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ABSTRACT
        This study examined the use of concept maps for Web-based
applications in higher education. The purpose of the project was to design
concept maps that could serve as prototypes for navigating and searching
Internet resources. It also explored the value of concept mapping as a method
of bibliographic retrieval for the ERIC database. Following an extensive
literature review, the study compared competing methodologies for developing
concept maps; analyzed primary ideas about concept maps; described procedures
for developing maps; discussed assumptions about what makes good concept maps
for facilitating Internet and print navigation; identified and tested
software for developing concept maps; and examined navigation issues for
utilizing concept maps. Results suggest concept maps are becoming more
widespread in their application to various purposes; software packages have
changed significantly since the advent of the Web but none of the software
evaluated offered all the necessary features. While concept maps may be
quickly created, the resulting maps may not adequately map the knowledge
base. Concept maps have much to offer the ERIC system, and a hybrid mix of
existing, inexpensive tools may be useful to leverage technology and provide
a new user interface. An annotated bibliography is included. (Contains 24
references.) (SM)

Concept Maps for Web-Based Applications

ERIC Technical Report

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I. Executive Summary

Introduction

This ERIC Technical Report documents the sponsored research conducted in 1999-2000 at the University of Virginia's Curry School of Education to study the use of "Concept Maps for Web-Based Applications." The research was funded by the National Library of Education and ERIC through a pass-through contract from George Washington University to UVa. Research Associate Professor Dr. John H. Milam, Jr., served as Principal Investigator with Research Assistant Susan A. Santo and Assistant Professor Dr. Lisa A. Heaton as staff.

The purpose of the project was to "conduct research and design concept maps about the knowledge base in higher education" and to "prototype these concept maps and the ways in which they may be used to help navigate and search Internet resources." This Technical Report and demonstrations to ERIC staff are the primary deliverables.

In addition, this research was funded to explore the value of concept mapping for ERIC as a method of bibliographic retrieval. The ERIC system is in the middle of extensive re-examination of its purposes, technology use, and success in meeting user needs. It is hoped that this discussion of the use of concept maps to navigate web resources will contribute to this larger dialogue and to the ERIC system.

Methodology

A thorough literature review was conducted of research studies about the use of concept maps generally and specifically in education. Competing methodologies for developing concept maps were compared and contrasted, with issues raised about conflicting terminology, definitions, and purposes for use. Primary streams of thought about concept maps were analyzed, such as instructional, evaluation, creativity, groupware, and qualitative research methods. Various procedures for developing maps were described. Assumptions were discussed about what makes a good concept map for facilitating Internet and print navigation. The resulting synthesis of research on concept maps is used to understand how to create better web navigation schemes.

Another component of the methodology involved identifying, analyzing, and testing software for developing concept maps. How are these packages being used for navigating resources on the Internet? How may they be used to quickly and effectively build concept maps for postsecondary education websites? How does the software affect the researchers' and users' thinking about concept maps? These and other capabilities of the software were explored.

Several concept map software packages were chosen for the next phase of the project, which involved developing actual concept maps. Through practice sessions, peer debriefing, and unstructured interview protocols, the researchers explored the use of concept mapping as a method for documenting the knowledge base of postsecondary

education. These maps were limited by necessity to the study of knowledge about college students.

Navigation issues for utilizing the resulting concept maps were examined. Experiments with different concept mapping software were conducted to determine which package would best aid in the rapid development of a complex website. Graphics software such as Photoshop, Paint Shop Pro, Fireworks, and Macromedia Generator, and web database application software such as ColdFusion and Active Server Pages, were considered. The utility of a navigation scheme based on concept maps was compared to traditional hierarchical menu structures.

Finally, the lessons and assumptions learned through the various phases of the research project were applied to the ERIC system and the ways in which concept maps might be used to meet user needs. Since much of the emphasis of ERIC is on facilitating use of the existing literature base, key resources were documented with annotated reviews.

Discussion

The literature on concept maps suggests that they are becoming more widespread in their application to such varied purposes as instruction, creativity, writing, and research. However, the literature about concept maps is at time contradictory and confusing, with different recommendations about such key features as the relationship between symbols. Since a consensus is not available, users must choose to adopt the work of one or more theorists in the context of one or more fields of study.

There are also implicit assumptions behind the choices for software used to build and to view concept maps. These packages have undergone significant changes with the advent of the web, with exciting new features such as collaborative groupware and cross-platform use of Java. However, none of the evaluated packages offered the researchers the desired capabilities, particularly in sharing concept maps without the use of "plug-in" software to view levels of linked Internet resources.

While concept maps may be quickly created by one or more persons, the resulting maps may not adequately "map the knowledge base" of any field. Even with clear assumptions and good qualitative research methodology, there are a myriad of ways to create a single type of map of the same content. It is important to either involve a group of scholars in developing a map and/or to recognize that the resulting map is simply one of many possible patterns for documenting the links between complex ideas.

There appears to be much that concept maps have to offer the ERIC system. The issues and constraints of producing graphics, moving from concept maps to bibliographic retrieval, effective use of the ERIC Thesaurus of Descriptors, technical support, and development costs are addressed. The authors show how a hybrid mix of existing and relatively inexpensive tools may be used to leverage technology and provide an exciting new user interface for ERIC.

II. Introduction

This research was funded by the National Library of Education and ERIC as an ERIC special project to study the use of concept maps for web-based applications. The primary objectives of the project were to "conduct research and design concept maps about the knowledge base in higher education" and to "prototype these concept maps and the ways in which they may be used to help navigate and search Internet resources."

George Washington University served as the pass-through contractor and the University of Virginia's Curry School of Education as the sub-contractor for this project. The project timeline spanned the 1999-2000 academic year. Within UVa, Dr. John H. Milam, Jr., Research Associate Professor in the Curry School, served as Principal Investigator and Project Director. Research Assistant Susan A. Santo and Assistant Professor Dr. Lisa A. Heaton served as staff.

An analysis of problems in existing web navigation schema and the potential of concept maps to help users better find web resources was undertaken. This Technical Report documents the research conducted on concept maps with these activities: (1) conducting an extensive online and print literature review about all aspects of concept maps; (2) testing and critical review of software for creating concept maps; (3) developing and testing of a qualitative method and technology for creating sample concept maps; and (4) a review of concept maps and how they are currently being used on the Internet. Experiments were conducted using a hybrid of website technologies to create and display concept maps on the web.

This project was undertaken because of the authors' belief in a vision of the web which allows users to explore new levels of learning and research. The web has grown so fast and the range and type of available resources has become so infinite that it is almost impossible for an individual user to keep up with what is offered online in a single sub-field, much less a broad academic discipline.

Concept maps are shown to have great potential for facilitating learning in a non-hierarchical, non-linear way that is highly intuitive and much more like the way in which humans think and act upon ideas. As the report and discussion of findings show, however, current software packages do not provide all of the features the authors desired for this effort. A hybrid of existing and relatively inexpensive tools is necessary to effectively leverage technology. The results suggest that a complex website may be built based on the use of concept maps. However, the design and creation of such a site are formidable tasks.

The application of concept maps for web-based applications need not be implemented at this most complex level, however. There are many ways in which websites may incorporate simple and complex maps to facilitate better navigation to help users locate and access the Internet resources they need. Additionally, it should be recognized that methods for serving web-based concept maps have the potential to significantly improve

the delivery of all types of information, including ERIC bibliographic and full-text material.

This research was funded in large part to explore the value of concept mapping for ERIC's method of bibliographic retrieval. The ERIC system is in the middle of extensive examination of its purposes, technology, and success in meeting user needs. ERIC increasingly relies on the use of the World Wide Web for cataloging, processing, searching, and delivering bibliographic material. It is hoped that this discussion of the use of concept maps to navigate web resources will contribute to the larger dialogue about the ERIC system.

What is concept mapping?

A concept map is a graphical display that illustrates concepts in a particular field or domain and the relationships between those concepts. Although there are different definitions of concept maps, all have in common the idea of a central concept or theme, with related concepts or subcategories.

Figure 3.1 provides an example of a small concept map. The central concept is at the map's center, with the related concepts branching around the central node. Differing shades and shapes help to make the level of the concept clear, while connecting lines indicate a direct relationship.

Figure 3.1: Concept map on higher education
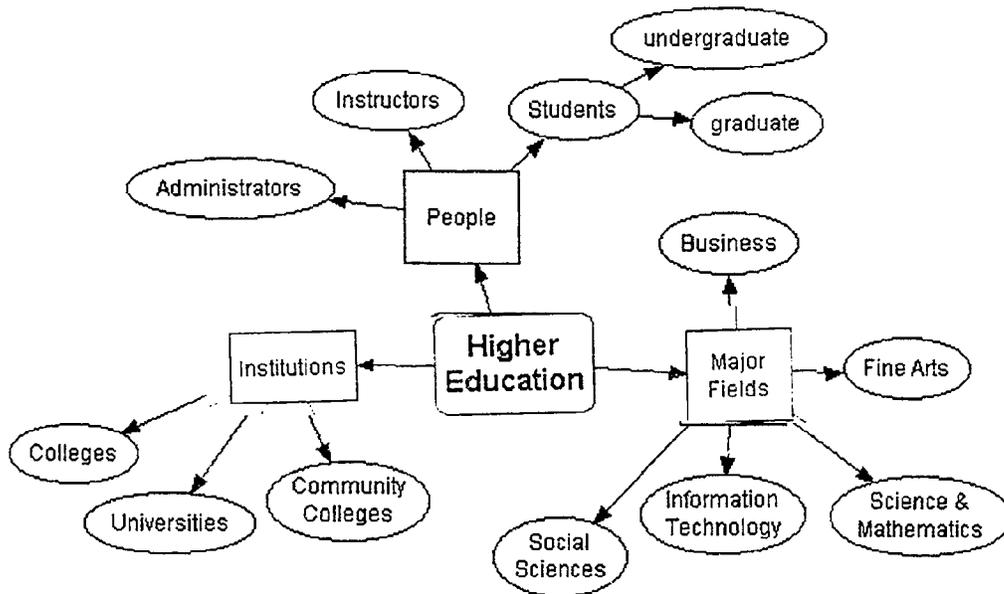
Why are concept maps important to educators? This chapter will show that such maps have many purposes and uses, ranging from teaching and assessment of learners to the representation of knowledge by subject matter experts. It is the vision of the authors that concept maps are a new and more efficient way to navigate the web. The future of ERIC is inextricably bound with the cataloging and retrieval of online resources and the use of concept maps may be the only way to do this.

Terminology, definitions, and purposes

What are concept maps in more general terms? According to Plotnick (1997), a concept map is a "graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts" (p. 3). This simple and concise definition seems to represent more what a concept map looks like than its intended purpose. Therefore, it seems worthwhile to take a look at some of the other definitions. Concept maps have been defined in a variety of ways using a wide range of names.

Joseph Novak did much of the early work on concept mapping in the 1960s using David Ausubel's assimilation theory of how learning takes place (Plotnick, 1997). Novak's (1993) theory of concept mapping suggests that learning is part of the process of assimilating new concepts into existing cognitive structures. These concepts and structures may be represented visually through the process of developing concept maps.

Novak's definition (retrieved 4/19/2000) is that concept maps are "tools for organizing and representing knowledge." Knowledge construction represents meaningful learning built through the organization of concepts and propositions. Concepts are a "perceived regularity in events or objects," while propositions contain concepts and other words combined to form meaningful statements (e.g., "trees" have "leaves").

Novak (1993) sees concept maps as having the following characteristics: (1) concepts represented as a hierarchy, with the most general concepts at the top of the map and the most specific below; (2) cross links showing how concepts in different domains are related; and (3) specific examples used to clarify the meaning of a concept. In other words, an abstract concept may be defined in more specific terms through examples of that concept.

Not every scholar on concept maps would agree on Novak's insistence that maps be hierarchical (in particular, those who stress the use of concept maps for encouraging creativity, where unusual juxtapositions of concepts may be desired). Jonassen et al. (1997) emphasize that hierarchies are not the only method of construction. The relationships between concepts may flow in many directions as in the form of concentric circles, or they may illustrate cause and effect relationships.

Buzan (1993) describes the concept map, or mind map, in poetic terms:

> It is in the shimmering and incessant embraces that the infinite patterns, the infinite Maps of the Mind, are created, nurtured, and grown. Radiant Thinking reflects your internal structure and processes. The Mind Map (Concept Map) is your external mirror of your own radiant thinking and allows you to access this vast thinking powerhouse.

