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CHAPTER 1

Overview of Knowledge Mapping

If You Want to Find Your Way, Get a Map!

Sara and Charlotte, driving from Cincinnati to San Francisco, leave the freeway in Colorado and soon realize they are lost. Sara, who is driving, asks Charlotte to get out the map so they can find their way again.

Susan and Roy, exploring the islands of the Caribbean in a Catamaran, get blown off course by a storm and aren't sure where they are. They take a reading on the GPS and pull out a chart to find their location.

Adam and Paul, taking a biochemistry course in college, find themselves hopelessly lost in the voluminous new material. They sit down over a weekend and map out where they have been and where they are going in the course, and return on Monday in much firmer control of their destiny.

WHAT IS KNOWLEDGE MAPPING?

Knowledge mapping or knowledge representation is a process in which a schematic representation of knowledge is created. Knowledge maps typically include the most important concepts (usually noun ideas) in boxes, ovals, or circles (Figure 1.1). Concepts are usually connected by lines which are often unlabeled (and thus represent mere associations, as in “is somehow related to”) and are sometimes given name labels. When the lines (links, relations, arcs) are labeled, it is usually with a verb phrase. The relationship indicated by a line between two concepts is always bidirectional, but the name label that is shown on a map may be either unidirectional or bidirectional. Arrowheads are often included on the line so the reader knows which way the relation should be read, but in hierarchical maps, arrowheads are often omitted on the assumption that the reader will read from top to bottom.

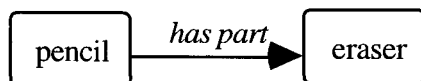


Figure 1.1. Elements of knowledge mapping include concepts such as pencil and eraser, links such as “has part”, and propositions such as “pencil has part eraser”.

It appears that knowledge mapping has originated independently multiple times and in multiple contexts. As one example, a young woman who recently worked for me had invented knowledge mapping on her own, as a tool for learning. To the best of her knowledge, she had never heard of or seen knowledge maps created by others. Her maps were hand drawn in rich colors, similar to the Mind Maps and Visual Thinking Networks described briefly below. Additional discoveries of knowledge mapping are described below.

A BRIEF HISTORY OF KNOWLEDGE MAPPING

Knowledge mapping began early, when cave men and women sketched their knowledge about their environment in the form of symbols on the walls of caves. We'll skip much history between these early events and modern times. The history presented below makes no effort to be comprehensive, but instead captures some of the highlights of knowledge mapping in education of particular interest to us.

According to Brachman and Levesque (1985), knowledge representation as a means of creating artificial intelligence (AI) in computers began in the 1950s. Specifically, they cite a 1950 paper by Turing and Shannon (1950) and a conference at Dartmouth in 1956 as the starting points for serious work in AI. The goal of AI is concerned with "writing down descriptions of the world in such a way that an intelligent machine can come to new conclusions about its environment by formally manipulating these descriptions (Brachman and Levesque, 1985, p. xiii). AI requires much more elaborate mapping techniques than those desirable in education.

The goals of knowledge mapping in education are quite different from those in AI. Educational knowledge mapping is seen primarily as a tool for learning, teaching, research, intellectual analysis, and as a means for organizing knowledge resources. In all fields using knowledge mapping, the idea is to tap into the workings of the brain. AI and education are two sides of a coin. AI wants to use knowledge mapping to build computers that mimic the brain's intelligence, while educators want to use knowledge mapping to stimulate and support students' efforts to increase their intelligent use of their own innate resources.

Gordon Pask developed many forms of cybernetic knowledge mapping in the 1950s through the 1970s, during which he published at least three books and 150 papers. His interest in mapping was applied to studies involving such topics as the "Styles and strategies of learning" (Pask, 1976a) and "Conversational techniques in the study and practice of education" (Pask, 1976b). He developed maps to represent the ideas that emerged in student conversations and to show the connections between those ideas (Pask, 1975, 1977). Since researchers today are once again turning to discourse and dialogic analysis, it seems likely that they will also find knowledge mapping helpful.

