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Concept Mapping: How to Help Learners Visualize Knowledge

Rebecca L. Fiedler[*], Eduardo Salas[**]

University of Central Florida

Abstract

Concept mapping is a powerful research-based strategy suitable for students across grade levels and content areas. It also has useful applications for adults in a cross-section of industries and for training. This paper addresses the theory supporting the use of concept maps and examines some of the research on using concept mapping. The authors offer practical applications of the research findings and suggest examples and additional reading for those interested in learning more.

CONCEPT MAPPING: HOW TO HELP LEARNERS VISUALIZE KNOWLEDGE

The *No Child Left Behind Act* has mandated the use of scientifically-based research to support teaching strategies, professional development initiatives, and technology purchases in today's schools. This paper will focus on concept mapping research including definitions, theoretical support, and practical teaching strategies for the upper elementary through post-secondary classroom. It is organized around questions practitioners are likely to have.

Why is this important?

People organize their knowledge in ways that allow them to learn and store new information (Ausubel, 1963, 2000; Novak, 1998). Their underlying knowledge structures allow them to retrieve existing information and apply it to new learning and new tasks. The quality and quantity of this knowledge structure is critically important to new learning and therefore of interest to teachers and instructors. In fact, Ausubel (1963) calls this structure "the principal factor influencing the learning and retention of meaningful new material" (p. 103). Ausubel (2000) further asserts "properties of existing cognitive structure are the most important single class of factors influencing the acquisition, retention, and transferability of knowledge" (p. 146). Concept maps can make these knowledge structures explicit, sometimes revealing misperceptions that may interfere with further learning.

Concept maps, an idea conceived and popularized by Joseph D. Novak, have been used effectively in corporate training (Overmyer-Day & Benson, 1996), at colleges and universities (All & Havens, 1997; Parkes, Zimmaro, Zappe, & Suen, 2000 & Suen, 2000; Roberts, 1999; Williams, 1998), in teacher preparation programs (Ferry, Hedberg, & Harper, 1998 1998; Kowalchuk, 1999; Trent, Pernell Jr., & al, 1998 1998), and in the K-12 environment (Guastello, Beasley, & Sinatra, 2000 2000; IARE, 2003; Sungur, Tekkaya, & Geban, 2001 2001). Similar ideas have been touted among CEOs by mind mapping evangelist Tony Buzan and his popular *Mind Map Book* (Buzan & Buzan, 1996), mentioned in *Forbes, Publishers Weekly*, and other magazines. In short, researchers have found positive effects of concepts maps on student retention and recall (Hall & O'Donnell, 1996), literacy development (Chang, Sung, & Chen, 2002 2002; Horton et al., 1993), and critical thinking in broad curricular areas (IARE, 2003).

What are concept maps?

Concept maps are alternatively called knowledge maps and mind maps. Some authors make distinctions among these, but all are similar in a number of respects. Novak (1997) defines concept maps as “tools for organizing and representing knowledge” (¶1). He goes on to specify the inclusion of concepts and connecting lines between different concepts indicating relationships. Linking lines are labeled in such a way as to form propositions or meaningful statements. Furthermore, concept maps include “cross-links” indicating the interrelatedness of different areas of the concept map. Finally, concepts are arranged in a hierarchical manner.

Others do not mention hierarchical organizations. Knowledge maps form more web-like structures that also include terms representing concepts drawn from a well-defined domain. Concepts are linked by lines and these lines are descriptively labeled to define the relationship between the concepts (Ruiz-Primo, Shavelson, Li, & Schultz, 2001). Wiegman and his colleagues (1992) define knowledge maps as “two-dimensional spatial arrays that represent information in the form of a node-link-node diagram” (Wiegmann et al.). Chung and O’Neil (1999) clarify this definition by pointing out that “nodes represent concepts and links represent relationships between connected concepts” (p. 463).

Buzan's (1996) mind maps are radiant in nature, rather than hierarchical. In a mind map, the main idea is at the center of the map with themes radiating from that central image. Branches and sub-branches form a network of connected nodes. Mind maps also rely on color and graphics.

For purposes of this paper, the terms concept maps and knowledge maps will be used interchangeably. These maps will be defined as a graphical representation of one's knowledge framework consisting of nodes and lines. Each node represents a concept and the lines express relationships. The optional label on the line defines the explicit type of relationship being represented.

What tools can I use to construct concept maps?

