Chapter 66
Conceptual Mapping Facilitates Coherence and Critical Thinking in the Science Education System

James Gorman
Northbridge High School, USA

Jane Heinze-Fry
Museum Institute for Teaching Science, USA

ABSTRACT

In this case, the authors propose a pathway of visual mapping through which the science education system from professional educators who produce representations of national and state standards to curriculum coordinators at the school district level to individual teachers and students in the classroom could be aligned in order to promote meaningful learning of a connected set of concepts. Conceptual mapping is demonstrated to be a tool that promotes critical thinking, cohesion, and meaningful learning in opposition to the learning of arbitrary facts and rote memorization. The authors offer many examples of conceptual maps that have been produced to externalize thinking at each level. This chapter provides a "synthesis case" demonstrating that not only does it require critical thinking to create conceptual maps, but, equally salient, these visual representations of our thinking catalyze further critical thinking and coherence within the science education system.

BACKGROUND: CRITICAL THINKING, MEANINGFUL LEARNING, CONCEPTUAL MAPS, AND THE SCIENCE EDUCATION SYSTEM

Critical Thinking and Concept Mapping

A host of researchers have linked constructing concept maps (cmaps) with critical thinking (Jonassen et al., 1998; von der Heidt, 2011; Fonseca & Extremina, 2008.) As the chapters in this book will make abundantly clear, "critical thinking" has been defined different ways by different authors. Further, Krathwohl (2002) recognized the terms 'critical thinking' and 'problem solving' lacked clarity of meaning in popular usage and advised that "one must determine the specific meaning of 'problem solving' and 'critical thinking' from the context in which they are being used." A clear articulation of the relationship between cmapping

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and critical thinking comes from the field of nursing education. Daley et al. (1999) turned to a Delphi research project of the American Philosophical Association (APA) (1990), which published a consensus definition of 'critical thinking' based on the views of 46 published critical-thinking theorists from numerous disciplines. This definition states: "Critical thinking is the process of purposeful, self-regulatory judgment. This process gives reasoned consideration to evidence, contexts, conceptualizations, methods, and criteria" (APA, 1990, p. 2). She continues with Facione (1995) "Like many other descriptions of higher order thinking, the original Delphi authors conceptualized a simultaneous, metacognitive, self-appraisal of one's thinking process (that is, thinking about and evaluating one's thinking while engaged in the process of purposeful judgment (p.2). Drawing the connections clearly to the cmapping process, Daley concludes: Cmaps. . . link directly to the APA (1990) definition of critical thinking. Cmaps are metacognitive tools that assist learners to develop a self-appraisal of their own individual thinking processes. The maps foster a careful consideration of evidence drawn from clinical practice. Through use of cmaps, learners develop the ability to consider the context of nursing practice in their conceptualization of client problems. Finally, purposeful judgments are made regarding interventions based on how methods and criteria are linked to the conceptualization of the problems." Chabeli (2010) sinks deeper, providing a table correlating core cognitive critical thinking skills, related subskills and affective dispositions with the educational processes of cmapping.

In his literature review pertaining to the use of cmapping techniques and technologies for education and performance support, A. Cañas (2003), listed "to teach critical thinking" along with a variety of uses of cmaps. Novak and Cañas (2008) further explain, that the creation of cmaps clarifies a growing conceptual framework as individuals (or a group) learn a new field of study. This conceptual framework is very significant because it forms one of the filters through which the world is observed and interpreted and forms the basis for problem-solving and decision-making processes. Note that these complex mental processes are undergirded by the higher order thinking processes of analyzing, synthesizing, and evaluating (Anderson & Krathwohl, 2001). Thus, we will restrict our comments to critical thinking as being able to carry out complex problem-solving and decision-making, supported by the foundation of Bloom's higher order thinking, as defined by the American Philosophical Association (APA), and as applied by Daley et al. (APA, 1990; Daley et al, 1999). Further, we make the intellectual leap that strand maps also require critical thinking in their construction. We will demonstrate connections between critical thinking and conceptual mapping at all levels of the science education system. We will articulate some of the critical thinking questions that are asked at each level and we will ask how clarity at each level contributes to the coherence of the system. The salience of this work is highlighted by the addition of "metacognitive knowledge" to the revised Bloom's taxonomy. Regarding knowledge about cognition in general and one's own cognitive knowledge, Krathwohl (2002) stated, "It is of increasing significance as researchers continue to demonstrate the importance of students being made aware of their metacognitive activity, and then using this knowledge to appropriately adapt the ways in which they think and operate." We hope that our work demonstrates the importance of cognitive knowledge for those who work at all levels of the science education system.

Meaningful Learning: Theoretical Underpinnings of Conceptual Maps

The authors will use the term "meaningful learning" as defined by David Ausubel (1978). In its simplest form, meaningful learning requires learners to actively attach new learning to their

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