Pask straddled the worlds of AI and education, as indicated by his dual appointments as Professor in the Department of Cybernetics at Brunel University and Professor in the Institute of Educational Technology at the Open University, both in Great Britain. These two topics are combined in his 1975 book, *Conversation, cognition and learning: A cybernetic theory and methodology*. In the introduction,

Pask describes his theory as being concerned with psychological, linguistic, epistemological, ethological, and social mental events of which there is awareness – that is, conscious thoughts and interactions. He was obviously ahead of his time, at least in education. But researchers today might appreciate the many strategies he developed for mapping the dynamics of a conversation.

In the same decade but on a different continent, science educator Novak and his graduate students invented concept mapping as a learning tool for K–12 students (Stewart, Van Kirk, & Rowell, 1979). Novakian concept maps grew out of Ausubelian learning theory (1963, 1968) with its emphasis on building connections between ideas. Novakian concept maps (described further in Chapter 8) are widely used in science teaching today from elementary school through the university.

With the advent of the Macintosh personal computer in the early 1980s, Fisher, Faletti and their colleagues created the SemNet[®] knowledge mapping software as a learning tool for college biology students (Fisher, Faletti, Patterson, Thornton, Lipson & Spring, 1987, 1990). The major objective was to help students shift from their prevailing rote learning methods to meaningful understanding of biology content. The design of this software grew directly out of AI and cognitive science, especially Quillian's (1967, 1968, 1969) semantic network theory for how we store information in long term memory (see Chapter 9 for more information).

Also in the 1980s, Wandersee (1987) developed concept circle diagrams (CCDs) for the purpose of helping students clarify their thinking about inclusive/ exclusive relationships. Being able to organize ideas into categories and to distinguish between similar but different things are key steps in learning and are supported by the use of CCDs (discussed in Chapter 7).

In the late 1980s and early 90s, Horn (1989) in the US and Buzon (e.g., Buzon & Buzon, 1993) in Great Britain took knowledge mapping into the business world. In fact, Buzon has been a tireless promoter of his strategy, Mind Mapping, in both education and business arenas throughout the British Empire. Buzon is interested in mapping as a means of promoting creativity and divergent thinking, and has developed the MindMan software to support his style of mapping (Table 1.1). Probably the best commercial success in knowledge mapping, at least in the US, is the Inspiration software (Table 1.1), a concept mapping tool available for both IBM and Macintosh platforms.

In the late 1990s we have witnessed the amazing growth and blossoming of the World Wide Web. The quantity of information available at our fingertips is staggering, and the need for intelligent, user-friendly mapping strategies grows stronger every day. So far, this need has not been adequately answered, although various efforts are being made (see, for example, Table 1.1).

Table 1.1. Some knowledge mapping software described on the internet, 1999

Software	World Wide Web Site
The Axon Idea Processor	http://web.singnet.com.sg/~axon2000/article.htm
Banxia Software	http://www.banxia.co.uk/banxia/
CoCo Systems Limited	http://www.coco.co.uk/
Inxight Hyperbolic Trees	http://www.inxight.com/Content/7.html
Inspiration Software	http://www.inspiration.com/
LifeMap	http://www2.ucsc.edu/mlrg/lifemapusermanual375/lifemapusermanual375.html
MindMan Software	http://www.mindman.com/
SemioMap Builder	http://www.semio.com/download/Download.cgi
SemNet Software	http://trumpet.sdsu.edu/semnet.html
Smart Ideas	http://www.smarttech.com/smartideas.htm
VisiMap	http://www.coco.co.uk/prodvm.html

HOW DOES KNOWLEDGE MAPPING HELP STUDENTS LEARN?