Concept maps may be constructed in a variety of ways and using diverse materials. Very young or pre-literate children may use picture cutouts and string yarn between the pictures to show relationships. Older students can use blank sheets of paper and colorful markers. Index cards or sticky notes that can be arranged and rearranged are also useful tools for constructing concept maps. In addition, there are a variety of software packages designed to facilitate creating and editing concept maps. Computers offer several advantages including the capability to edit, save, and print work.

Inspiration and Kidspiration software

The software packages *Inspiration* and *Kidspiration* are widely used for concept mapping and other activities requiring visual organizers. The software is designed specifically for education and features predefined templates for a number of educational activities. Users can toggle back and forth between graphic and outline views of concept maps under construction and can export their maps in a variety of formats. The Oregon-based company offers a free 30-day trial download of each product from their website at http://www.inspiration.com. Interactive demonstrations, a quick-start tutorial, and examples from a variety of curriculum areas are also posted at the website. The company offers academic pricing and volume licensing and the software is available for both Macintosh and Windows computers.

CmapTools Software

CmapTools is available at no cost to educators at http://cmap.ihmc.us/download/. The newest version of the product is currently available for Windows, Linux, and Solaris platforms. Work to release the software of Macintosh OS X is ongoing. Developed at the Institute for Human and Machine Cognition at the University of West Florida, *CmapTools* offers the ability to create concept maps, to share them using Internet technologies, and to work collaboratively to construct maps.

Mind Manager

Available for Windows computers only, *Mind Manager* is targeted to the business customer. *Mind Manager* promises seamless integration with Microsoft *Office* and *Project* products. Additional capabilities include a variety of modes and the ability to export to a variety of file formats. A free 21-day trial download is available at the company's website (http://www.mindjet.com), along with several tutorials and case studies.

What is the theoretical support for concept mapping?

Ausubel's Assimilation Learning provides a theoretical foundation for concept mapping (Novak, 1998). According to Ausubel (2000) learners must be presented with "potentially meaningful material" and they must have a cognitive structure to anchor or connect the new ideas in order to form new meanings. New knowledge is placed in the existing organizational structure and new meanings are formed. These new meanings are formed by interaction between old and new knowledge. The newly acquired knowledge modifies the old knowledge, and vice versa. Over time, the new knowledge is subsumed by the existing knowledge structure.

This subsumed knowledge prepares learners to more easily learn additional, related information (Novak, 1998). "If existing cognitive structure is clear, stable, and suitably organized, it facilitates the learning and retention of new subject matter. If it is unstable, ambiguous, disorganized or chaotically organized, it inhibits learning and retention" (p. 103). In fact, the learner's prior learning and resultant cognitive structure is the most important consideration in whether or not meaningful learning will occur.

For purposes of training and teaching, an understanding of the novice learner's structure is useful in order to present potentially meaningful material. Facilitating the development of an appropriate cognitive structure maximizes the likelihood of meaningful learning and retention (Ausubel, 1963).

Ausubel's view is consistent with the Information Processing model of learning. Neurocognitivists interpret learning as an active process where new learning is integrated into existing knowledge structures that have been idiosyncratically constructed based on prior experiences. These structures of prior experiences influence how new experience and newly acquired knowledge will be stored in long-term memory. Arousing these networks of stored knowledge by activating prior knowledge is a critical condition to facilitate new learning (Anderson, 1992, 1997).

Information processing models suggest existing ideational networks are activated when there is new input. Further, the analysis of the new input is mediated by the prior existing conceptions to provide a context for the new input. Information processing research indicates "new learning tasks involve a reconstruction process of assembling information from fragments in memory that are pertinent to the context of the task" (Anderson, 1997 p. 80). Further, Anderson asserts "these networks may be the neurocognitive equivalents of schemata in psychology" (p. 86).

From a theoretical perspective, concept maps can facilitate learning by making cognitive structures explicit. The process of completing maps forces the map constructor to think specifically about the relationships within a given domain. Misconceptions may also surface, providing instructors opportunities for correction.

What does the research say about using concept maps?

A thorough literature review is beyond the scope of this paper. Readers interested in a comprehensive literature review have two readily-accessible options. Cañas and colleagues at the Institute for Human and Machine Cognition (2003) prepared a summary of literature for the Navy. They reviewed the use of concept mapping (as defined by Novak) in education, business, and government. Their major conclusions included: the idea that it is better to integrate concept map use in the learning process, rather than incorporate it in isolation; that concept mapping is especially useful for learning about relationships between and among concepts; that a broad cross-section of students, including those of lower ability, can benefit from concept mapping; that there are numerous uses for concept mapping in the field of education; and that learners must actively interact with the subject matter under study to maximize achievement.