Jonassen, Beissner, and Yacci (1993) explain that concept maps are an illustration of "structural knowledge," or how concepts within a particular domain are related. Concept

maps help learners to link new information to what they already knc /. Assumptions are made that knowledge cannot exist without structure, that structural knowledge is necessary for both understanding and problem-solving, and that experts in a domain have more elaborate structural knowledge than beginners. Thus, a new purpose for concept maps has been added: the process of mapping used to elicit structural information from experts in a particular domain.

Maxwell (1996) describes two types of concept maps. Variance maps illustrate general concepts and show how different variables or properties may affect others. Process maps are chronological and provide an illustration of events. He also suggests using a Venn diagram with the concepts illustrated as a series of overlapping circles.

It is important not to assume that concept maps contain everything that is important about a domain, even when developed by an expert. Jonassen et al. (1997) make the point that concept maps are used to represent what is thought to be the constructor's mind; but the connections in the actual mind are far more complex than could ever be displayed, representing thousands of concepts. Concept maps are usually two-dimensional, while images in the mind may be multidimensional. Concept maps are an approximation. Also, structural knowledge is dynamic. What is recalled by a person will depend on the time, context, and purpose in which the concept map is being created. Therefore, it is important to specify in advance the context and purpose for which the map will be used.

Finally, Waters and Zhou (1999) have a caution to add: Concept mapping works much better in a domain in which both concepts and the relationships between them are well-defined. It works less well when both concepts and relationships are vague.

Table 3.1 provides some alternate definitions of concept mapping. While these vary to some degree, the underlying definition may be formed from the consistent use of terms such as graphical or pictorial, concepts or ideas, and relationships. In simpler terms, concept maps may be described as a picture of the relationship of ideas about a specified topic.

Table 3.1: Alternate definitions of concept maps

Source	*Concept Maps Are...*
Jonassen et al. (1997)	Spatial representations of concepts and their relationships
Grasha (1996)	Organization of instructional information into a personal scheme for better retention and understanding
Maxwell (1996)	A method of visually displaying a working theory in qualitative research
Miles & Huberman (1994)	Representation of concepts and how they are related within a certain domain
Anderson-Inman & Horney (1996-1997)	Pictures that represent the relationships between ideas in a domain of knowledge

Source	Concept Maps Are...
McAleese (1998)	Concrete representation of cognitive processes
Ferry, Hedberg, & Harper (Retrieved 11/6/1999)	Two or three-dimensional displays that represent relationships between concepts
Trochim (Retrieved 3/4/2000)	Pictorial representation of ideas developed through group brainstorming and multivariate statistical analysis
Watters & Zhou (1999)	Visual language for representing and communicating knowledge within a community

The purpose of the map may differ depending on the definition being used. Note that Jonassen's (1997) definition is very general. Grasha's (1996) definition implies that the purpose of concept mapping is to help students learn. Both Maxwell (1996) and Miles and Huberman (1994) have used concept mapping as an aid in conducting qualitative research. Watters and Zhou (1999) consider the sharing of maps among a community to be important. Trochim (2000) also emphasizes community in his use of group brainstorming to develop the concepts, although he is the only scholar among those listed above to suggest the use of statistical techniques for constructing maps. The idea of sharing concept maps that have been created with others and coming to some sort of consensus seems valuable, especially when there is less immediate agreement regarding structure or content.

Not only do definitions of concept maps differ, but the term itself differs in how it is used and applied. Concept maps have been called by other names. How they are defined and drawn may vary slightly, but all of these examples are similar in that they represent a visual way to display complex concepts and their relationships. Table 3.2 provides some of the alternate names for concept maps.

Table 3.2: Alternate names for concept maps

Name of Term	Definition	Source
Mind maps, pattern notes, or brain patterns	A note-taking technique developed by Buzan in 1974, but now often used for creativity and problem solving. The main topic is placed in a box in the center, and ideas are written on lines radiating around it.	Buzan (1994); Jonassen, Beisner, & Yacci (1993); Russel (Retrieved 3/4/2000)
Cognitive maps	Representation of concepts and how they are related.	Grasha (1996); Miles & Huberman (1994)
Cognitive maps (same term, different meaning)	Dimensional representations developed through multidimensional scaling, an advanced statistical technique; the distances between concepts indicate semantic proximity. Trochim calls these "concept maps.")	Jonassen, Beisner, &. Yacci (1993)

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Name of Term	Definition	Source
Spider maps	Originated with Hanf in 1971 as a method for note-taking by mapping the structure of a passage of text. The map resemble a spider's web (similar to mind maps).	Jonassen, Beisner, & Yacci (1993)
Networks	Developed by Dansereau in 1978 as part of a study strategy for college students. Networks are composed of nodes (concepts) and links (relationships).	Jonassen, Beisner, & Yacci (1993)
Semantic maps or semantic networks	Use of a graphical format to convey hierarchical relationships between concepts. Research has focused on: 1) enlarging the student's vocabulary through mapping hierarchical relationships between words; 2) increasing reading comprehension; and 3) helping student recall content of instruction.	Jonassen et al. (1997); Jonassen, Beisner, & Yacci (1993)
Semantic webs	Also known as mind maps or concept maps, semantic webs are constructed with nodes that represent concepts and links that represent relationships between concepts.	Anderson-Inman & Horney (1996-1997)

These terms were all developed independently by different researchers, resulting in a somewhat confusing list. However, the chart may be simplified by realizing that there are really only three general appearances:

1) the typical concept map that uses shapes and lines connecting the shapes to indicate relationships, with the name of the concept written on each shape; and

2) the mind map, which uses lines instead of shapes radiating out from the central concept, with the name of the concept written on the line;

3) maps created using multidimensional scaling, a statistical technique beyond the score of this document.

Other familiar terms that represent visual tools such as flowcharts, organizational charts, and Venn diagrams also reflect the nature of concept mapping.

Primary streams of thought about concept maps

Why are concept maps used? Plotnick (1997) outlines five major categories of use for concept mapping, including creativity, hypertext design, communication, learning, and assessment.

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Jonassen et al. (1997), Novak (1998), Watters and Zhou (1999), Berg (1999), Ferry, Hedberg, and Harper (1999), and others discuss the attributes of concept mapping in terms of their instructional value. Concept mapping in an educational setting mi_ : be used for problem solving, instruction, or assessment of student understanding. Teachers use concept maps for planning instruction and illustrating relationships. Students use them to represent knowledge and information in a learning situation. Concept maps are also used as part of an evaluation procedure or in place of more conventional testing.

Another use of concept maps is to facilitate outlining as a pre-writing activity (Anderson-Inman & Horney, 1997). Maps are used in the classroom to facilitate creativity and creative writing. As a creativity tool, the process of concept mapping may be used for both brainstorming and organizing new ideas. The use of a visual tool, as opposed to using just words, may be stimulating and help thoughts to flow.

Novak (1998) promotes concept mapping to facilitate learning, creating, and using information in both the education and business sectors. Instructional designers use maps for content and task analyses. In business and industry, concept maps are used for brainstorming, project management, problem solving, and communication.

Another possibility is that the visual language of concept maps may be used to facilitate communication of knowledge with a group or community (Watters & Zhou, 1999). Teachers and students may represent and share information within the instructional setting. Business persons may communicate the flow of ideas related to a specified project or topic. Educators may share ideas with other educators or administrators.

Berg (1999) discusses the use of concept mapping for displaying relationships between ideas in memory. In this format, maps may be used to assess the knowledge and relationships that students retain. One significant problem mentioned in this regard, however, is that there may be multiple right methods for mapping a single knowledge base. One way of dealing with this problem is to use multiple people to create a concept map, or to have multiple experts come together to review an already created map and reconcile any perceived differences.

Graphical format

Concept maps may represent hierarchical structures, chronological events, causal relationships, or spatial relationships in a graphical format. Four core elements make up the graphical display possibilities for generating concept maps: 1) patterns; 2) shapes or nodes; 3) connectors or links; and 4) connecting words. Each element is described below.

Patterns for organizing the map may follow a top-down hierarchical structure or a circular, central hub structure. Novak (1998) believes that concept maps should always be created and read from the top down. Others, such as Jonassen et al. (1997), believe that concepts do not have to follow a hierarchical structure, but that they may flow in many directions represented by concentric circles or linking back to multiple nodes. Since not

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all relationships fall within a hierarchy, limiting a concept map to a hierarchical structure could seriously restrict the development of relationships within some topics.

Shapes or nodes, usually including ellipses and rectangles, constitute the primary content of a concept map. Color is often integrated within the shapes to signify levels of importance and relationships within and between sections.

Connectors or links in the form of lines, arrows, and curves or arcs help to identify relationships and the flow of information from node to node. Novak (1998) uses a solid line to define a relationship, a line with an arrow to show a causal relationship, and sometimes a dotted line to represent a secondary, weak, or missing relationship. Many of his examples also include curved rather than straight links. The arc could represent a circular flow, or it might be used in an effort to fit in connectors around the various boxes and ovals used to represent the nodes within a given map. If software is being used to create a map, the capabilities of the software will affect the appearance of the connectors.

Connecting or linking words are sometimes used along with connectors to further clarify relationships between nodes. Jonassen et al. (1997) calls these linking words that connect concepts "propositions."

Table 3.3 provides a list of common linking words generated from three sources: Grasha (1996); Jonassen, Beissner, and Yacci (1993); and Spradley (1979). The fourth list, generated from Novak (1998), represents a selection of linking words used in examples throughout the text. While the first three sources reveal some common patterns in linking words, the Novak examples illustrate that almost anything may be used in selecting terms to use between nodes.

Table 3.3: Common connecting or linking words

Grasha (1996)	*Jonassen (1993)*	*Spradley (1979)*	*Novak (1998)*
• analogy • characteristic • definition • evidence • example • influences • leads to • next step • part of • purpose • type of	• analogy • characteristic • evidence • leads to • part of • type of	• cause of • different from • kind of • part of • place to • reason for • result of • similar to • stage in • steps • use of • way to	• based on • but if • controlled by • demand • for • including • involves • may lead to • prevents • recognizes • such as • supported by • stored in • through • to enhance • using • validates

Almost all of the maps included as examples in these sources include connecting words that help to define the relationships. Reading the maps from top down is very much like putting a complete statement or sentence together. Of course, some are more complex, and several "sentences" may branch from the main concept at the top. The process is similar to reconstructing diagrammed sentences in an English grammar exercise.

Figure 3.2 provides an example of a map of the concept "physical fitness," which contains linking words.

Figure 3.2: Concept map with linking words
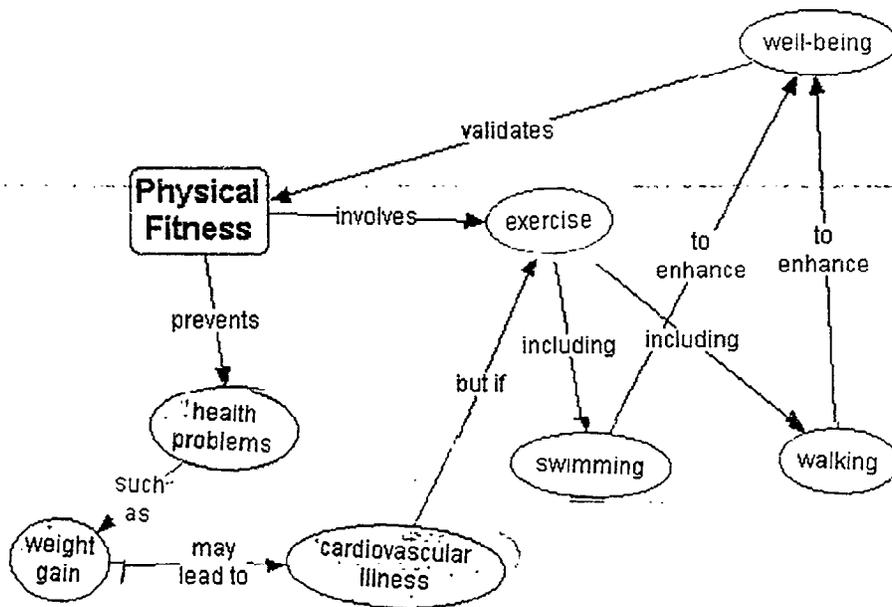
To summarize, concept maps make it possible to organize and structure knowledge, retain knowledge for long periods of time, and use knowledge in new contexts. They may be used as a learning tool, as an evaluation tool, in curriculum and instruction planning (through both global "macro maps" and specific "micro maps"), and to facilitate cooperative learning through concept mapping in small groups. Clearly, concept mapping is versatile enough to have many purposes.

