Computer–Based Concept Mapping

Sherman R. Alpert
IBM T.J. Watson Research Center, USA

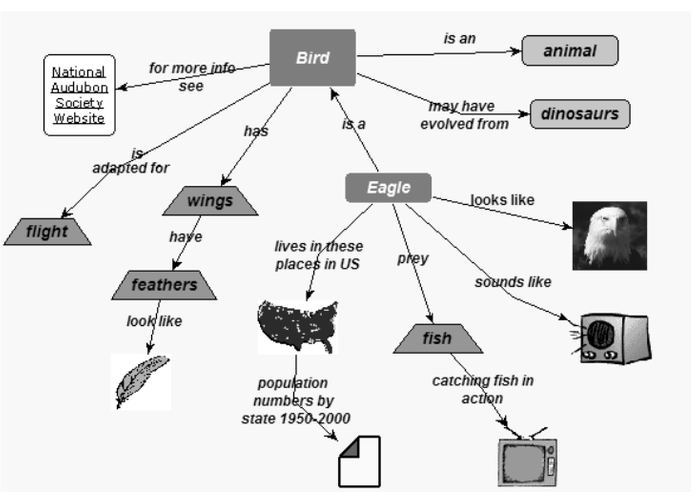
INTRODUCTION

A *concept map* (also known as a *knowledge map*) is a visual representation of knowledge of a domain. A concept map consists of nodes representing concepts, objects, events, or actions connected by directional links defining the semantic relationships between and among nodes. Graphically, a node is represented by a geometric object, such as a rectangle or oval, containing a textual name; relationship links between nodes appear as textually labeled lines with an arrowhead at one or both ends indicating the directionality of the represented relation. Together, nodes and links define propositions or assertions about a topic, domain, or thing. For example, an arrow labeled *has* beginning at a node labeled *bird* and ending at a *wings* node represents the proposition "A bird has wings" and might be a portion of a concept map concerning birds, as portrayed in Figure 1.

BACKGROUND: CONCEPT MAPS AS KNOWLEDGE REPRESENTATION

Representing knowledge in this fashion is similar to semantic network knowledge representation from the experimental psychology and AI (artificial intelligence) communities (Quillian, 1968). Some have argued that concept maps accurately reflect the content of their authors' knowledge of a domain (Jonassen, 1992) as well as the structure of that knowledge in the authors' cognitive system (Anderson-Inman & Ditson, 1999). Indeed, in addition to the structured relationships among knowledge elements (nodes and links) that appear in a single map, some concept mapping tools allow for multiple layer maps. The structure of such maps is isomorphic to the cognitive mechanisms of abstraction, wherein a single node at one level of a map may represent a chunk of knowledge that can be further elaborated by any number of knowledge elements at a more

Figure 1. A concept map in the Webster concept mapping tool. Nodes in this concept map portray a variety of representational possibilities: A node may contain a textual description of a concept, object, event, or action, or may be an image or a link to a Web site, audio, video, spreadsheet, or any other application-specific document.



detailed level of the overall map (Alpert, 2003). Concept maps, thus, can be viewed as knowledge visualization tools.

CONCEPT MAPS AS COGNITIVE TOOL

Concept maps have been used in educational settings since the early 1970s as both pedagogical and evaluation tools in virtually every subject area: reading and story comprehension, science, engineering, math word problems, social studies, and decision making (see, e.g., Bromley, 1996; Chase & Jensen, 1999; Fisher, Faletti, Patterson, Thornton, Lipson, & Spring, 1990; Novak, 1998). Concept maps permit students to demonstrate their knowledge of a domain; act as organizational and visualization tools to aid study and comprehension of a domain, a story, or an expository text; and support the generation and organization of thoughts and ideas in preparation for prose composition. They are also used as instructional materials whereby teacher-prepared maps present new materials to learners, showing the concepts and relationships among concepts of a domain new to the students. Concept maps constructed by students help those students to learn and exercise the metacognitive practice of reflecting on what they know to explain or demonstrate their knowledge to others. Such activities may lead to self-clarification and elaboration of their knowledge. There is considerable anecdotal and experimental evidence that the use of graphical knowledge-visualization tools such as concept maps helps improve student comprehension and enhance learning. For example, Fisher et al. (1990) have reported that providing concept maps constructed by domain experts to present new information to learners and illustrating how an expert organizes concepts of the domain results in demonstrable pedagogical benefits. Dunston (1992) and Moore and Readance (1984) have shown that concept maps are pedagogically effective when students create their own maps to reflect on and demonstrate their own knowledge.

In educational environments, the use of concept maps has evolved from paper-and-pencil to computer-based tools. A number of computer-based concept-mapping tools have been reported by researchers (e.g., Alpert & Grueneberg, 2000; Fisher et al., 1990; Gaines & Shaw, 1995b; Kommers, Jonassen, & Mayes, 1992), and there exist shareware programs as well as commercial products for this activity (e.g., Inspiration,[1] Axon,[2] Decision Explorer,[3] SemNet,[4] SMART Ideas,[5] and the IHMC CmapTools[6]). With such tools, users using a mouse and keyboard can create, position, organize, modify, evolve, and store and retrieve the nodes and links that comprise concept maps. Concept-mapping software offers the same sorts of benefits that word processors provide over composing written works on paper. That is, such software facilitates revision of existing work, including additions, deletions, modifications, or reorganizations. In fact, students often revisit their existing maps to revise them as their knowledge of a subject evolves (Anderson-Inman & Zeitz, 1993).

Computer-based concept mapping tools have also been used outside educational settings. In business settings, for example, concept-map tools have been used for organizing notes taken during meetings and lectures, and for the preparation of presentations and written works. There have also been efforts to use concept maps as organizing vehicles for both designers and end users of Web sites and other hypermedia environments (e.g., Gaines & Shaw, 1995a; Zeiliger, Reggers, & Peeters, 1996). In this context, concept maps have provided visualizations of the structure of the pages, documents, or resources of a site and the hyperlink relationships among them, as well as a mechanism for directly navigating to specific pages.

FUTURE TRENDS

More recently, concept-mapping tools have been enhanced to enable the representation of information or knowledge that is neither textual nor proposition based. In many tools, for example, a node may be an image rather than a geometric shape with an embedded textual description. In the Inspiration product, nodes in a concept map may also reference media files, such as video and audio, and application-specific files, such as spreadsheet or presentation documents. The Webster knowledge mapping tool (Alpert & Grueneberg, 2000) offers a Web-enabled version of these facilities, in which nodes in a concept map may reference any media that can be