In a study commissioned by *Inspiration* software, the Institute for the Advancement of Research in Education (IARE, 2003) identified 29 studies that meet the *No Child Left Behind Act's* definition of scientifically-based research. From their review of these studies, they concluded that visual organizers improved student performance in reading comprehension; enhanced thinking and learning skills; and improved retention and recall of information. They also noted increased student achievement across grade levels and content areas.

The rest of this paper will focus on the findings from specific research studies with direct application to today's classrooms.

What effect, if any, does concept mapping have on student perceptions?

Hall and O'Donnell (1996) examined subjective perceptions such as anxiety, motivation, and concentration of subjects in an experiment using university students (n=43). Researchers also examined differences in objective, cognitive outcomes related to recall. Subjects studied a 1,500-word passage on the autonomic nervous system. Some subjects studied a text passage, while others received the information in the form of a knowledge map. Throughout the experiment, subjects rated themselves on anxiety/nervousness, motivation, and concentration. Two days later, subjects completed a free recall test in which they were asked to recall as much information as possible from their studying.

Results indicated a significant positive effect on both motivation and concentration during the study session. This effect favored knowledge maps. There was no significant difference between the knowledge map and text groups on ratings of anxiety. Ratings of motivation during the testing session were not significant. Ratings on concentration were higher during the study session than during the testing session.

Recall results favored use of knowledge maps. The favorable effect was evident in both superordinate and subordinate propositions, but most pronounced in recall of superordinate information. Researchers suggested the structure of the maps provided emphasis on the macrostructure of the content to be learned (Hall & O'Donnell, 1996).

What does this mean for your classroom?

Those who used knowledge maps during the study session were more motivated to study and better able to concentrate. Not surprisingly, this resulted in a better performance on the recall test a couple of days later. Subjects were able to remember both large and small ideas from their study materials. The most pronounced improvement was in their recall of the bigger ideas.

Are there any suggestions for designing concept maps?

The design and configuration of concept maps influence students' using them. Researchers have examined design questions such as spatial configuration, whole maps versus stacked maps, and plain versus embellished links (Wiegmann et al., 1992).

In an experiment involving 37 university students, subjects were given two different types of maps. The first group received a map designed as a hierarchy in which gestalt principles of symmetry and proximity were applied. The second group studied a map organized with the topic node at the center, with supporting nodes surrounding. This map resembled a "spider web." Maps were informationally isomorphic and both contained embellished (or labeled) links. Subjects in the "gestalt map" group outperformed those who studied the web map on both a fill-in-the-blank test and a multiple-choice test.

Most concept maps are formatted as a single, large map. These are called "whole" maps. Alternatively, large complex maps may be broken into more manageable chunks. Such maps are presented sequentially. To determine the relative effectiveness of these map formats, 34 university students were given maps with information about human biology. One group of subjects received a whole map containing embellished links. Gestalt principles of organization were applied. The second group of subjects received a series of six stacked maps. Subjects were randomly assigned to treatment groups and studied their maps for 20 minutes.

After one day's delay, subjects returned to take a short answer and a multiple-choice test. Both groups took each test. The short answer test was administered first to eliminate cueing from the first test. Results from this experiment indicate that subjects with high verbal ability performed better with the stacked map format. This same format hindered the low verbal ability subjects.

In contrast, those with lower verbal ability performed better with the whole maps, while the higher verbal ability subjects' performances suffered. The map format had a greater impact on the short answer tests than the multiple-choice test. The researchers suggest this effect is due to the higher demands placed on the retrieval processes.

Another experiment conducted by these same researchers compared the performance of subjects using maps containing plain links to that of subjects using maps with embellished links. Embellished links contain arrowheads to show direction, words or abbreviations to label the lines, or differently drawn lines (solid, dashed, barbed) to indicate various types of relationships. Embellished links do not necessarily exhibit all of these characteristics simultaneously.

Thirty-one university students participated in the experiment examining links. Subjects studied stacked maps that were organized according to gestalt principles. One group of subjects studied maps with plain links, while the other group examined maps with embellished links. The next day subjects were administered a free recall and a multiple-choice test, in that order. In this experiment, higher ability students' performance was facilitated by embellished links while lower verbal ability subjects' performance was hindered. Conversely, lower verbal ability subjects' performance was enhanced using maps with plain links while the higher verbal ability subjects' performance was hindered.

What does this mean for your classroom?

Researchers found students studying a hierarchical map following principles of symmetry and proximity outperformed students studying a map organized more like a spider web on fill-in-the-blank and multiple-choice tests. This suggests that when creating concept maps to share with students, a hierarchical structure should be used.