Procedures for making concept maps

How are concept maps developed? Identifying the best process for developing concept maps is largely dependent on the purpose for the map and the preference of the map developer. The following are a series of process examples from the literature.

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A basic method is presented by Jonassen, Beissner, and Yacci (1993), who begin by identifying a set of important concepts in a domain. The most important word is enclosed in a circle at the top of the map. All other concepts are ranked in order of importance, and then the ranked concepts are built into a concept map. Connecting lines and linking words are added during the process until all of the original "important concepts" are included. The product is then reevaluated for organization and relevance of nodes and links. This method is particularly useful in that it may work regardless of the intended purpose of the concept map or the type of person constructing it.

Grasha (1996) suggests a three-step approach: 1) put together a list of key terms and ideas that cover the major issue being considered; 2) organize them in a way that will make it clear how the ideas are related; and 3) show the connections among ideas, not only within a category but across categories. He recommends determining the context of the concept being examined and the concept's purpose within that context. It is helpful to include specific examples of the concept. Also, it is important to assess whether the psychological size of concepts and their distance from each other may be illustrated graphically. This recommendation, though interesting, is not often implemented.

Tony Buzan's 1974 mind-mapping approach (as described in Jonassen, Beissner, & Yacci, 1993) is more like brainstorming and may be helpful in encouraging the flow of many ideas. This process always begins with a central image or main topic that is developed by adding ideas on branches in the pattern of a tree diagram. If there are problems in continuing a branch, the developer should skip over it and move on to the next theme. The process would continue until reaching a saturation point at each level. This solves the problem of how far to develop a branch before going on to the next branch. In addition to the tree structure, the design of the map might also include arrows, icons, and color to depict themes, associations, and links.

Anderson-Inman and Horney (1996, 1997) describe a brainstorming process that uses concept mapping as part of a prewriting strategy for students. They outline a more complex, three-phase process of concept map generation that flows from "generate" to "orchestrate" to "elaborate" (p. 302). Using concept mapping software and a projection device to facilitate the group effort, students participate in identifying relevant concepts - beginning with a "rapid fire" approach to "generate" the primary and supporting levels of information. In the "orchestrate" phase, the original nodes are grouped into relevant clusters. The third step allows the students to revisit each node and cluster in order to "elaborate"—i.e., make additions and clarifications for the final draft. The use of software for the process is seen to facilitate visual thinking and to encourage reflection and revision over time, a process that Anderson-Inman and Horney see as less feasible if the maps are developed on paper.

The approach of Miles and Huberman (1994) stems from the need to map the domain of a content expert during qualitative research. They suggest using a pre-mapping interview that may last for up to two hours to generate key concepts. The key concepts are then developed into a concept map along with descriptive text of the map and its organization.

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The map and text are then analyzed by the person interviewed to check for accuracy. Finally, the map is revised.

Spradley (1979) suggests questions to ask when interviewing an expert that may elicit structural knowledge for a domain. These questions may also be helpful when developing a list of related concepts for a concept map. Examples are:

> What are all the different kinds of ___?
> What are all the ways to ___?
> What are all the parts of ___?
> What are all the reasons for ___?
> What are all the uses for ___?
> What are all the stages in ___?
> Is ___ a type of ___?
> Which concepts are alike and which are different?

But when should one stop asking questions? Spradley (1979) recommends making a decision upfront regarding whether to do a surface analysis of many concepts or an in-depth analysis of fewer concepts. Different probing techniques are involved and there will be entirely different results. Researchers need to decide whether it is more important to know a lot about a few concepts or a few things about a lot of concepts.

Shaw and Gaines (retrieved 3/4/00) suggest bringing multiple experts together to brainstorm as a group. This gives them the chance to discuss different viewpoints and approaches. The important thing is not to force a false consensus. There is no one "correct" map. Rather, the important thing is to come up with a map that represents a reasonable approximation of the knowledge.

Trochim's (2000) procedure is by far the most complex, using concept mapping as a research technique involving group brainstorming as a structured process. Trochim outlines six steps in the process of developing concept maps, including multivariate statistical techniques. The steps include:

1. The *preparation* phase involves the selection of a brainstorming focus or topic and bringing together a broad variety of relevant participants.

2. The brainstorming begins in the *generation* phase. After being provided with a focus statement that defines the topic, participants begin the process of developing a large list of statements and ideas. A facilitator guides the process.

3. The *structuring* phase is used to record the ideas onto cards and sort them into related groups. Within groups the topics are rated on a scale of 1-5 by level of importance.

4. In the *representation* phase, the grouped information from the cards is organized into a concept map using multidimensional scaling and cluster analysis.

5. The *interpretation* phase provides time for reevaluating the organization and structure of the map before moving to the final phase.

6. In the *utilization* phase, the maps are used for planning or evaluation.

As Berg (1999) has observed, there is no one right way to draw a concept map. Rather, there are many right ways. It is important to choose the format most compatible with the purpose and scope of the research.

What makes a good concept map?

Table 3.4 lists some of the recommendations made by various scholars about what makes a good concept map.

Table 3.4: Recommendations for creating good concept maps

Source	*Recommendation*
Jonassen et al. (1997)	The more concepts to which a concept is linked, the better defined that concept. Concepts linked to only one other concept are dead ends to avoid. The relationships of concepts should be clear, descriptive, and valid. Links should be used in a consistent manner.
Maxwell (1996)	Not all concepts shown should be global and abstract. Include those that are specific and concrete. The content of the map is more important than its form. If a map looks symmetrical or includes duplication, it may be possible to combine categories. It helps to write an accompanying description of the map and what it means.
Spradley (1979) Note: Spradley never actually uses the term "concept map."	Select a limited number of domains that will appear in the diagram and do an in-depth analysis (as opposed to selecting many with a superficial analysis). Put a square or circle in the center, and use lines to show relationships.
Watters & Zhou (1999)	Concept mapping works best when there is an agreed-upon set of concepts and relationships. The process is difficult if concepts are vague.
Buzan (in Russel, 2000)	Once the growth of one branch is saturated, go on to another section, and return to each later as desired. Be creative. Use drawings and colors to help make the concepts clear.
Ferry & Harper (1999)	Evaluate the map by looking at whether the relationships shown are valid and if the maps are too broad. Revise and improve the map. Indicate any cross links between topics.
Trochim (2000)	Ask whether the map makes sense? How would someone else use it?

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Concept mapping for the current project

The purpose of this project is to determine the usefulness of concept maps for web navigation. Although few examples of this use currently exist online, concept maps have many benefits as a method of displaying and retrieving knowledge. These include a way of breaking knowledge down into its associated structure of concepts and relationships, a visual display that is both easy to draw and interpret, and a rich history of using concept maps for many purposes within the field of education.

After reviewing the literature, the authors practiced with pencil and paper to create informal concept maps on topics with which they were familiar. Rather than coming up with a list of concepts in advance and then drawing them, the process was found to go more smoothly if both steps were done simultaneously. A decision was made not to use linking words. The maps constructed could be easily interpreted without the use of linking words, and it was felt that adding them would be a distraction. It was also decided not to force hierarchical relationships if other types of relationships between concepts existed. This would enable the resulting maps to be more flexible. This process was continued once the authors moved to working with concept map software.

In the traditional approach, creating concept maps for the ERIC system would require interviewing subject matter experts to elicit the concepts and relationships. During a formal pilot interview with a subject matter expert on the topic "college students," one of the researchers constructed a concept map with software as the expert was speaking. The visual representation of ideas seemed to enhance the thinking process, aiding the expert in formalizing his knowledge. The map was later colored and printed out, giving the expert a chance to review and revise it.

This process is more thoroughly described in the next chapter. Types of concept mapping software and methods for placing the concept maps, once developed, onto the web are discussed.

IV. Reports on Studies

The following sections report on the various phases of the project, including (A) analyzing concept map software; (B) creating sample maps; (C) reviewing examples of concept maps on the web; (D) using a hybrid of web technologies; and (E) evaluating the potential use of concept maps for ERIC.

Section A discusses the results of extensive review and testing of various software packages used to produce concept maps. These are evaluated according to certain criteria, such as whether they allow web-enabled display of maps that may be linked to online resources.

Discussion of the authors' work to create sample maps, including methodological issues and the process of working with qualitative interviews, is discussed in Section B.

Examples of concept maps on the web are described in Section C.

Constraints, issues, ideas, and recommendations for producing web-enabled concept maps are presented in Section D. In order to accomplish the authors' vision for ERIC to effectively incorporate concept maps, a hybrid of Internet technologies must be used and these are discussed in detail.

Finally, the potential use of concept maps for the ERIC system is analyzed, including what may be involved for ERIC to both create complex maps and make them available to users on the web for bibliographic retrieval. Issues, ideas, and strategies in the possible implementation of such a strategy are presented.

A. Concept Map Software

The purpose of this section is to analyze the utility of various software packages for developing concept maps. Computer software may facilitate the development of concept maps in a variety of ways. These include "ease of adaptation and manipulation," "dynamic linking," "conversion," "communication," and "storage" (Plotnick, 1997, p. 4). It is important to recognize that the software tool used to draw a map may also condition the type of response and final product (Spradley, 1979). For example, software that requires the concepts to be hierarchical may result in a different kind of brainstorming and thinking process than a tool that is more flexible in how the map may be drawn.

Pfaffenberger (1988) warns that any technology has ingrained within it a set of values or assumptions regarding usage. "Technology is loaded with pre-understandings – and what is more they are all the more dangerous because they are denied, hidden, and submerged from view in ordinary day-to-day discourse" (p. 17). It is essential that researchers keep a balanced perspective, particularly in terms of software limitations.

"The point of applying the computer to qualitative research... is not to become involved in the microcomputer, but... in the research data" (Pfaffenberger, 1988, p. 23). Therefore, researchers choosing a software package should consider the flexibility of the software, consistency in how the data are entered, whether the software allows changes to be made, and the size of the storage requirements for the resulting product.

Desired software capabilities

The following factors should be considered in evaluating concept map software.

The software should enable concept maps to be constructed quickly and easily, especially during the interview process. It is important that the map which emerges during the process be both clear and appealing to the interview respondent.

The authors prefer the ability to create a map that is not inherently hierarchical. This is because hierarchical maps may limit thinking with the assumption that all concepts may be characterized in terms of hierarchies. The authors believe that hierarchies are not the only appropriate way in which to think about concepts.

Other useful features for concept map software include the ability to:

> Use different shapes and link shapes with connectors
> Use different colors (for shapes and connectors)
> Write the names of concepts on shapes
> Write linking words on connectors
> Make changes easily
> Print the resulting map
> Use the map on the web with hyperlinks

One invaluable feature of this type of software is real-time group collaboration with different people meeting synchronously across the Internet to create or revise maps. Another is that the map be accessible on the web to anyone who wants to view it. There is, therefore, an inherent assumption that the ideal concept map software package will allow concepts to be hyperlinked in a database containing both web and print resources.

Trial or evaluation copies of five software packages were downloaded and tested for the purposes of developing a website with concept maps. These included Inspiration, MindMaps, SMARTIdeas, CMap, and VisiMap. For this purpose, it is helpful if the demonstration or evaluation copy allows full functionality, including help features.

Each of the software packages reviewed has both advantages and disadvantages. Descriptions, including major features and potential problems, are provided in the following sections. The features of additional packages are compared and contrasted, but were not fully tested.

Tested Software

Inspiration
http://www.inspiration.com

Requirements for PC:

- 486 or higher processor
- Windows 95, 98, or NT
- 8 MB RAM
- 5 MB hard drive space minimum, 20 MB for all symbols and help
- 640 x 480 screen resolution
- CD-ROM drive
- Also available for Macintosh

Inspiration was developed to encourage visual thinking and learning in education. A demonstration copy of version 5 was tested in the fall of 1999. The most recent version, Inspiration 6, released in 2000, was also tested. This review describes the features of both versions.

Inspiration produces the most attractive output of the products reviewed: The concept maps are composed of graphical shapes, which are formed to produce a three-dimensional effect. The user chooses which shape to use by clicking on a menu. The shape chosen may then be colored or resized, and the name of the concept may be entered onto the shape. The user manually adds arrows (dotted or solid) as connectors, which may be colored. Lines or arrows may be either straight or curved, and the software allows connector words (such as "type of") to be entered on lines.

