intuition or motivation of the observer. Thus teachers who subscribe to this view of science tend to view students in a class as video cameras, each capturing with equal accuracy the transaction that takes place in the classroom between the teacher and the learners. There is no recognition of the existence of prior knowledge of the learner, nor about its interaction with new knowledge that the teacher is imparting. In this type of pedagogy, any experiments and demonstrations carried out, if at all, are used to verify some of the knowledge "covered" by the teacher.

The consequences of such pedagogy can be extrapolated or inferred. If students view and learn science as isolated facts, and teachers teach didactically without engaging their minds (or prior knowledge) actively, it is not surprising that students tend to view science as bits and pieces of information and do not see the big picture of a unit of learning or topic or subject (di Sessa, 1988; Ebenezer, 1992) and to learn science by rote (Songer & Linn, 1991), instead of with understanding. As a result, new knowledge is not assimilated into the long-term memory of the students (Novak, 1993), and there lack of understanding of concepts and principles. Novak (1993) asserts that "The unfortunate truth is that much school instruction inhibits student learning."

As a way of addressing the problems of low level of understanding and large numbers of misconceptions which persist even after traditional instruction, researchers have been advocating constructivist teaching strategies and techniques which are premised upon the constructivism and information processing theory as a way of knowing and learning. There is research evidence to show that constructivist methods are useful in promoting better understanding of concepts (Driver, 1995).

What is the theory of constructivism and information processing?

The key theme of this theory is that learning involves a sequence of mental operations that result in constructions of meaning for experiences and the subsequent storage of those meanings in the long-term memory of the learner. Further operations enable the recall or reconstruction of the meanings and their use in coping with new situations.

The operations begin with the selection for attention of a fraction of the numerous events that surround the learner. The selection depends on what the learner already knows and is interested in, his or her immediate purpose or motivation, and physical and emotional states. Another operation is the translation of incoming physical stimuli into meanings. Translation, too, depends on the prior knowledge of the learner so that different learners may construct different meanings from the same piece of information.

Most models of information processing postulate a long-term memory of essentially infinite storage capacity and a short-term memory of limited capacity for storage of information. Processing of information from the short- to the long-term memory store involves an operation of linking of incoming new knowledge to existing or prior knowledge of the learner. The outcome is understanding: an outcome that represents the pattern of links and the various types of knowledge that are present.

Thus in this theory of constructivism and information processing learning is seen as multi-dimensional—because learners vary in their abilities to have control over the different mental operations involved in the process of learning.

Methods for enhancing meaningful learning are aimed at assisting the learner to “select” (or give attention to) the new knowledge that the teacher is trying to impart (or “birth” in the learner), as well as at helping the teacher to translate the new knowledge into new meanings by making the appropriate links to their existing knowledge. One such method, that is, concept mapping, is discussed in the next section.

Concept mapping as a method for enhancing meaningful learning

A concept map is a concrete representation of abstract ideas. It is a diagrammatic or schematic representation of the meaningful relationships among concepts. The more links there are among the concepts, the greater the understanding is shown.

Concept mapping is a teaching and learning strategy that has been developed by Novak (1977) and which helps students to organize concepts into hierarchies. It has been developed as an outgrowth of Ausubel's (1963, 1968) theory of meaningful learning which highlights the importance of prior knowledge in the learning of new concepts. Ausubel asserts that students learn meaningfully by building knowledge on the basis of what they already know. In other words, new knowledge (or new concepts) acquire their meanings through relationships with existing knowledge (or concepts) and meaningful learning occurs when new knowledge is consciously related to relevant concepts which the student already possesses (Cliburn, 1990; Stewart, Van Kirk & Rowell, 1979).

Ault (1985) also supports the view that concept mapping enhances meaningful learning by leading students "away from rote learning and toward true understanding of concepts and their relationships." Concept mapping is a useful tool for helping students learn about the structure of knowledge and the process of knowledge production or meta-knowledge (Novak & Gowin, 1984). Stice and Alvarez (1987) suggest that meaningful learning may be enhanced as a result of students' social interactions during brainstorming, initial mapping, discussions and revisions.