Consider providing a “whole” map to convey a broad idea for low ability students, though this is not helpful to high ability students. High ability students are better served by a series of “stacked” maps presented in a logical sequence. However, low ability students do not benefit from the “stacked” maps. Where possible, offer “stacked” maps to high ability students and “whole” maps to low ability students.

Researchers have found similar results with linking. High ability students benefit from embellished links conveying additional information, though these are overwhelming for low ability students. Plain links are beneficial for low ability students, but a hindrance to high ability students.

How do I use concept maps in my classroom?

Researchers have examined a variety of methods for using concept maps. These include the use of concept maps as advance organizers, teacher versus learner prepared maps, and different strategies for providing expert maps to learners.

Are advance organizers valuable?

“Advanced organizers refer to a category of activities such as outlines, text, aural descriptions, diagrams and graphic organizers that provide the trainee with a structure for the information that will be provided” (Cannon-Bowers, Rhodenizer, Salas, & Bowers, 1998 p. 298). Such advance organizers have been used in a variety of training and educational contexts including the military (Kraiger, Salas, & Cannon-Bowers, 1995) and foreign language instruction (C. Herron, 1994; C. A. Herron, Hanley, & Cole, 1995; Tripp & Roby, 1990), among others. Advance organizers have been the focus of researchers' attention since Ausubel introduced the idea in the early 1960s.

Richard E. Mayer (1979a) performed an exhaustive search of advance organizer studies completed after 1960. Based on his selection criteria (published in a journal or book and research design including a control group), 44 studies were selected for further analysis. Mayer concluded that advance organizers offer the largest benefit when used in a domain in which the learner does not have, or does not use, a framework for assimilating the knowledge. Further, benefits to using an advance organizer will occur when the material is disorganized or unfamiliar to the learner. Achievement on tests measuring broad conceptual learning or requiring transfer to related tasks is favorably impacted by the use of advance organizers. "Twenty years of research on advance organizers has clearly shown that advance organizers can affect learning, and the conditions under which organizers are most likely to affect learning can be specified" (Mayer, 1979b, p. 161).

Of interest to practitioners are six specific themes that have emerged in research on advance organizers: acquiring concepts, reading comprehension, organization of material, effects of repetition, learner perceptions, and graphics. Each is briefly addressed below.

Acquiring concepts. Mayer (1979a) and Hannafin and Hughes (1986) have concluded that advance organizers and diagrams help learners acquire concepts in meaningful ways. Students are better able to make novel inferences, generate creative solutions, and improve their performance on far transfer tasks.

Reading comprehension. Mayer (1984) and Mayer and Bromage (1980) examined advance organizers to aid reading and text comprehension. They concluded that advance organizers positively affected the number of conceptual idea units recalled and learners' ability to perform far transfer tasks. Hirumi and Bowers (1991) studied the impact of concept trees, a graphical advance organizer, on comprehension and perceived motivation of college students performing a reading task. They found increased acquisition of concepts, a higher perceived level of motivation, and more student confidence in completing the reading task.

Organization. Mayer (1978) investigated the role of advance organizers on learning. His assertion was that advance organizers provide a meaningful context for integrating new material. To test this theory, he used college students who were given complex text. The experimental group received an advance organizer and the control group did not. In an experiment with logically organized text, followed by questions closely related to the text, the advance organizer group had no positive effect. In contrast, subjects in another experiment were given poorly organized text and a post-test that was not closely related to the subject matter of the text. In this case, the advance organizer group performed significantly better than the control group.

Repetition. Mayer (1983) found results to support that repetition increases performance on recall tasks. Subjects were scored on recall of idea units, verbatim recognition, and problem solving. Additionally, Mayer found that repetition also impacts in a qualitative way; more conceptual learning, along with problem-solving ability, takes place. Advance organizers seem to have the same effect as repetition in allowing subjects to build a conceptual framework for their learning (Mayer, 1983).

In an attempt to extend and replicate the previous work on repetition, Kiewra, Mayer, Dubois, Christenson, et al. (1997) compared the use of advance organizers to repetition of videotaped learning material. They used novice students to compare different types of organizers and repetition of a lecture one, two, or three times. Subjects were tested on recall, relationships, and facts.

Results indicated better recall for the conventional organizer, but only for main topic information. This was unexpected. For the relationship test, the more detailed organizers resulted in a positive difference. Further, results indicated a positive effect on the organizers that was related to the criterion task (Kiewra et al., 1997).

Perceptions. Hirumi and Bowers (1991) examined perceived levels of motivation and confidence among college students completing a reading task using concept trees. They found an increased perceived level of overall motivation. Students in the experimental group reported significantly higher levels of confidence than their counterparts in the control group (Hirumi & Bowers, 1991).