Features of version 5 include:

> Library of images and symbols
> Outline view, which converts a map to a text outline
> Zoom in/out
> Expansion/contraction of maps up to three levels
> Notes that may be added to a map
> Spell checker
> Search and replace for text
> Templates that may be edited

Potential problems with version 5 include:

1) On the trial version, important functions have been disabled. The company's decision to disable major features (in particular, making it impossible to save) makes the demonstration software difficult and frustrating to use. Printed maps say "Trial version" across the bottom. The full version of the software comes with an extensive library of 500 images/symbols, but the trial version has only a few.

2) The Help menu on the tested version is incomplete. The fact that most of the Help information is contained in a printed manual. The manual is not provided in PDF format, making it difficult for the prospective customer to tell what the full version of the software will do.

3) The software automatically places the main idea in the center of the map. This may not be where the user wants it.

4) With complex maps, having numerous arrows everywhere may make maps confusing. Also, the diagram has a tendency to get "messed up" as the user must keep moving the shapes and arrows out of the way.

5) There are no Internet functions or groupware features.

Version 6 features some significant improvements. These include the following:

1. The demonstration version available for download is fully functional and includes the ability to save and print. The Help menu has been expanded. It is also possible to download a smaller version if the user does not have enough free disk space.

2. It is now possible to create hyperlinks for each concept on a map. To perform this function, highlight the word written on the shape and choose the Internet feature under the Utilities menu. A prompt enables the user to enter a web address. The linking arrows may also be made into hyperlinks.

3. Once all of the links for a given map have been entered, the software may create a web page through an HTML export function. The diagram is automatically converted to a hyperlinked image map saved in graphical format. Text outlines may also be converted to HTML.

4. There is an extensive symbol/image library (1,250 symbols), including animated graphics. Symbols may be altered and the color changed to any color on a color palette. In addition, GIF and JPG images may be pulled from a website into Inspiration.

5. The Inspiration website provides educational examples of how the software has been used. These examples include concept maps for language arts, social studies, and science. There is an concept map shown for a multimedia presentation, but the example is non-functional.

Potential problems with version 6 of Inspiration include the following:

1) Hyperlinks cannot be generated from a database. In cases where many links are involved, as in a complex website, it is cumbersome and time-consuming to enter them manually for each individual concept.

2) Once hyperlinks have been placed onto a concept map, it becomes difficult to make any changes on that map without accidentally activating one of the hyperlinks and bringing up the Internet browser.

3) Making a special image (such as an image of a sun) from the software library is not possible. Outside images may, though, be imported for use.

4) When a diagram is exported to a web page, Inspiration automatically includes the notice "This diagram created using Inspiration by Inspiration Software, Inc." (This may be removed by modifying the HTML code.)

In general, the significant improvements associated with version 6 make Inspiration a good choice for concept mapping for users who do not need a groupware feature.

The free trial version may be downloaded from the website and used for 30 days. After that time, it will cease to function and cannot be reloaded. Old maps cannot be viewed unless they have been exported onto a web page.

Purchase Information

Contact Inspiration Software, Inc., at sales@inspiration.com or 1-800-877-4292.

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Current Prices:
- Inspiration 6 CD $69 per copy
- Inspiration 6 Upgrade CD $39.95 per copy
- Available in single copies and volume licenses

For the location of distributors, see the geographical list at this web address:
http://www.inspiration.com/edsales.html

MindManager, Version 3.5

http://www.mindman.com/download/index.html

Requirements:

- PC only
- Windows 95, 98 or NT
- 12-20 MB hard disk space
- 17 inch monitor recommended, with 1024 x 768 screen resolution

MindManager bills itself as "the ultimate organization tool." This software is based on Tony Buzan's creativity approach to concept mapping and is excellent for brainstorming.

The main concept is automatically placed in a rectangle at the center of the map. Whenever the user types a word and presses Enter, branches are entered automatically by the software. The branches appear as lines rather than shapes, with the concept words appearing above the lines. The resulting output is very easy to read and looks like a tree diagram, with branches extending in different directions. The size of the branches may be altered (e.g., thick, thin, or bold lines). A helpful feature is that any text already entered automatically moves out of the way as the user enters new text.

Notes may be included and are marked with a tiny book symbol. When the mouse is moved over the symbol, the notes may be opened and read. The resulting map may be printed across multiple pages, or the diagram may be compressed for printing on a single page.

MindManager enables real-time group collaboration through its conference function. This function works by having participants access the MindManager website. As conference moderator, it is possible to send out an invitation (which may look like a mind map) and provide the name and password to access the conference. Users access the "Conference Command" on the Tools menu to collaborate. The conference feature provides a chat function, though only one person may edit at a time. A map may also be sent as an e-mail attachment.

Hypertext functions are included, and branches of the map may be linked to either websites or external files. MindManager has web exporting capabilities that allow maps to be posted over the Internet as either image maps or text outlines with hyperlinks. The

automatic HTML export function allows conversion to clickable image maps, a Java outline (using frames and Java), or a text outline with plain HTML. This allows users without MindManager software to access the result via the web. The export function creates the HTML files and image files, copied into a single new directory. In addition, the software may create a web page layout which may be customized.

Other useful features of MindManager include:

> Library of images, with capability to import additional symbols
> "Multi-Maps" feature (enables different levels of a map to be layered and linked to other maps)
> Outline view (text)
> Zoom in/out
> Expansion/contraction up to 5 levels
> Good help menu, especially for setting up conferencing
> Visual tutorial that provides a quick introduction (users may point to the element they want explained)
> Spell checker
> Search and replace of text
> Keyboard shortcuts
> Customizable toolbars and templates

Figure 4.1: A hierarchical concept map created with MindManager

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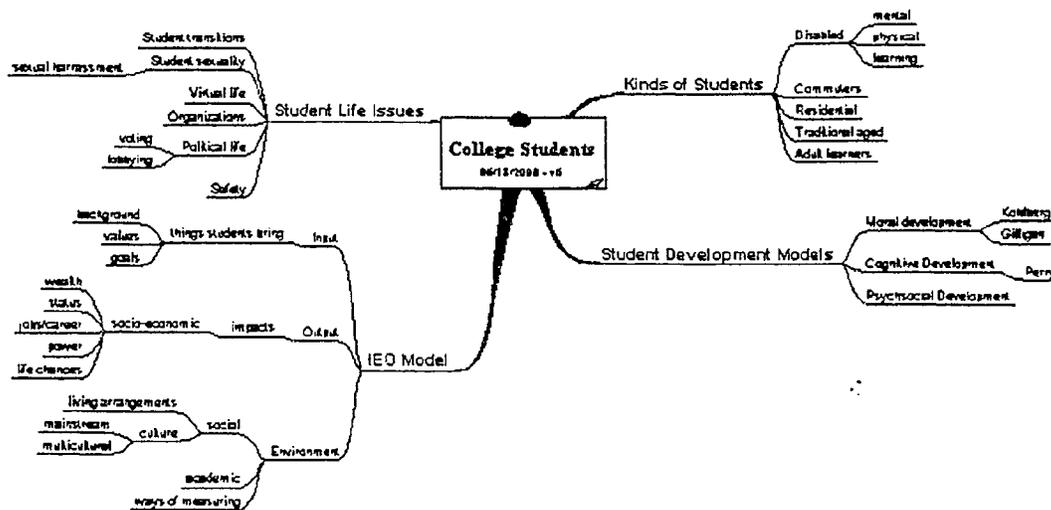
Potential problems with MindManager include the following:

1) Hyperlinks cannot be linked to a database. In cases where many links are involved, as in a complex website, it is cumbersome and time-consuming to enter them through MindManager.

2) The software forces the main idea to appear in a rectangle in the center of the map.

3) Concepts automatically appear on lines rather than shapes. This means that there is no way to indicate linking words, if desired.

4) The tree diagram process forces the use of a hierarchical structure and may therefore impose hierarchical and linear thinking, which may not be the best way to represent the concepts being studied.

5) The output is not very attractive. The software's spider map appearance, with lines spreading out to indicate topics or subtopics, does not look like a traditional concept map.

The free trial version of MindManager may be downloaded and used for 21 days. After this time, it is still possible to view and print all maps that have been created, as well as use the conferencing function, but no new maps may be created.

Some functions are not included in the trial version (e.g., symbol editor and most of the symbol gallery). The company's website provides specific information on the download page about what is not included.

Purchase Information

Distributor: Future Communications System Inc., Syosset, NY; 800-563-7773; fcs@mindman.com.

Price:

- $139 for single copy
- $60 for students
- Discounts are available on multiple licenses.
- Users who recommend MindManager on their websites get a 15 percent discount.

SMARTIdeas
http://www.smarttech.com/smartideas

Requirements:

For standalone version
- PC only (Pentium strongly recommended).
- Windows 95, 98, or NT
- 20 MB memory
- 12-20 MB hard disk space for installation

For server version
- Pentium computer
- Windows NT version 4.0
- 20 MB memory
- 20 MB hard disk space for installation

Version 2.1 was evaluated in the Fall of 1999. A newer version, 2.2 , has been developed and should be available for purchase soon after the publication of this report. Some information about new features in version 2.2 is included at the end of this description.

SMARTIdeas is easy to use and includes an intuitive help menu. It was recommended independently by two concept map researchers (private e-mail communication by Ms. Santo with Rob Kremer and Brian Gaines, University of Calgary, on 11/11/99).

SMARTIdeas is similar to Inspiration in the appearance of its concept maps. It is excellent software for brainstorming, and maps may be quickly and easily created. No pictures are provided, but they may be easily imported from other software.

One advantage of this software is that the main idea may be put anywhere on the page. Many graphical shapes are available. The user chooses which shapes and colors to use. Arrows may be automatically or manually entered, and the colors of arrowheads may be changed. Linking words may be written on lines or connectors.

An especially helpful feature is that clicking on a shape brings up a group of little "handles" that appear around the shape. These handles make it easy to use the mouse to attach arrows to shapes or to resize shapes. Figure 4.2 shows an example of the handles being used to create a map. The shape of each handle indicates its purpose. For example, the upper circle with the arrow is used to connect two shapes with a line. The "I" handle is used to edit the concept label. The square may be dragged in any direction to reshape the size of the object. The two hexagon handles are used to resize the shape horizontally or vertically. The inverted triangle brings up a popup menu for the shape with options to change the shape and format.

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Figure 4.2: The handles feature in SMARTIdeas
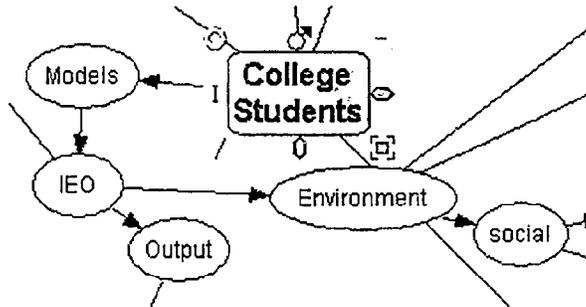
SMARTIdeas has many additional features. One innovative feature is "Playback," in which additions or deletions to the map nodes may be viewed in the order they were placed. Another is displaying a visual diagram of the whole map in miniature at the left hand side of the screen. A third is style sheets that enable a file to be set up that includes the specific graphical shapes the user wants to use for that map. The user chooses a group of symbols, defines their appearance, and then saves the style. The software also has a layering function that creates multiple layers and links between layers, useful for maps that are highly complex.

The print function allows users to print the map out in its full size. If necessary, the printout will be expanded across as many sheets of paper as required. If desired, users may then tape these printouts together to create a large map. An expand/contract feature is helpful when the map becomes cluttered with numerous branches, making it possible to view certain branches at a time. However, it is not possible to print the minimized map.

The server version of the software has a real-time conferencing function. The host of the conference sets up a server site and then invites others to access the map. The server sends a Java applet to the client's computer. It is possible to use a chat function to communicate with one person in the group, or with the entire group (up to five concurrent clients). Concept maps may include hyperlinks to web pages or local documents (e.g., Word, Excel, PowerPoint). Changes made to the map offline may be merged with the map stored on the server. An e-mail notification feature tells group members about changes that are made to the map.