Research suggests that in more cases than not, knowledge mapping exercises of all types help students learn. Why is this? There are many possible answers to this question. First, mapping provides sustained support for *time on task* in thinking about a topic. Second, if mapping is done collaboratively, it can lead to *extended discussions about the meanings of concepts and the relations between them*. Third, the act of creating an organized structure of ideas on paper or in a computer necessitates and often *prompts the creation of such a knowledge structure in the mind*. Fourth, knowledge mapping prompts students to *take implicit, often fuzzy, associations and make them into explicit and precise linkages*, a process that is at the heart of meaning-making. Fifth, knowledge mapping *takes many cognitive and metacognitive skills that remained invisible for so many generations and makes them visible, explicit, and accessible*. Sixth, mapping prompts students to *make finer discriminations between ideas*, another process at the heart of learning. Seventh, the more one practices, *the better one becomes at organizing and relating concepts* (Cliburn, 1990). And eighth, each time two concepts are joined with a relation in working memory, *that information is believed to be "broadcast" to all the modules in the brain* so it can be used to solve any current problem the vast subconscious brain may be working on (Baars, 1988).

Jonassen, Beissner, & Yacci (1993, p. 8–10) describe the advantages of knowledge mapping in another way. First, they say, semantic structure is inherent in all knowledge. Second, structural (organized, semantic) knowledge is essential for recall and comprehension. Third, learners assimilate structural knowledge effectively. Fourth, knowledge structures in memory reflect the world. Fifth, structural knowledge is essential to problem solving. And sixth, there are significant differences between the structural knowledge of novices and experts, so that for novices, working on their structural knowledge to make it more expert-like is a natural part of learning.

HOW CAN KNOWLEDGE MAPPING CONTRIBUTE TO EDUCATIONAL REFORM?

Mapping is a tool for personal and social knowledge construction and a tool that supports meaningful learning. In the classroom, mapping can provide

- structure for the *minds-on* part of *hands-on/minds-on* teaching,
- a systematic means for reflecting on and analyzing inquiry learning,
- a knowledge arena for operating on ideas, and
- tangible support for the transition from teacher-centered to student-centered classrooms.

WHAT IS THE EDUCATIONAL REFORM MOVEMENT?

Serious educational reform began in the 1970s in Great Britain and Australia. In the early 1980s the US came on board. The momentum of reform has steadily gathered steam ever since.

The reform movement advocates meaningful science learning at every grade level. The group in the American Association for the Advancement of Science (AAAS) that is working toward reform is called Project 2061, to signify their expectation that it will take that long (until the year 2061) to revamp education in the US. AAAS has produced several well-known guidelines to help the process along (1983, 1989, 1998), and has succeeded in bringing the two cultures (scientists and science educators) together to work on the project. The National Research Council (1996) also has taken a leadership role, as have many other professional and granting agencies.

Among other things, reform documents (Appendix 1.1) repeatedly cite the need for strategies that help science learners acquire interconnectivity and discrimination among science ideas, two features that most clearly differentiate novices from experts and most dramatically affect recall and application of knowledge. It also happens that these two features especially benefit from knowledge mapping activities. Cohen (1991, p. 46), in studying a newly reformed mathematics classroom, describes the problem succinctly:

If the recent reforms are to succeed, students and teachers must not simply absorb a new body of knowledge. Rather, they must acquire a new way of thinking about knowledge and a new practice of acquiring it. They must cultivate new strategies of problem solving that seem to be quite unusual among adult Americans. They must learn to treat knowledge as something they construct, test and explore, rather than as something they accumulate.

One obstacle to achieving reform is that many teachers are confused or overwhelmed by the demands of teaching science for understanding (Flick, 1997). They understandably mix many of their old teaching strategies with the new (Cohen, 1991). Further, American schools have not been organized to support continued growth and learning by teachers (although this is changing slowly and in piecemeal ways). Teachers lack the basic requirements of a professional workplace such as a work station and telephone, and they are not given work time to prepare their lessons



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