Graphics. There is research support for using graphical or pictorial advance organizers. Herron, Hanley, and Cole (1995) compared two advanced organizers in second year French classes at a college. In one treatment condition, students heard an aural description setting the scene for a videotaped conversation that was going to be played. The other treatment group listened to the same aural description and were simultaneously presented with representative pictures. The description + pictures treatment yielded significantly better scores on comprehension tests. Additionally, 100% of the students reported a preference for the description + pictures treatment (Herron et al., 1995).

Mayer (1989) examined the use of conceptual models to aid scientific understanding. In his review, he found significantly stronger performance in the areas of conceptual information and transfer problems. In fact, he replicated these findings using a variety of reading tasks across a range of scientific concepts. Students who had received a model prior to instruction outperformed those who had not.

What does this mean for your classroom? Advance organizers provide a small but consistent advantage to learners using them. These advantages are more marked when unfamiliar material is provided, the material is poorly organized, when learners are novices, or when the test measures transfer (Mayer, 1983). In situations where the learner is immersed in an unfamiliar domain, or confronted with dense or disorganized text, the advance organizer may have the effect of increasing understanding.

When the goal of the materials presented is to develop higher order thinking or problem solving among learners, an advance organizer should be an effective tool to help learners acquire key concepts. These concepts are critical to reach problem-solving goals, make novel inferences, and successfully complete far transfer tasks.

Should concept maps be teacher-generated or student-generated?

Smith and Dwyer (1995) assessed the effectiveness of instructor-prepared and learner-generated concept maps in facilitating student achievement. In this study, the primary mode of learning was reading the text. Researchers wished to determine whether there is interaction between prior knowledge, and instructional strategy. This study assigned 81 college students to three different treatments. All participants read a passage about the heart and were tested in a variety of ways: drawing, identification, terminology, and comprehension. Treatment 1 was to read only. Subjects in Treatment 2 read the text and generated concept maps. In Treatment 3, the instructor prepared the concept maps in addition to the student’s reading of the text. Results were positive, but not significant for instructor-prepared maps.

What does this mean for your classroom? Researchers recommend that instructor-prepared maps be accompanied by a thorough explanation (Smith & Dwyer, 1995).

Are there effective strategies for presenting concept maps to students?

Chang, Sung, and Chen (2002) explored the effectiveness of concept mapping in enhancing text comprehension. Researchers attempted to correct for the passiveness that may be a byproduct of providing expert maps to students. They also recognized that having subjects construct their own concept map might result in cognitive overload. To correct for these problems, they used scaffold fading, a completion strategy, and a map-correction approach to examine the effect of concept map training on summarization skills.

Participants for this study were 126 fifth grade students (60 girls and 66 boys) in Taipei. Class groups were assigned intact to the three experimental groups and a control group. There was a pre- and post-test, along with 7 weeks of instruction on reading and map construction. The dependent variables were text comprehension and summarization.

The researchers used seven examples of scientific writing, each reviewed by two 5th grade teachers to determine suitability. In all analyses, the map correction group out-performed the other groups. The researchers discuss the possibility that the failure of the scaffold fading and map generation groups to outperform the control groups may be due to the complexity of the task (as reported by the subjects) and the resulting cognitive load or insufficient training time for the learners to develop the required skills. The findings suggest the use of map correction as a potential approach to the effective use of concept mapping (Chang et al., 2002).

Training effects were also noticed as subjects trained in concept mapping techniques transferred these skills to novel situations, especially summarization. Only the scaffold-fading group significantly outperformed the control group in the summarization test.

What does this mean for your classroom? Concept maps are useful to scaffold students' understanding of complex material. As they become more familiar with the domain under study, the maps can become less detailed and eventually fade completely. Implementing in this manner may improve students' ability to summarize important ideas. Additionally, asking students to correct concept maps is an effective approach to use concept mapping.

How can concept maps be used to assess students?

Using concept maps to compare novice conceptual understanding to expert understanding has generated substantial research interest. Researchers have determined this is a useful undertaking.

The first study took place in the Calculus domain. Eight professors and 14 students participated in the study. Qualitative analysis of the concept maps they generated revealed substantial differences between the novice maps and the expert maps. The researcher was able to determine subtle differences in understanding among the students and noted homogeneity among the experts' maps (Williams, 1998).