Other features include:

> View, which provides an outline of the map. Outlines must be saved to a file and printed from this txt format)
> Zoom in/out
> Keyboard and mouse shortcuts
> Capability to expand the whole tree or expand by one level at a time
> Notes, which may be placed anywhere on the map
> An extensive help menu with the use of animation to demonstrate procedures, as well as context-sensitive help

- ➢ Spell checker
- ➢ Search and replace text
- ➢ Automatic conversion of text outlines to concept maps (or vice versa)
- ➢ Compatible with Inspiration.
- ➢

Potential problems include the following:

1) SMARTIdeas was developed for use as group collaboration software, not as a way to create concept maps for websites. The server version of SMARTIdeas requires that a client PC use the special Java applet to make it possible for users to view a concept map through their web browser. Hyperlinks may be used within the map, but must be hand-entered into a text box. There is no way to link the map to a database to dynamically add hyperlinks behind each concept.

2) Anyone wanting to share a map must first access the server set up by the organization hosting the map. If hosted by the vendor, there is a charge to the host each time a user accesses the server. For users to host their own server, there is a charge per client access of the software. This fee structure makes it essentially impractical for maps to be viewed in this manner by a potentially large audience that might visit an ERIC website with concept maps.

3) If the size of the concept map is very large, the software becomes sluggish in its response. When a large file is reopened later, it takes the software a while to reformat the map correctly. According to the SMARTIdeas vendor, this problem will be fixed in version 2.2.

4) The SMARTIdeas website suggests ideas for using the software in education, business, and medicine; but only one sample map is provided (having to do with medicine). In addition, the company's main site (http://www.smarttech.com) surprisingly does not include a link to the SMARTIdeas site, but instead features other products such as SMARTBoard, an interactive whiteboard.

5) Maps may be imported from Inspiration into SMARTIdeas, though the specific appearance of the arrangement and space between nodes is not always retained.

For version 2.2 of SMARTIdeas, the vendor promises enhanced performance and a simpler user interface. New features include the following:

- ➢ The product will be faster to use
- ➢ Sound, images, and web links may be attached to maps
- ➢ Maps may be multi-dimensional
- ➢ When working on a map online, content is automatically saved to the remote server so that data cannot be lost

A trial version of SMARTIdeas is available for a 30 day period. The server version, which enables group collaboration, is not available for evaluation at this time.

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Purchase Information

Potential customers need to contact Smart Technologies directly. The pricing for version 2.2 was still being determined when this report was published.

info@smarttech.com
403-228-8536 (Calgary, Canada).

Prices for version 2.1 are:

- $119 for one desktop client and server usage
- $49 for one desktop client
- $79 for one server usage, combined with a web client
- Rental for $9.49 per month per user
- Discounted prices for five or more users

IHMC Concept Map Toolkit Software (CMap), version 2.5.3
http://cmap.coginst.uwf.edu/

Requirements:

- PC with Windows 95/NT, Macintosh, or Solaris

The CMap Concept Map Toolkit is network-based software for knowledge modeling, browsing, and sharing. It enables users to construct, navigate, and share knowledge in the form of hierarchical concept maps. If the CMap Network Server is installed, users may collaborate on the construction of concept maps online.

CMap was designed based on Joseph Novak's theoretical work on concept maps. Unlike the other products reviewed, this software was developed by an educational institution: the Institute for Interdisciplinary Study of Human and Machine Cognition (IHMC) at the University of West Florida. IHMC has been using concept maps to develop expert systems (i.e., the representation of an expert's knowledge of a domain).

The software produces a two-dimensional representation of a set of concepts. The default is for all concepts to appear within rectangles, with linking lines connecting related concepts. However, the default may be changed by choosing "rounded" from a list of border types. The maps are plain in appearance, but functional.

CMap was built using Java technologies and is platform independent. The user may browse and edit concept maps on either a local machine or the CMap Network Server. To access concept maps from the web and view hyperlinked resources, the network server must first be downloaded and a web server installed. Both the network and web servers

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may be downloaded free from the IHMC site. Instructions are given for downloading and configuring the servers.

CMap organizes concept maps into what are called "projects," collections of maps within a domain. When the software is launched, what resembles a series of file folders appears on the left side of the screen. To build or edit a map, the user must first create a project within either the Local or Public directory. A new map may then be created. On the left side of the screen, the map appears within the directory as an icon that looks like a house. On the right side of the screen, a separate window opens with a blank background. This is the user's workspace. The width and height of the background may be changed with the Properties menu.

The user may create a concept anywhere on the background by double clicking. A shape appears with a highlighted question mark that allows the user to type in the name of the concept. Selecting the concept causes two arrows to be displayed. If the user clicks on the arrows and then clicks on a related concept, the software will create a linking line between the concepts. A useful feature is that connecting lines may be straight or curved, and the user is able to adjust the shape of the curve. The user may also choose whether to include arrow heads.

An unusual feature of CMap is that it forces the user to include one or more "action words" (i.e., verbs) between concepts which describe how they are related (e.g., plants "are" green). When the user creates a linking line, a smaller rectangle is automatically created between two concepts. In the example just given, the verb "are" may then be entered depicting the relationship.

Concepts may be moved to a new location by dragging with the mouse. This will also move all of the related links. Concepts may also be cut and pasted. Notes may be attached that include lengthy text descriptions. These may then be viewed later by clicking on a text icon appearing beneath the concept. Color may be added to the background of the map, the interior of the shapes used, the font used, or linking lines. The color of all concepts may be edited or changed in one step. The user may add a shadow to the border of any shape.

Saving the map requires entering the map's name, description, creator, and server (i.e., local or network). When the user wishes to retrieve the map, depending on how far down the map is in the directory, it may take several clicks to locate and open. The map may be viewed with "browse mode" or edited with "edit mode." An icon of a pencil appears by the folder of a project if it is in edit mode.

Concept maps may be linked together in meta-maps that are constructed of several concept maps. The CMap documentation refers to linking as "populating." The first map brought up automatically shows the top level. By clicking on any of the concepts, a second more detailed map may be brought up around that selected concept. Each successive map shows finer detail, while the first map is the most general.

Concepts may also be linked to what CMap calls "resources." This is indicated on the map by an icon appearing below the concept. Resources may include images, text (such as short explanatory notes), movies, sound, web pages, or PDF (Adobe Acrobat) files. The user chooses "Import Resource" and may then browse through a list of resources in the directory before selecting one to add. Some options, such as JPEGs, have a preview available.

A URL may be added to a concept by using the "Import Internet Resource" function from the File menu. The documentation recommends finding the URL in the web browser and copying it into CMap with the Edit menu. A concept map may be exported to a GIF image.

Several examples of projects, and layered concept maps within projects, may be accessed by clicking on "IHMC-UWF" in the file directory. Online documentation is available from the Help menu by choosing "About Web Documentation." This option actually takes the user to the IHMC site, so a web browser is required. Excellent information about concept mapping in general is also provided. See, for example, the CMap FAQs at http://cmap.coginst.uwf.edu/info/faq.html. Keep in mind that this information is based on Novak's approach, which sees concept maps as a teaching/learning tool and as hierarchical (i.e., having the broadest topic at the top, with the most detailed concept at the bottom).

Potential problems include the following:

1) It forces a top-down hierarchical format.

2) It is harder to use and less user-friendly than similar commercial products (SmartIdeas, Inspiration), and the output is less attractive.

3) To be used in conjunction with the Internet, both a CMap Network server and a web server (such as Apache) must be installed.

4) JavaScript must be turned on to view the maps.

5) The software comes as a Beta version only with no warranty.

6) It is only available for non-profit organizations.

Purchase Information

The beta version of CMap may be downloaded free for educational and nonprofit use only. The software is not available for purchase as a commercial product.

For information about CMap, e-mail cmapsupport@ai.uwf.edu.

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VisiMap 2.5c and VisiMap Lite 2.5d
http://www.visimap.com/ or http://www.coco.co.uk/

Requirements:

- PC with 386 or higher microprocessor
- Windows 3.1, 95, or NT
- 6.5 MB disk space for single user or 8.0 MB for network server

VisiMap was developed by a British company, CoCo Systems, Ltd. It is creativity and productivity enhancing software that creates "visual maps" for business and personal applications. The central concept appears in a rectangle at the center, and lines extend outward that contain words with related concepts. This program comes with a free VisiMap Viewer that may be e-mailed to others, along with a copy of a concept map, so that they may read it without having to download the full software. A "Getting Started" document is available in PDF format.

The first time the software is opened, an Introduction to VisiMap with a full help menu pulls up automatically. Help options are presented as a hyperlinked concept map. For example, one of the concepts is "What's new in version 2.5." Clicking on the concept brings up a paragraph of information that appears below the map. While working in VisiMap, the user may also press F1 to get help. A "Beginner's Guide to VisiMap" is provided at http://www.visimap.com/guide-visimap.html.

A VisiMap concept map looks like a tree diagram with thick branches (topics) extending out from a central box containing the main concept, and thinner branches (sub-topics) extending from the thick branches. Words of related concepts are written on the branches. The structure is hierarchical (the appearance is similar to MindManager). VisiMap refers to these concept maps as "visual maps."

When the user begins a new map, a rectangle automatically appears with the word "unnamed" in the center. Pressing the Enter key brings up the Map Properties Box, which makes it possible to name the concept. Branches are created by selecting the "Add Branch" command. Branches may be dragged to a new location, and all sub-branches are automatically moved. An "Undo" command makes it possible to change it back.

Branches may be colored by clicking on a color palette that appears at the bottom of the screen. The background may also be colored. Fonts may be used and style sheets are available. Graphical icons may be added to a branch or the central box with the "use own icon" option that allows the user to select from a database. Although currently only hierarchical links between branches may be created, CoCo Systems is planning to include a non-hierarchical feature in a future version of VisiMap.

An HTML export function (graphics or text format) makes it possible to save maps as an HTML document and link the branches to web pages, FTP files, or gopher sites. Features of this function include the ability to convert a map to GIF format with transparent

background, control the font size of note text on an HTML page, specify a background image selected using a built-in image previewer, or include a clickable image map with links to URLs. Interconnected maps (maps linked to other maps) may also be converted by saving the top level map. All map links and maps will be included in HTML files.

Branches may also be linked to data files such as text documents. Maps may be looked at in text outline view, and text files may be imported and automatically converted to concept maps. Maps may also be exported as graphics using metafiles or bitmap formats.

One unusual feature of this software is that it allows the user to attach sizable annotated notes, of up to five pages, to branches of the map. Clicking on a symbol that indicates the note will take the user to the full text, located below the diagram. Other features include configurable toolbars, multiple page layouts, find/replace, and spell checking. An example of a hyperlinked map created using VisiMap is included at a vendor site, Dynamic Thinking, located at http://www.dynamicthinking.com/toc.htm.

VisiMap Lite is the personal edition of VisiMap. It was developed to provide a low cost edition for students. It contains the same map construction, editing, and printing features, but limits the map and note sizes. It has no networking features, cannot import or export from other programs, and does not provide spell checking. Users may download the free VisiMap Viewer to distribute so that others may view their maps.

The VisiMap website contains an extensive section for customer support, including known problems, bug reports, and a place to suggest product improvements. Ordinarily, there is also a discussion forum, which was temporarily removed at the time of this review.

Potential problems include the following:

1. It resembles MindManager in forcing a spider-like, hierarchical appearance, with a box at the center and lines spreading on either side.

2. To view maps created with VisiMap, users must either own the software or download the free VisiMap Viewer.

3. Although it is possible to e-mail maps to colleagues, there is no real-time collaboration feature.

Purchase Information

A trial version of VisiMap may be downloaded free for 30 days. It does not include spell checking, and printed pages say "for evaluation purposes only." The GIF and TIFF export functions are disabled.

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The commercial price for VisiMap is $117 (if downloaded) or $127 (retail pack with CD), with reduced prices for academic institutions. For information about purchasing the retail version, e-mail sales@visimap.com or call 1-800-884-0489.

VisiMap Lite may be downloaded free and used as a demo for 14 days or purchased for $45.

The VisiMap Viewer may be downloaded free.

Other Software – Reviewed but not tested

The following two products offer more complex, interactive maps. The disadvantage is that they are considerably more expensive to purchase and more difficult to use for creating maps.

