DEVELOPMENT MODEL FOR KNOWLEDGE MAPS

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Introduction

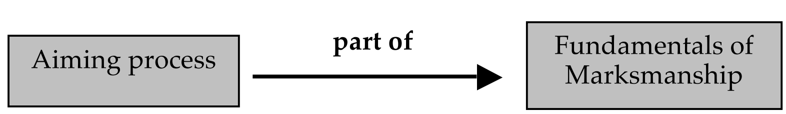
Knowledge maps are the representation of 'detailed, interconnected, nonlinear thought' (Fisher & Kibby, 1996). Knowledge mapping serves as both an instructional and assessment tool to illustrate both declarative knowledge (facts, definitions, statements) and to a lesser extent, procedural knowledge (how something is done, e.g., processes for problem solving, plans, decision making). A well-constructed map demonstrates knowledge of key ideas within a domain as well as how these ideas are interrelated (Baker, Niemi, Novak, & Herl, 1992; Chung, O'Neil, & Herl, 1999; Churcher, 1989; Herl, Baker, & Niemi, 1996; Jonassen, Beissner, & Yacci, 1993; Jonassen, Reeves, Hong, Harvey, & Peters, 1997; Novak, 1998).

This paper is a brief introduction to knowledge mapping, and provides an overview of the key features of a concept map and how to go about creating one, and ends with some recommendations for selecting meaningful links.

Features of Knowledge Maps

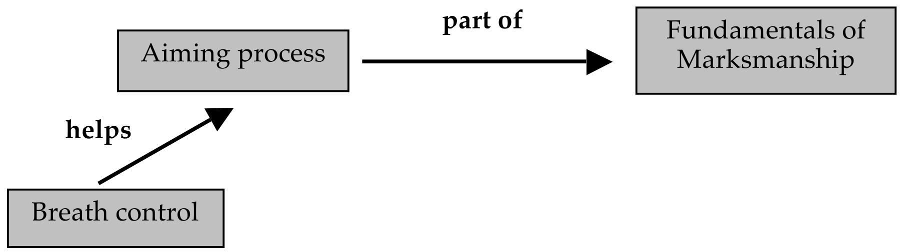
Knowledge maps are a network representation of terms, or **concepts**, usually enclosed in circles or boxes of some type, and links, or **relationships**, between concepts, as indicated by a line between two terms. Words on the line specify the semantic relationship between the two concepts. The basic unit of meaning is composed of a concept-link-concept set, also called a **proposition**.

In the domain of rifle marksmanship, for example, the statement, *Aiming process is a fundamental part of marksmanship,* can be simplified and represented in the following way:

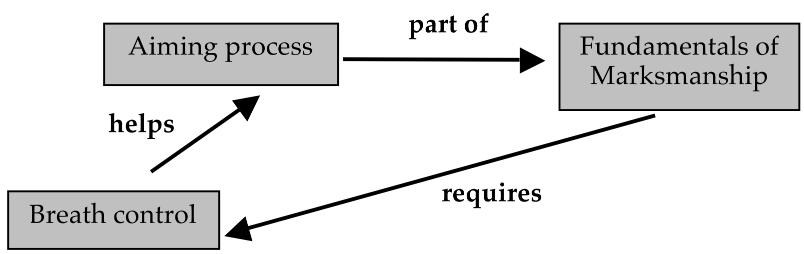


In the proposition, the two concepts *Aiming process* and *Fundamentals of Marksmanship* are related to each other through the link *part of*.

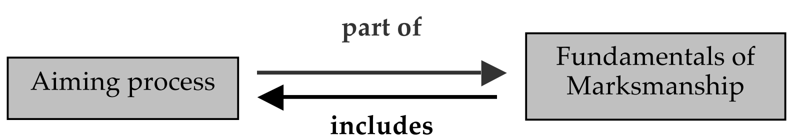
Likewise, *Breath control* can be associated with *Aiming process* through the link *helps:*



and to Fundamentals of Marksmanship through the link *requires*:



Additionally, concepts can be related to one another in several ways, i.e., by changing the direction of the link.