In an attempt to develop more effective measurement systems for individual cognition using concept maps, Aidman and Egan (1998) turned to computers. Their study involved two professors and 100 first year psychology students. Researchers presented eight concepts to the two professors. These professors developed "expert" maps. Students mapped the same concepts and student maps were compared to the "expert" maps as well as to student performance on a standard test. Researchers found there was high reliability between the experts' maps. Student maps could be divided in four different groups according to mapping performance: expert, novice, mixed, and other. Student maps were consistent with the students' academic performance. Researchers concluded that implicit maps can be reconstructed and compared to experts. They further concluded that maps can indicate differences between learners (Aidman & Egan, 1998).

Identifying the misconceptions students hold is important so these misconceptions do not interfere with future learning. In a 10^{th} grade science class, researchers used concept mapping to examine misconceptions. An experimental group (n=26) used concept maps, while the control group (n=23) was taught using traditional instructional methods. The period of treatment was five weeks. The study found a positive effect on students' understanding of concepts through the use of concept mapping (Sungur et al., 2001).

Bolte (1999) looked at student-generated concept maps and essays to assess students in three undergraduate math courses. Their primary objectives were to measure correlation between concept map scores in conjunction with essays and those of exams and course grades. Additional objectives included measuring students' perceptions of this approach along with assessing the "connectedness" of students' knowledge.

Subjects included 108 undergraduate students enrolled in three different courses. Results allowed instructors and researchers to identify misconceptions held by the students, and the researchers concluded the combination of concept maps and accompanying essays was more powerful than either approach individually. Statistical analysis showed a significant correlation with more traditional measures. Students perceived their learning was enhanced in numerous ways because of the creativity involved, the reflection required by the task, and the encouragement they received to modify and extend their knowledge in order to construct the map. Bolte (1999) concluded the combination of concept maps and essays is a worthwhile addition to more traditional assessment methods and that it is no more subjective than traditional methods. Students' reactions were positive.

The practicality of implementing a new and time-consuming form of assessment is a legitimate issue for practitioners to raise. McClure, Sonak, & Suen (1999) attempted to assess practicality, along with reliability and validity. They compared six different scoring methods using 63 undergraduate education majors with 12 graduate students serving as scorers.

Participants received 90 minutes of instruction on concept mapping. Instruction included three guided tasks of increasing complexity. McClure and his colleagues (1999) concluded the use of concept mapping was very feasible for classroom application. Instruction and scoring was no more time consuming than typical assessment tasks. They further concluded that concept maps produced useful results for the classroom teacher.

Finally, Ruiz-Primo et al (2001) examined three types of concept maps: construct-a-map, fill-in-the-nodes, and fill-in-the-blank. They asked subjects (experts, expert students, and novice students) to talk aloud during the concept mapping task in order to understand the thinking process that was occurring. Subjects included two high school chemistry teachers and six students. Each subject completed each mapping task using the talk aloud protocol. The topic was chemical names and formulas. The researchers examined inferred cognitive activities through verbalizations and did empirical analysis of performance scores.

The primary purpose of this study was to develop a system or protocol for examining the claims of cognitive validity of concept mapping as an alternative assessment technique. Tasks ranged from high-directed to low-directed across the three different concept mapping techniques. The researchers concluded fill-in-the-lines maps were cognitively more difficult than fill-in-the-nodes maps. Construct-a-map from scratch provides the best differentiation of respondents' knowledge. The greater latitude allowed respondents to show their knowledge as well as misconceptions. The small sample size (n=8) yielded 24 verbal protocols to analyze. Researchers cautioned that generalizing the findings of this study should be done with caution (Ruiz-Primo et al., 2001).

What does this mean for your classroom? There are several ways concept maps can be used to assess student learning. Some of these may be too complex to objectively score for routine classroom use. At a minimum, student-generated concept maps are likely to reveal misconceptions held by students. This information is useful to instructors interested in designing interventions for students and modifying instruction to "fix" misconceptions. Student-generated concept maps will vary in quality and these differences are likely to correspond with other measures of student achievement. Though not the most effective use of concept mapping, several map completion strategies (fill-in-the nodes, link labeling, and fill-in-the blanks) may prove useful for assessment purposes.

Can concept maps be used for organization and planning?

Two studies (Ferry et al., 1998; Kowalchuk, 1999) have examined using concept mapping to assist preservice teachers in curriculum issues and planning. The first study used concept maps to examine the knowledge structures of preservice art teachers, and the second investigated how concept mapping can be used to plan and organize a science education curriculum.

In the first of the two studies, Kowalchuk (1999) addressed four issues: the influence of a published lesson plan, possible variations in approaches to a single published lesson plan, examination of concept maps to gain insight into novice art teachers' thinking about instruction and learning, and the potential usefulness of concept maps to examine and facilitate thinking.