Site Lens Studio
http://www.inxight.com

Requirements:

- Pentium
- At least 32 MB RAM (60 recommended)
- 800 x 600 display (1024 x 768 recommended)
- Windows 95, 98, or NT

This tool for portal designers and website managers from Inxight, a Xerox-PARC spin-off, enables users to have a graphical view of an entire website. The graphical interface, or "site lens," puts the current web page in the middle of a spider-like structure, with connected pages branching all around it in fine lines. The advantage is that all parts of a site become visible at once, and users may find content without having to navigate through a series of links or view unnecessary pages. In addition, this visual map makes it more likely that users will "accidentally stumble" upon valuable information, a process that Inxight refers to as "serendipity." For complex sites, this ensures multiple paths to the same content and limits users leaving the site because they don't find what they want immediately.

The software may generate an overview page for a portal or website with a list of all pages. A taxonomy may also be imported and used to guide the site navigation. The results may then be edited and used as a type of site map.

The initial view shows the home page and all of the surrounding links. The map is interactive. Dragging with the mouse brings different parts of the map in and out of view. Double-clicking brings up a specific web page. Color and patterns of different parts of the "site lens" may help users to recommend where certain information is located.

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Additional features of SiteLens Studio include predefined templates, the ability to publish the "site lens" on the Internet, and updating capabilities, including moving additional files to the site. SiteLens may also be used to map a document repository or sales catalog.

Site demonstrations of websites using the product are provided in these categories:

- General Internet
- Online Shopping
- Entertainment, Travel and Sports
- U.S./Governmental
- Pharmaceutical
- Randomly selected demos

Purchase Information

A 15-day free trial offer for this product is available.

Current Price: $4,995 per server. Contact Inxight Software at 1-877-INXIGHT.

Thinkmap
http://www.thinkmap.com/

Thinkmap is intended for displaying large amounts of complex information, or a collection of objects, on the web. It contains an animated display that encourages interaction and interfaces directly with a database on a server. According to the website, "Thinkmap tools animate and display complex sets of interrelated information, creating interfaces that transform data into insight and knowledge" (Retrieved 10/2/00).

The software provides a macro view of a website, showing data visually connected by surrounding relationships. An advantage is that it does not impose a linear, hierarchical structure on a site. Rather, it lets the user see broad associations and related content around any item on that site. For example, selecting an item may pull up related items from different categories within the database.

The Thinkmap Server creates a link to a database on the server. The Thinkmap Client uses Java to display data animations on a web browser. It then communicates queries to the server. Thinkmap is intended to simulate conversation that a user might have with a database program. It does this by using algorithms that model behavior on natural phenomena. It uses plug-ins called "informotions" that define the behavior of data in the interactive display.

Links to six websites are included that use Thinkmap technology. Unlike the other concept mapping products reviewed, this software does not produce a standard visual interface. Each of the examples provided look quite different, and it is not readily apparent that the same software was used for all six. One of the sites, Bacardi Martini,

also uses an interactive concept map. However, the Sony Music site uses a very different graphical interface to navigate through its database of music. This example is more user-friendly, but does not resemble a concept map. The "Revealing Things" exhibit from the Smithsonian Institute explores the history of every day objects by allowing the user to explore a database.

For more information, contact Thinkmap.com at 1-888-272-8600 or info@thinkmap.com.

Additional products – not reviewed

Other software that could be used for concept maps includes the following:

ATLAS.ti for Windows 95/98 and Windows NT 4.0 - (http://www.atlasti.de, retrieved 9/11/00) - The Windows version of this software was first created in 1994. Although not dedicated to concept mapping per se, ATLAS.ti has some mapping capabilities. This software is intended for qualitative analysis of large amounts of text, graphical, audio, and video data. It is based on grounded theory and may be used to analyze unstructured data, including coding different segments of text, annotating, comparing segments, memo writing, and search and retrieval of segments. A network building feature lets the user visually connect selected passages, memos, and codes through diagrams. These networks define a conceptual model that may be used to query the data. The appearance is like that of a spider map of codes. ATLAS.ti is not intended for brainstorming. The text must be imported and then coded. It does, however, have a feature that allows data to be converted into HTML format and accessed through Internet connections.

ClearWeb (http://people.ne.mediaone.net/vadim/clearweb/index.html, retrieved 9/11/00) - This software was designed to automatically create maps of entire websites and import URLs from a web browser. Maps may be published or viewed by downloading the CLEARWeb Viewer, a graphical navigation tool for the Internet. From the description of CLEARWeb, it looks like a useful product. Unfortunately, it is no longer available for purchase, and the website appears not to have been updated since 1996.

ConstraintGraphs – This experimental concept mapping software has hypertext capabilities and works as a Netscape plug-in. An article on its use may be read at http://www.cpsc.ucalgary.ca/~kremer/dissertation/Ch8.html (retrieved 9/11/00). However, according to Rob Kremer, this software is currently not commercially available.

KMap - C++ software for the Mac. The appearance looks like rectangles and circles linked by arrows. This software may be used as a web client helper with Netscape, but only for Macintosh computers. HyperCard may be used with it for text annotation. For information, see the article at http://spuds.cpsc.ucalgary.ca/articles/WWW/WWW4WM/ (retrieved 9/11/00). A website for the vendor could not be located.

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**NUD*IST** version 5 (http://www.qsr.com.au/products/n5.html, retrieved 9/11/00) – This software for both the PC and Mac is intended to help researchers with qualitative analysis of extensive data. The name NUD*IST is an acronym for Nonnumerical Unstructured Data by Indexing, Searching, and Theorizing. NUD*IST enables manipulation of the index system for data, including graphical display of categories (codes) that were created. Index categories may be managed in linked tree hierarchies or unlined free nodes. These graphical displays may help in developing grounded theory, but the software is not intended for brainstorming. An online tutorial is available in the free demo version that may be downloaded.

QuestMap (http://www.gdss.com/omq/aboutQM.htm, retrieved 9/11/00)- Team collaboration mapping software. The suggested use is for problem solving in organizational teams. Similar in appearance to MindManager, the software runs with Windows 3.1/95/98 with a 386 or above computer. Free 30-day trial. Information: Group Decision Support Systems, 202-338-2525.

Choosing concept mapping software for this project

SMARTIdeas was chosen as the preferred concept mapping software for this project for several reasons: (1) it creates an attractive concept map display that is non-hierarchical; (2) it is quick and easy to use in constructing a map during interviews with subject matter experts; (3) it has advanced features such as an expansion/contraction feature that makes it possible to look at part of a map at a time (extremely useful when the map is very large); and (4) its groupware feature enables the real-time sharing of maps among experts at different sites. Figure 4.3 shows an example of a concept map created using SMARTIdeas.

Figure 4.3: A concept map created with SMARTIdeas

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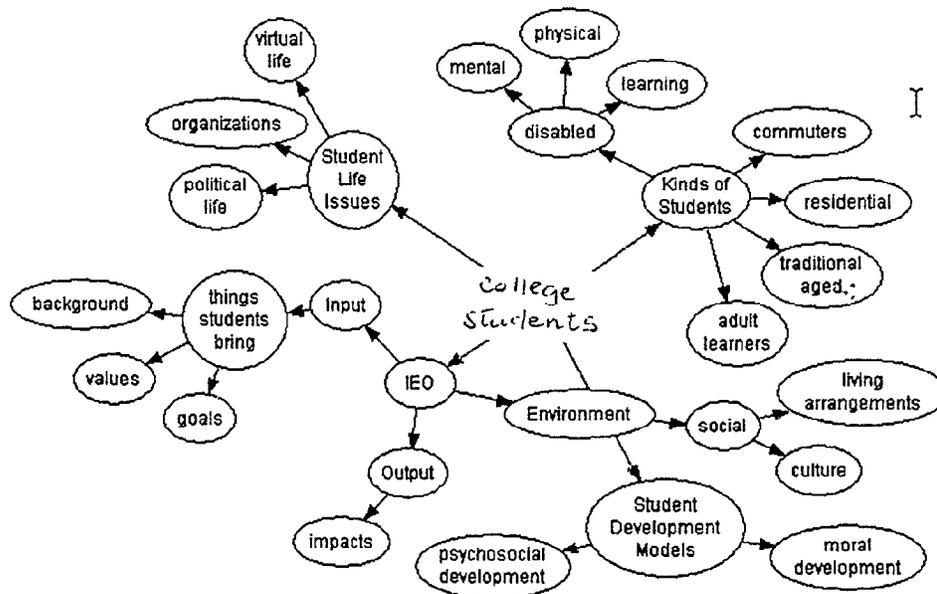
The standalone version was used to create an initial concept map during a pilot interview with a higher education subject matter expert. The collaborative feature was seen as useful for the development of future maps.

SMARTIdeas was found to be an effective tool during a pilot interview. See the next section for a description of this process. The extensive concept map was drawn by one of the authors on a laptop PC, with the monitor projected on a larger screen so that it was visible to the team. Everyone involved could see the map as they discussed it. There was no problem in keeping up with the interview respondent's pace. The process of getting the respondent to state concepts and having the team member draw them was relatively seamless. Changes in the map, such as moving concepts, making shapes larger or smaller, and adding color, were easily made after the interview to make the map more readable. After the map was revised, it was printed and given to the respondent to check for accuracy and any additions.

B. Creating Sample Maps

Use of naturalistic inquiry

The process used by the authors to create a concept map is based on the principles of naturalistic inquiry. The methodology incorporates emergent, polychotomous coding categories, peer debriefing, member checking, and other techniques as described by Lincoln and Guba (1985) and Patton (1990). The advantages of using a qualitative or naturalistic approach for concept maps may be interpreted as follows:

Qualitative research is naturalistic and takes place in the field. Its purpose is understanding, rather than prediction or control. It is the hope of the authors that concept maps may be used to enhance understanding and to view patterns in websites for complex resources about higher education.

Qualitative research allows an emergent design that develops as the study proceeds, rather than being defined completely beforehand. While investigating the topic of concept maps, the authors learned about the wide variation in the theory and use of maps among different experts. The realization gradually became clear to the authors that there is no one right way to draw a map; rather, there are multiple ways. The chosen way depends on the purpose for which a map is intended.

This approach to research relies heavily on interviews or observation. Trust is built with respondents. In addition to paying attention to their words, tacit knowledge (i.e., intuitive) is seen as important. During the pilot concept mapping session, an expert on college students was interviewed. The first part of the meeting was spent on building trust through informal discussion and getting the expert comfortable with the idea of using concept maps. When the expert had difficulty expressing his thoughts, prompting was provided through open-ended, unstructured questions to help draw out his tacit knowledge.

Knowledge, according to Lincoln and Guba (1985), is socially constructed rather than there being a single objective reality. The researcher tries to elicit the view of reality as seen by the respondent. Qualitative research relies on an emic perspective (inside perspective of respondents) rather than an etic perspective (the perspective of the researcher). In the case of the concept map on college students, different maps could have been drawn using the same topic. The map that was created represents the view of the particular subject matter expert interviewed at a particular point in time, not the view of the researchers.

Naturalistic inquiry relies on negotiated outcomes, in that data gathered by the researcher are then reviewed by the respondent to see that they are credible and what the person meant to say. The meaning of the respondent's comments may then be confirmed. The resulting concept map was given to the respondent to review.

The grounded theory approach recognizes that new theory emerges from the data, rather than the other way around. The current research did not begin with a theory about concept mapping. Rather, information was sought about how maps were being developed and used in different areas.

Data analysis is inductive, and coding is used to indicate categories and themes that are emerging. Data are gathered and coded into emergent, polychotomous themes until there is a point of saturation or redundancy to ensure that no new themes or ideas are excluded. The concepts used in the map on college students represented emerging categories and themes. Some concepts appeared more than once on the map.

The timing of a qualitative study is difficult to predict because it depends on what happens during the study. Prolonged engagement in the field is important to determine what is really happening. In the current case, the issues and complexity involving concept maps and concept mapping software made the period of investigation longer than initially anticipated.

Finally, records are kept of evolving procedures and findings (such as field notes or memos) so that the process could be traced by someone else. Notes, email, correspondence, and concept maps were kept for the project. While at the outset, the authors planned to keep individual methodological logs, the reliance on email supplanted this approach and provided comparable documentation of the evolving design.

Methodological decisions

The methodology decisions that were made by the authors were based on practice as well as the literature. Before the pilot interview was conducted, a series of practice sessions were held during the same time frame as the literature review and analysis of concept mapping software. The sessions made it possible to test some of the questions and assumptions developed during the literature review and to further develop the interview protocol. During the practice role-playing sessions, the authors took turns in the positions of interviewer, respondent, and recorder. These early sessions involved taking notes and drawing the concept maps with pencil and paper. The authors also practiced using different software packages to draw their own concept maps.