Concept mapping has been found not only useful in promoting students' understanding of science concepts but also in facilitating students' abilities to solve problems and to answer questions that require application and synthesis of concepts (Novak, Gowin & Johansen, 1983). Furthermore, concept mapping is seen to promote a minds-on approach to learning. Students are able to construct knowledge in their own terms and hence remember better what they have learned.

As a diagnostic tool, concept mapping has allowed the teacher to establish the main ideas held by the students before they begin to experience new material (Cross, 1992; Willson & Willson, 1994). Such diagnosis has shown the teacher spontaneous reasoning of students as well as their misconceptions (or preconceptions) which might have otherwise gone unnoticed. There is also evidence to show that concept maps can be used for formative as well as summative assessment (Comber & Johnson, 1995; Gibson, 1991; Kilshaw, 1990; Sorsby, Bury & Gibbons, 1992).

How to teach concept mapping to students?

In teaching students how to draw concept maps, it is best to demonstrate how concept mapping is carried out with a topic which they have already mastered or the content of which is familiar to them. The steps below relate to teaching students to draw a concept map on the familiar topic "water and its change of state."

1. Identify ideas related to the topic of "water and its change of state." E.g., liquid, ice, solid, steam, water vapour, gas, condensation, freezing, boiling, evaporation, and so forth.
2. Write ideas on pieces of card or paper.
3. Arrange ideas which are related close together, e.g., "ice," "solid," "water," "liquid," "steam," "water vapour" and "gas."
4. Put most general ideas at the top, e.g., "matter," followed by "changes," followed by "state" and so forth.
5. Draw lines between related ideas.
6. Write words on lines drawn to describe relationships between ideas.

From the contributions of students and with prompting or cuing by the teacher, the relevant ideas are elicited and the above procedure followed through and the concept map at Appendix 1 is developed.

The concept map in Appendix 2 is done by a group of students on the topic of "chemical bonding."

CONCLUSION

One important benefit of concept mapping, among others, to the learner is that it helps the learner about the structure of knowledge and the process of knowledge production. The usefulness of concept mapping to the teacher is that it helps in promoting student understanding of concepts; it also helps in the assessment of student learning, in particular, the diagnostic and formative aspects which enable the teacher to use the maps as starting points in building links between the prior knowledge and new knowledge that s/he intends the students to learn as well as in addressing misconceptions or preconceptions that students may have at the beginning of learning each topic.

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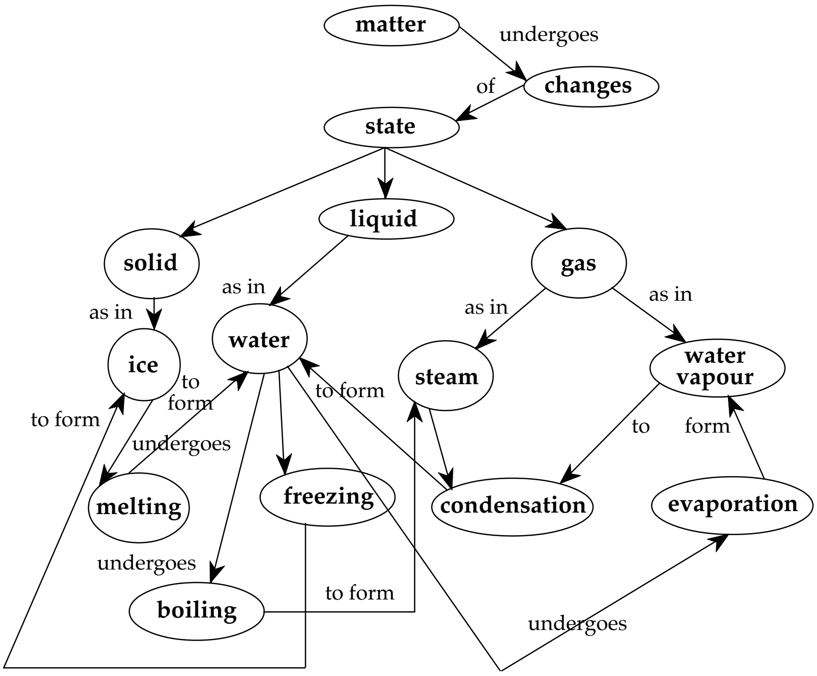
Appendix 1: Concept map on water and its charge of state



Appendix 2: Concept map on chemical bonding