A final feature of a knowledge map is its overall organization. As concepts and links accumulate, the map begins to take on a structure that is both semantically richer (more meaningful links) and better integrated (more connections). A hierarchical structure, as advanced by Ausubel's (1963) research on cognitive structure, defines mental schemas as the integration of new ideas, or concepts, into preexisting knowledge structures. Concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. This approach is especially useful for well-structured disciplines such as the sciences.

Another cognitive framework stems from an associationist memory theory (Deese, 1962, 1965), wherein cognitive structures are elicited though associations. Under this model, structures are not limited to a hierarchical framework, but instead allow for a variety of relationships among concepts.

Guidelines for Creating Knowledge Maps

The creation of knowledge maps involves 7 steps (see Table 1 for summary).

1. **Select domain area.** Since concept map structures are dependent on the context in which they will be used, it is best to identify the learning objective, or the particular problem or situation one is trying to understand—e.g., the fundamental elements of rifle marksmanship (NAVY), the mechanics of inheritance (GENETICS), how photosynthesis works (ENVIRONMENTAL SCIENCE), features of different physiological systems and how they interact (HUMAN PHYSIOLOGY), or the factors behind the 1930s Depression (HISTORY).
2. **Identify key ideas.** With the learning objective in mind, experts review curriculum material and generate lists of the most important main ideas. Experts can be the course instructor or a designated content specialist. A rank order of the list is established from the most general, most inclusive concept to the most specific, least general concept.
3. **Construct preliminary map.** Using the list of concepts, experts construct a preliminary concept map, linking concepts with links. Note that concepts are usually nouns, and links, verbs. See next section for guidelines on selecting links.
4. **Review maps.** Check the map to ensure all concepts are depicted and that the relationships between concepts are meaningful and complete. Check also for overall organization of the maps for density (number of links), level of complexity, and interconnectedness (that concepts are interrelated, i.e., no concept is isolated).
5. **Modify maps according to student level.** Adjust the maps according to student level. Will students be able to understand the meaning of the concepts and links or do the terms have to be simplified for student comprehension?
6. **Final list of concepts and links.**
7. **Final knowledge map**. Experts create final map based on revised list of concepts and links. This process should be much quicker and involve slight revisions to preliminary map.

Table 1

Summary for Developing a Knowledge Mapping Task

Step	Procedure
1	Select domain.
2	Experts identify key concepts within that domain, i.e. major ideas and more specific, associated ones.
3	Experts create preliminary map with links.
4	Expert maps compared and reviewed.
5	Concepts and links are modified according to student level.
6	Create final list of terms and links.
7	Experts create final knowledge maps.

Guidelines for Selecting Links

According to Jonassen (1996) the most difficult part of semantic networks is the linking process. Good links, which are usually verbs, describe not only precisely but completely the nature of relationships between all the ideas. And because ideas can be related to one another in several ways, and on different levels, it might often be necessary to either select the more meaningful link or have more than one link in different directions between concepts.

The following is a list of guidelines for link selection (Jonassen, 1996).

1. **Preciseness and succinctness**. Try to avoid surface links, such as *is connected to, is related to,* or *involves,* for they do not tell anything meaningful about the relationship. Select instead links that discriminate meaningful differences on functional, temporal, or causal levels. For a list of relational categories, see Table 2.
2. **Parsimony**. Try not to use more links than are necessary. For example, if 5 different links will describe all the relationships among the terms, do not use more than 5. And, do not use different links that mean the same thing, e.g. *attribute of*, *property of*, and *characteristic of*.
3. **Consistency**. The meaning of any link should be the same each time it is used.
4. **Avoid over-reliance on one or two links**. A predominance of a few links reflects a narrowness of thinking. Additionally, it implies the links are too general and that other, more specific links might better describe the relationship between concepts. One strategy is to calculate the proportions of relational categories among the links, i.e., frequency of causal, characteristic, functional, etc., to ensure a balanced representation.
5. **Calculate *term: link* ratio**. There should be fewer links than terms. This goes back to the idea of parsimony.