The subjects were 18 art education majors enrolled in a curriculum and instruction class at a Midwestern university. Participants received a published art lesson plan researchers believed would provide ample opportunity for rich concept maps. After a brief training period, participants were asked to create their own maps using the published plan and drawing on their own expertise. They were encouraged to make cross-connections and draw on personal expertise. All participants completed their maps within one hour.

Kowalchuk (1999) examined subjects' perceptions of relationships between content, pedagogy, learning, and other factors. He found the maps lacked complexity. His recommendations included future research to exam the compartmentalization of novice teachers' knowledge in order to address the problem of simplistic thinking despite a relatively rich art background, cognitive flexibility, and the uncritical acceptance of published art lessons.

In the second study, researchers examined how preservice teachers used a concept mapping tool to organize a science education curriculum. The research questions for the study were: "How do preservice teachers use computer-based concept mapping tools to organize their curriculum content knowledge?" and "What features of the computer-based concept mapping tools help preservice teachers to link effective instruction with curriculum content knowledge?" (p. 88).

Subjects in this study used computer-based concept mapping tools. Two tutorials were held before subjects were asked to make their final concept maps. Researchers analyzed changes in software features that subjects used by comparing the first round of maps to the second. An increase in the number of links was found, as well as the use of the notes feature to describe pedagogical ideas for concept-specific nodes.

Subjects reported comfort with the process of concept mapping and using the computer. Follow-up studies with 21 of the subjects indicated they continued to use concept mapping as an instructional planning strategy. Researchers found enhanced planning skills, suggesting that the process of completing the concept map enhanced plan might be more important than the product itself (Ferry et al., 1998).

Jamie McKenzie (2003) has written about using *Inspiration* software as a tool for investigating complex issues. In his article, McKenzie discusses mind mapping strategies to explore complex questions and note taking strategies to record information. The paper you are reading was organized and written using the strategy described by McKenzie and the resulting diagram is illustrated in Figure 1.

What does this mean for your classroom? Teachers and students alike can benefit from the use of concept mapping to plan complex tasks such as lesson planning, papers, websites, and multimedia projects. Use of computer software allows the flexibility to easily edit and reorganize. Different software packages offer a variety of features including note taking, commenting, outlines, and exporting to simplify complex tasks.