Early in the process, issues were explored such as when to use probing questions and what types of questions would work best, how far to go in the interview process before adding categories or clustering and combining categories, and how to determine the point of saturation within a strand. It was decided to cover one category in as much depth as the respondent could go, before moving on to a new category. Later, the former category could be returned to and the respondent asked if anything more needed to be added.

During the first practice interview, the resulting concept map did not reflect the key interest and direction of the respondent, but was more a product of the direction taken by the questions of the interviewer. Although the respondent had expertise in that area, the

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others involved in the team did not. The result was that the respondent was not satisfied with the map.

This simulation highlighted the potential for maps on the same topic to take on a totally different look and theme. It was at this time that the importance of developing probing questions that would prompt, but not lead the respondent to any specific end, was realized. One useful probing question was: "What stands out for you?" This helped the respondent focus on what was important without being led in a particular direction. The decision was made to avoid supplying any pre-existing maps or map examples that might mistakenly lead the session in a path that did not emerge from the respondent.

It also became clear that the purpose for the session should be discussed and agreed on before developing the concept map. The reason for this project and any procedures to be used, such as having the software illustrate concepts that emerge during the discussion, should be explained at the beginning of the session to the person being interviewed. It was also important to explain any next steps at the conclusion of the interview and any further involvement that would be needed from the respondent.

One of the biggest challenges to address in developing concept maps is being able to reach what Novak (1998) refers to as "shared perspective." The literature indicates that maps generated by different individuals on the same topic may take a variety of forms (Novak, 1998; Berg, 1999; Jonassen et al., 1997; Shaw & Gaines, retrieved 3/4/2000). A reasonable method was needed for identifying a shared perspective on major concepts (such as college students). If the maps could not reflect some degree of shared perspective, then this method for developing a valid website navigation structure would not be feasible.

While the original interview protocol called for conducting one interview per major topic, an interest in developing shared perspective led to a decision to recommend including multiple experts for each topic. Mapping would need to be done in incremental stages with different scholars and practitioners. Shaw and Gaines (retrieved 3/4/2000) suggest interviewing multiple experts as a group. However, they caution that it is necessary to avoid forcing consensus while promoting the expression of viewpoints from all participants. To avoid this difficulty, multiple interviews could be conducted with individual experts. This would make it possible to gather unbiased information from a number of sources. The content of the maps would be reconciled by identifying the major themes and trends. The resulting navigation structure should have more meaning to more users.

Pilot testing the interview protocol

The next aspect of this project involved testing assumptions about the concept mapping process by conducting a pilot interview with a subject matter expert. In beginning to experiment with concept maps about the higher education knowledge base, Dr. Milam approached several faculty members in the higher education doctoral program at the University of Virginia. There was general interest in their helping with a research

project, though they expressed confusion about what a concept map was and how it could potentially help students' understanding of the literature and research about higher education.

Dr. Sam Kellams, an associate professor with thirty years of teaching experience in the doctoral program, agreed to be the pilot respondent in the interview research. Dr. Kellams' topical areas in the doctoral program are college students and curriculum, and it was decided that the interview would focus on the topic of college students.

For the pilot interview, concept mapping software was used. By using a projector connected to a laptop with the SMARTIdeas software, the enlarged concept map was projected for the respondent and others present to follow as the map was created. The software package made it easier to provide the flow and visual representation than was previously possible with pencil and paper versions. The post-session analysis of the tryout paper and pencil versions was often difficult to decipher. Leaving off and picking back up with strands was facilitated with the use of the concept mapping software.

Spradley (1979) notes that the typical interview process involves four steps: apprehension, explanation, cooperation, and participation. What is important is to get the person talking as soon as possible and to show a nonjudgmental interest in what is said. This process appeared to take place during the first interview, and any apprehension about the concept mapping process quickly evaporated as the respondent saw the map actually being built based on his knowledge.

Dr. Kellams expressed some initial apprehension about the purpose of the research and his role in generating the map. Although the idea of concept maps and the technology for creating the map were discussed, it was not until the process actually began and he could see a map being generated that he finally understood what the researchers intended. The respondent was both surprised and pleased to see the map gradually emerging with his concepts. It provided him with a visual picture and an intuitive grasp of how the concepts related to one another that the mere posting of written notes could not have done. In seeing the map evolve as he thoughtfully talked about important ideas to know about college students, Dr. Kellams' interest increased noticeably. This reaction led to a more productive interview.

Once the respondent became used to the process, he seemed to have no difficulty thinking visually. He commented that the further out the map went with additional branches being constructed, the more specific the concepts became. Going in the opposite direction, the map became more abstract and therefore more holistic.

The process became rather interesting and fun for all involved and the resulting map, although complicated and simply one possible pattern of all the maps that could have been created, is a useful teaching tool in itself.

Once an interview has been conducted, it is important to allow the person time to look over the map and make changes. Miles and Huberman (1994) suggest providing a

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feedback form with a list of specific questions to be answered such as how accurate is the map, what errors are present, are any important elements missing (and if so, may they be drawn), and are the arrows showing links accurately? In addition, the person may be asked to draw a revised map if the changes are complex.

Several weeks passed as the resulting map was redesigned and colored to reflect different layers and subtopics. A printed copy stretching two by three feet was created and hung on the wall of the researchers for further study. A second copy was presented to Dr. Kellams for his review and hung prominently in his office for all to see. While the authors assumed that he would look closely at the map and come back with changes, corrections, or new ideas, this did not take place as envisioned. Rather, the map seemed to please him as is, without change, as a sort of moment in time piece of artwork.

It was decided to conduct additional interviews about college students and to compare and contrast the different maps for similarities and differences. While several other faculty members agreed to participate in these sessions, the authors were not able to continued this aspect of the research as part of the study. Rather, other components of the project, in particular the creation of a hybrid technology for displaying concept map results on the web, took priority.

In conclusion, the use of an LCD projector, notebook computer, and SmartIdeas software proved very satisfactory to the interview process. The results of the naturalistic inquiry are by nature somewhat amorphous until the themes and patterns begin to emerge in the data. During this project, much was learned not only about the creation of concept maps, but also about the emergent, polychotomous nature of ideas, which may be presented as connected threads of concepts that are not linear, hierarchical, or cumulative. Overall, this was an exciting and useful exploration of a technique in qualitative research.

Figure 4.4: A view of the complete concept map
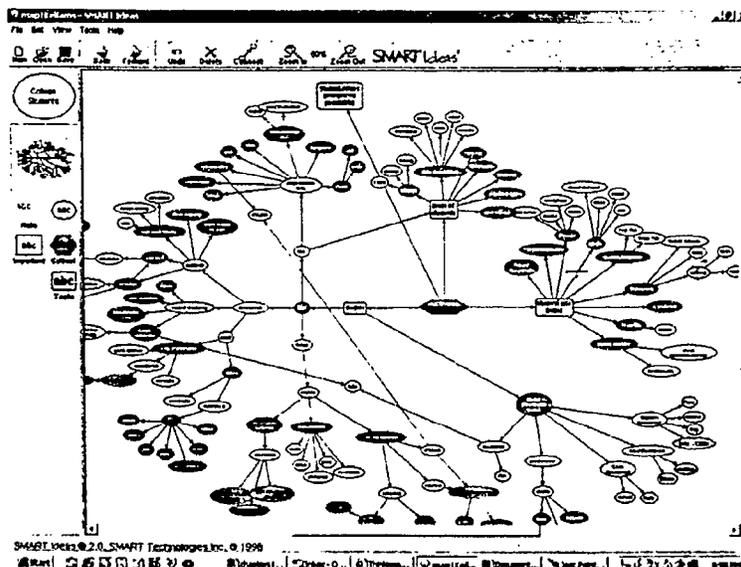
C. Examples of Concept Maps on the Web

Despite their utility, the number of concept maps on the web is still fairly limited. The following are representative samples of sites that use a concept map structure as a site map. Several websites link organizational charts that may be considered site maps. Except for a few exceptions, none of the examples which were located by the authors integrate maps throughout the site.

Ranging from simple to complex, maps are being used on the web for the following purposes:

> Providing a graphical display of a limited set of links to other websites (e.g., UCMP Subway)
> Serving as brief guides to a particular subject, with layers of a map showing related concepts (e.g., The Integrative Nurse)
> Displaying a hierarchical site map with topics and sub-topics to aid with navigation of the website (e.g., LEO Site Map)
> Displaying interactive animated or three-dimensional site maps that give a graphical view of where information is located (e.g., Key Technologies Map)
> Providing an interactive graphical search engine (e.g., WebBrain)

Each site is described below.

CET Website Map
http://gsaix2.cc.gasou.edu/cet/sitemap.html

A hierarchical site map containing active links in yellow boxes. From the Center for Excellence in Teaching, Georgia Southern University.

Concept Maps
http://library.thinkquest.org/10335/concept.shtml

Ten concept maps from "A Collaborative Study in American History," an online study group of students and teachers. Each map is based on a different time period or subject.

The Integrative Nurse
http://mypage.direct.ca/s/sbart/index.html

This site for nurses, students, and health care providers offers concept maps on medical topics such as "Postoperative Patient Assessment" and "Anxiety: Patient and Family."

Key Technologies Map
http://www.ipli.com/aboutipl.htm

An interactive concept map from Innovative Projects Lab, Inc. Uses artificial intelligence technology to form a representation of knowledge.

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LEO (Link Everything Online) Site Map
http://www.leo.org/leo_home_e.html

A hyperlinked site map from the University of Munich, Germany, which is maintained primarily by students. This map offers a hierarchy of topics dealing with software. Click on an information topic to bring up a list of subtopics.

Mapping Websites: Planning Diagrams to Site Maps
http://www.dynamicdiagrams.com/seminars/mappingdc/maptoc.htm

This summary of a presentation by Paul Kahn at the 1996 Web Design and Development Conference contains some truly stunning examples of animated or three-dimensional maps.

In Kahn's section on Data-Driven Maps, there is an animated site map created with MAPA software (based on Java) from Dynamic Diagrams. At the Dynamic Diagrams site (http://www.dynamicdiagrams.com/minimapa.html), users may click on Java.Sun.Com to see a three-dimensional map resembling a series of buildings that are hyperlinked. The view changes when using a mouse to drag and move items. It is as if the viewer were walking through the area, with the "buildings" that represent data coming nearer or moving further away.

Kahn's section on Current Research Prototypes is especially fascinating. For example, clicking on "Visual SiteMap" leads to an example from Boeing Company that uses what looks like colored puzzle pieces and dots to indicate where data lie on a website. This technology was developed at the University of Kentucky. "Navigational View Builder" leads to a three-dimensional concept map example from the Georgia Institute of Technology. Concepts are labeled on colored blocks, and the map is intended to be interactive (only a screen capture is provided). "Directed Graphs in 3D Hyperbolic Space" from Stanford University uses Site Manager software to provide a spherical map that may be used in site development. "Mapuccino (aka Webcutter)" technology (http://www.ibm.com/java/mapuccino/) uses Java to provide a two-dimensional "fisheye" view of a website.

SMSU Computer Science
http://www.cs.smsu.edu/new/academics/flowchart.html

An example of a hyperlinked flowchart for a computer science curriculum. Created by the Computer Science Department at Southwest Missouri State University.

UCMP Subway
http://www.ucmp.berkeley.edu/subway/subway.html

A virtual subway takes the user to destinations throughout the Internet. From the Museum of Paleontology, University of California, Berkeley.

Web Brain: The Fastest Way to See the Web
http://www.webbrain.com/open_IE.htm

This unusual site, billing itself as "The Smartest Way to See the Web," offers a graphical search engine. Users may type in a term or choose a term from a list of categories. A list of web links is automatically generated that visually resembles branches moving outwards from a central concept. Clicking on a branch may lead to another, more specific map being generated, or the user being taken to the chosen website.

Plumb Design Visual Thesaurus
http://www.plumbdesign.com/thesaurus/
The Plumb Design Visual Thesaurus is an interactive concept map created with the Thinkmap software. The map is drawn with lines rather than shapes, with lines flowing out around a central concept. Users may click on the word they are interested in (or type in a word), the view will shift, and similar words will branch out. This map is sometimes difficult to read, however, as the view is constantly shifting and the lines linking the concepts never stop moving.

D. Using a Hybrid of Website Technologies

SMARTIdeas software was used during the interview process for generating an initial concept map. However, it was not seen as the ideal choice for website use in that the pricing structure was prohibitive for sharing the maps with a wide audience. Also, a decision was made to avoid any use of plug-in or helper applications.