Based on preexisting work on semantic and language structure (Sowa, 1984; Evens, Litowitz, Markowitz, Smith, & Werner, 1980; Wilkins, 1976), CRESST research has classified links from knowledge maps into 10 relational categories (see Table 2, Chung, Baker, & Cheak, 2002). In considering the relationship between concepts, first determine the nature of the relationship [e.g., what kind of thing is it? (membership) What is it made of? (whole/part) What are its distinguishing features? (characteristic) What does it do? (functional)] and then select the appropriate descriptor, e.g., *is, made of, has, controls*, respectively. For an extended list of possible links, see Table 3.

Table 2

Relationship Categories For Knowledge Maps.

Relationship category	Definition[a]
Causal	*X* creates a change or effect on *Y*, e.g. *causes, leads to, increases, improve*s
Characteristic	*X* is an inherent feature or characteristic of *Y*, e.g. *has, is*
Classification	*X* is a class, category or type of *Y*, or vice versa, e.g. *type of, example of*
Comparison	*X* involves a comparison in order to show a similarity, difference, or equality with *Y*, e.g. *similar to, different from, equal*
Conditional	*X* contingent on *Y*; a possible event, e.g. *may lead to, requires, necessary for*
Function	*X* designed for or capable of a particular function with regard to *Y*, e.g. *controls, transports, carries, use*
Location	*X*'s spatial relation to *Y*, e.g. *under, over*
Part-whole	*X* is contained within, or a part of *Y*, e.g. *part of, belongs to, made of, includes*
Temporal	*X*'s time relation to *Y*, e.g. *beside, during, follows, prior to*

[a]General form: *X* type-of-relationship *Y*, where type-of-relationship is the relationship category.

Table 3

Sample Links (Adapted from Jonassen, 1996)

Relationship category	Examples	
Symmetric	has sibling	is same as
	has synonym	is independent of
	is opposite of	is equal to
	is near to	is opposed to
	is similar to	
Asymmetric		
1. Inclusion	composed of/ is part in	contains/ is contained in
(typically the most common)	has part/ is part of	has instance/ is an instance of
	has example/ is example of	includes/ is included in
2. Characteristic	has characteristic/ is characteristic of	has attribute/ is attribute of
(second most common)		has type/ is type of
	has property/ is property of	defines/ is defined by
	has kind/ is kind of	models/ is modeled by
	describes/ is described by	implies/ is implied by
	denotes/ is denoted by	has disadvantage/ is disadvantaged
	has advantage/ is advantage of	has size/ is size of
	has function/ is function of	is higher than/ is lower than
	is above/ is below	
3. Action	causes/ is caused by	used/ is used by
	solves/ is solution for	exploits/ is exploited by
	decreases/ is decreased by	increases/ is increased by
	destroys/ is destroyed by	impedes/ is impeded by
	influences/ is influenced by	determines/is determined
	enables/ is enabled by	absorbs/ is absorbed by
	acts on/ is acted on by	consumes/ is consumed by
	converted from/ converted to	designs/ is designed by
	employs/ is employed by	evolves into/ is evolved from
	generates/ is generated by	modifies/ is modified by
	originates from/ is origin of	provides/ is provided by
	requires/ is required by	regulates/ is regulated by
	sends to/ receives from	
4. Process	has object/is object of	has output/ output of
	has result/results from	has subprocess/ is subprocess of
	has process/is process in	organizes/ is organized by
	has input/is input to	proposes/ is proposed by
	depends on/has dependent	concludes/ is concluded by
5. Temporal	has step/ is step in	has stage/ is stage in
	precedes/ follows	

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