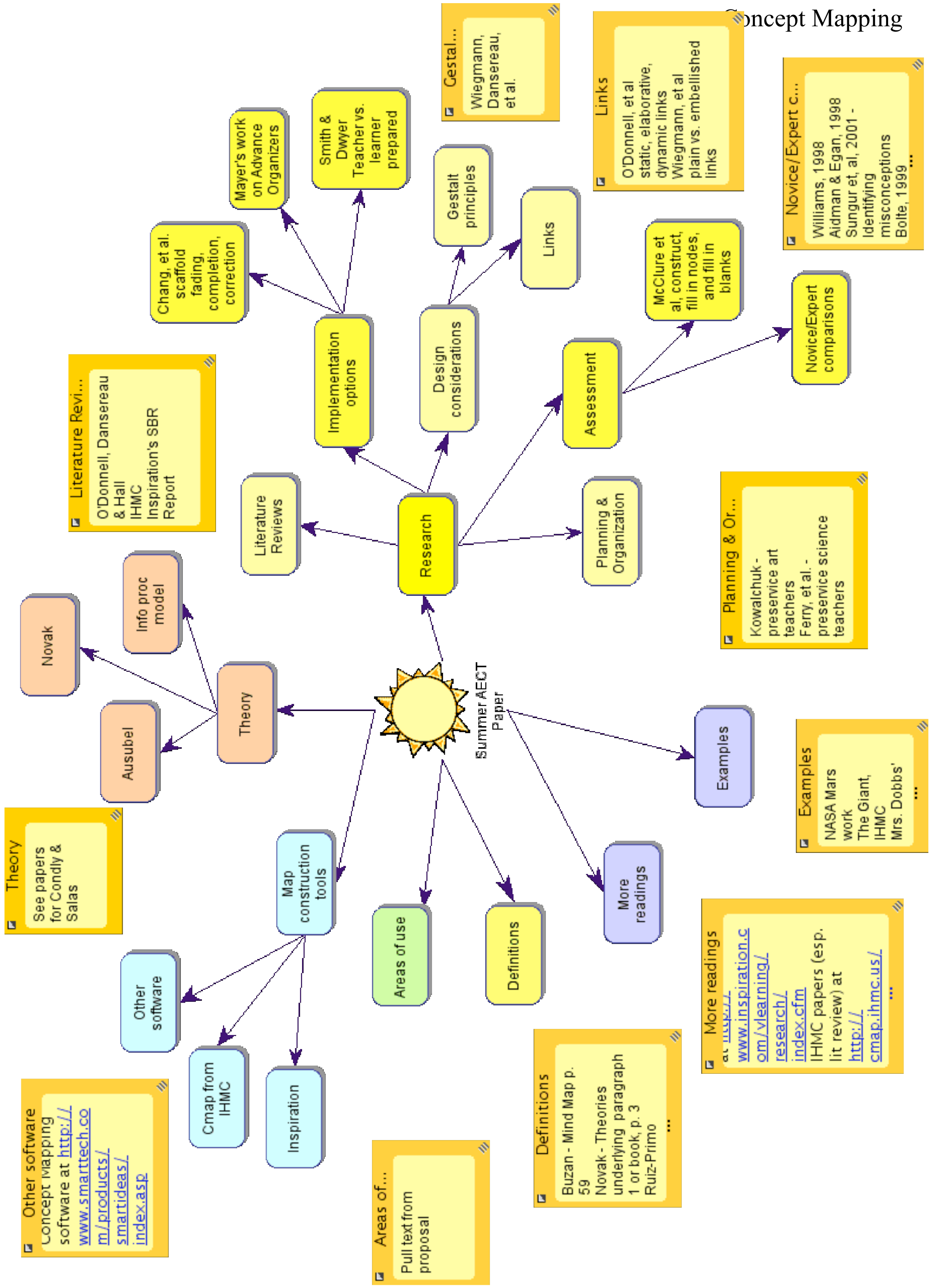

Figure 1. Inspiration diagram of this paper

Where can I see examples of concept maps and how they are used?

A variety of concept maps, illustrating many of the ideas in this paper, are available on the World Wide Web. Far from comprehensive, the following list offers several maps in a variety of styles used for a variety of purposes.

Mrs. Dobbs's Social Studies class website (http://home.earthlink.net/%7Etsdobbs/) hosts a colorful array of student generated samples. All are examples of "whole" maps. None are hierarchical.

NASA and the Institute of Human and Machine Cognition (IHMC) have collaborated to create Mars concept maps (http://cmex.arc.nasa.gov/CMEX/Map%20of%20Maps.html). This is an example of "stacked" maps that are hierarchical in nature. The maps have elaborative links and are used for website navigation. IHMC's website at http://cmap.ihmc.us/ offers another example of "stacked" maps with elaborative links used for website navigation.

Michael Ruffini's *MapACourse* website (http://www.mapacourse.com/FlashMX%20html/MJFlashMX.html) uses *Mindjet's Mind Manager* software to organize course materials and provide navigation to the materials. This is an example of a "whole" map with plain links.

Concept maps for study and instruction are available for statistics (http://cmap.coginst.uwf.edu/cmaps/MDM2/), biology (http://www.fed.cuhk.edu.hk/~johnson/misconceptions/misconceptions.htm), and as a pre-writing strategy (http://slc.otago.ac.nz/studyskills/conceptmap.asp). *Inspiration* and *Kidspiration* have posted examples in math, science, language arts, social studies, multimedia and lesson planning at http://www.inspiration.com/vlearning/index.cfm?fuseaction=example.

How can I learn more?

Michael Zeilick has created a tutorial in using concept mapping as part of the *Field-Tested Learning Assessment Guide* for science, math, engineering, and technology instructors. This brief tutorial is available at http://www.flaguide.org/cat/minutepapers/conmap1.php.

Joseph D. Novak (1997) has a brief paper *The Theory Underlying Concept Maps and How to Construct Them* posted at http://cmap.coginst.uwf.edu/info/. He has also written two books: *Learning How to Learn* (Novak & Gowin, 1984) and *Learning, Creating, and Using Knowledge: Concept Maps as Facilitaivte Tools in Schools and Corporations* (Novak, 1998).

Tony Buzan's *Mind Map Book* (Buzan & Buzan, 1996) offers another popular approach to creating maps of knowledge.

Conclusion

The powerful concept mapping strategy is suitable for students and teachers of all ages. It offers a motivating activity to increase student achievement across the curriculum and in such areas as problem solving, retention, recall, and comprehension. It is a powerful planning and organizational strategy for both students and teachers. Concept mapping is supported by scientifically-based research, thereby opening funding sources offered through *No Child Left Behind*. Concept mapping is easy to learn and easy to teach. Put it to work in your classroom tomorrow!

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