Since SMARTIdeas could not be used to generate the actual graphics desired for the website, it was necessary to explore other software possibilities. These included: 1) generating the images manually with software such as Photoshop, Paint Shop Pro, or Fireworks; 2) using table backgrounds that offered the illusion of concept map nodes; 3) investigating the possibility of using software such as Macromedia Generator for more complex graphics generation; and 4) using web databases and software such as ColdFusion and Active Server Pages (ASP) to make the concept maps dynamic.

Designing the graphical interface with graphics software

The pilot interview generated 149 unique concepts or nodes that needed to be represented graphically, either as a whole or in parts. Developing these images in Photoshop or a comparable graphics package is a labor-intensive process, however, especially if interviews on other higher education topics are being conducted. The capabilities of various button creation software were also explored without a useful solution emerging that could lessen the labor involved.

In order to see how time-intensive developing graphics would be, a template was developed and saved in Photoshop that would be used as the background in creating a single node. The process of generating the web version of the nodes was then a matter of entering the text for a node and saving the graphic—a process that would need to be repeated for each of the 149 nodes identified in the interview.

The process of generating graphics for the original 149 nodes took two team members a combined time of approximately five hours. While this time frame seemed reasonable for a one-time creation of the nodes, it would not be feasible for developing the mass quantity needed to represent each of the nodes possible in an ERIC website.

A method was also needed to distinguish the central node from the secondary nodes. With Photoshop, this would require generating two versions of each graphic—a procedure that would double the time spent creating the single version of each node. Note that this evaluation of the use of Photoshop was not based on the newest version 6, which was recently released and includes more features for manipulating web images.

Fireworks software was explored as a possible alternative to Photoshop. Fireworks is dedicated web graphics creation software that offers certain time-saving features. For example, it is easier to use Fireworks to edit text on a graphical shape. The text may be edited at any time simply by double-clicking, even after adding a drop shadow to the shape. (If converting from a Photoshop file, users may import the text as "editable" so

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that it may be edited.) Fireworks also has an "Auto Sizing" feature, which means that as text is typed on a shape, the text block automatically expands. The Align command may be used to perfectly align the text within a shape, making it unnecessary to do this manually.

Image mapping capabilities enable the creation of image maps with "hot spots," or sliced images that may be used to connect URL links to a shape. URLs are entered using a Link Wizard on the Object toolbar. URLs and their descriptions may be stored in the "Library" and be edited and/or assigned to a hotspot.

Fireworks 3 includes the 216 color palette, the web-safe colors common to both PCs and the Mac at the 256K monitor resolution. While Photoshop 5 also includes this palette, once it has been applied to an image the entire color palette is saved as part of the file, even colors that do not appear in the image. Fireworks automatically strips out colors not in the image from the palette, thus reducing file size. Another useful feature of Fireworks is its ability to automatically code and embed JavaScript into a graphical button, giving the button a different appearance (e.g., a different color) depending on whether the user's mouse is hovering over the button, clicking on the button, or elsewhere on the screen.

Just as in Photoshop, optimized images allow users to preview the graphic with different optimization settings. Fireworks will split a window so that an image may be viewed in up to four different ways at the same time so that the user may decide which to use (e.g., four different levels of quality). Fireworks provides the file size and will estimate the download time of the image, so that the quality may be adjusted if needed. An Export to Web Page command creates an HTML page and separate files containing graphic images.

Both Photoshop and Fireworks enable a group of commands to be saved as a single command and reused. Fireworks also has a find-and-replace feature that makes it possible to replace text, URLs, fonts, and colors (e.g., change colors to web-safe colors) in multiple files. A Project Log records each changed document, and the date and time of the change.

Despite these features, the creation of individual graphics and the linkage of them to URLs still requires a significant investment in time. This problem led to a continued exploration of alternatives.

**Using table backgrounds for concept map nodes**

These factors triggered a new look at possibilities for utilizing tables, backgrounds, and html-generated text to represent the nodes in each map. Even with the Photoshop-generated nodes, tables are used to organize the graphics into a circular pattern that offer the user a visual image with the central topic or node in the center, surrounded by secondary nodes (see Figure 4.5).

Figure 4.5: Sample nodes created as separate graphics
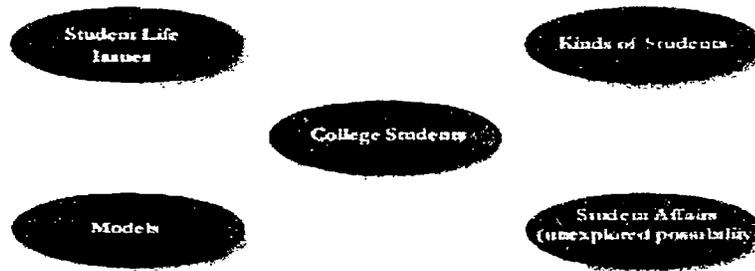
A colored background within specified cells of a table could offer the illusion of a button or node that looks very similar to those developed in Photoshop. In order to keep the circular shape of the nodes, a new background template was created using Photoshop. This background was then used in specified table cells in combination with regular text (see Figure 4.6). To facilitate appropriate size and line breaks for nodes containing a large number of characters, the number of pixels for each table cell was manually set to the size of the background graphic.

Figure 4.6: Sample nodes created using a table background image and html-generated text
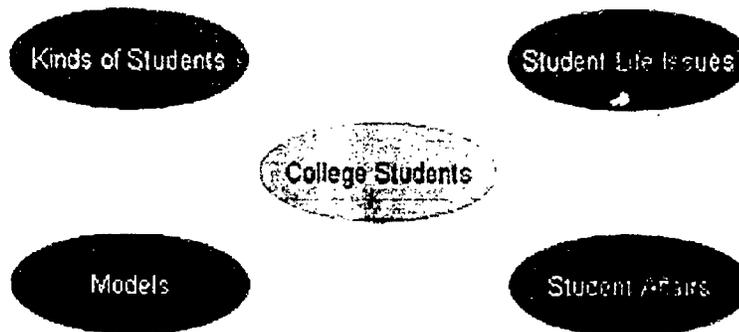
To distinguish the central node from the secondary nodes, two different versions of the same graphic image are used. The database-driven component allows the appropriate combination to be viewed on screen as users browse through the pieces of a map. The next section will provide a more detailed description of this component.

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Using the table cell backgrounds to represent the concept map nodes has some advantages:

> Adding new nodes is faster and e ⸱⸱r
> Making changes to the text represe ⸱ed on a node is a matter of changing the text, not the image
> Using alternate colors for the central and secondary nodes requires only two graphics
> Making alterations in the design or color of the nodes only requires changes to the two graphics files

One disadvantage identified with this method occurs in printing the map. The background design within each table cell that represents the node does not print. The authors are currently looking for a JavaScript or other type of programming mechanism transparent to the user that could set this background to print. Another disadvantage is that when there are many cells that require a background graphic or an odd number of cells, as may be the case with complex concept maps, the text may not wrap correctly.

Exploring Macromedia Generator

None of the concept map software packages reviewed offer the capability of exporting or translating the resulting maps into a text-based database. In order to make the website dynamic, changing with different levels and topics of concept maps, an underlying database technology needs to be employed. The possibility of using Macromedia Generator for this purpose was explored.

Generator 2 software may be used for creating dynamic websites. It merges graphics templates with databases, enabling web graphics to be created on the fly. Authoring templates within the Macromedia Flash 4 development environment are used with the Generator software to deliver various web graphics formats.

Several major problems are inherent in the use of Generator, however. These include:

> Generator 2 is a server solution. Users have to download a plug-in to be able to use the concept map.
> The Windows NT Web Server version of Generator is expensive ($4298). Flash 4 software also needs to be purchased.
> The Generator software is not intuitive and has a steep learning curve. Training is usually necessary for new developers.
> Although it sounds as if Generator could be used for the desired purpose, no examples of using Generator for dynamic concept maps on the web could be located.

The conclusion of the authors was that using Generator to make an ERIC website with concept maps is too costly to justify its use.

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Making it database driven

The solution to this complex problem was for the authors to design a database application themselves, with Dr. Milam using ColdFusion web database application software. The following steps were necessary to produce this application:

First, the authors produced a text-based list of all concepts. Next, the list was modified and imported into a spreadsheet with 149 different rows – one for each concept. The different columns of the spreadsheet were used to document related nodes for each concept that needed to appear at the same time.

The primary concept map includes one central node (college students) and four related nodes. The spreadsheet row for this central node will list college students in the first column, then the other four concepts in the next four columns. Other concepts might have fewer or more related nodes, depending on the map that was drawn. Other potential maps such as the ERIC thesaurus of descriptors might include 10,000 potential central nodes, with 100,000 related nodes.

After initial use for development purposes, the spreadsheet was converted to an Access database table. Any database software would work, but the web database software chosen for this purpose already has ODBC drivers that allow easy use of Access

Figure 4.7: Access table with data from concept map on college students

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Once converted, the next step of the development process was to design a web application that would arrange in table format within HTML the five nodes in the sample map previously displayed in Figure 4.6. How many table cells are needed for each different map? This depends on how many nodes are desired. For this example, only five concepts are displayed. For the key node to be displayed in the center and the four others around it, it is necessary to envision an HTML table structure that includes nine cells – three for each of three rows that contain one or two concepts per row.

For several different research efforts, Dr. Milam maintains a web server at the University of Virginia. This dual Pentium III 450 Dell server with RAID Level 5 was installed with Microsoft Windows NT Server, Internet Information Server, SQL Server 7, Office 2000, and ColdFusion Server Professional.

While there are many web database application software packages to choose from, Dr. Milam has used and written about ColdFusion extensively since 1995. In contrast to Active Server Pages, Perl, or PHP, this software allows non-programmers who understand HTML an easy way to create or "paint" dynamic web reports. It is necessary, though, to have knowledge about database design.

The website of dynamic concept maps was developed in HTML level 2.0 so that the pages are easily viewed in all currently used versions of Netscape and Internet Explorer. A ColdFusion template or "cfm" file was created that displays the central node in a concept map. Clicking on the related nodes changes the map, putting the related node in the center and displaying its own set of related nodes. With 149 nodes, there are essentially 149 different low-level maps. Additional maps could be created that show maps together. However, experimentation with different website designs suggests that a single map is efficient in giving users a simple, quick, and intuitive interface.

Other software such as SMARTIdeas allows users to view maps on the web, but users must download, install, and use plug-in software and/or Java applets. Also, not all layers of a map may appear at the same time. Although Inspiration 6 could be used to view maps on the web without a plug-in, the links would have to be hand-coded into the image map, rather than database generated. The choice of ColdFusion requires no plug-in or helper applications and reduces web processing time on the client side considerably, as all of the work is done on the server side.

The resulting maps suggest that it is possible to use a hybrid mix of technologies to create and view concept maps on the web. While various concept map software packages may be used to create maps, these are inadequate for the requirements for display. For the purposes of this project, all of the concept map nodes were created with Photoshop and the images were displayed using a ColdFusion web database application.

In order to accommodate an unlimited number of nodes, it was determined that HTML table cell properties would be used to display a background image in each cell, with the ColdFusion application displaying the text for a node over a generic image with HTML.

One of these two solutions must be implemented for the concept map images to be displayed.

E. The Use of Concept Maps for ERIC

While this research on the use of concept maps in navigating the web is interesting in itself, the funding of this project had a particular goal in mind – to explore what concept maps might offer the ERIC system. ERIC is in a transition phase and a great deal of attention is being directed to the effective use of new Internet-based technologies to better meet user needs.

What do concept maps have to offer ERIC?

This question may not be answered without addressing how the concept maps will be created and how they will be made available on the web. Without a sense of how a hybrid set of web technologies may be leveraged, an adequate assessment of potential for ERIC is not possible.

Creating maps

There are two choices for developing concept maps which will drive the overall vision of their use for ERIC: (1) creating new maps; and (2) using the existing thesaurus of descriptors.

(1) creating new maps

The first choice involves the creation of entirely new maps. This is essentially what is presented in Section B of this chapter about Creating Sample Maps. Software is available which makes this process much easier, especially when used in conjunction with a computer and LCD projector to facilitate a team approach to generating a map. This document provides a current guide to this software. It also addresses many of the methodological choices which must be made, both those hidden in the constructs of the software and those inherent in the way the map developers use subject matter experts to create the maps.

While the process is documented and may be replicated using the description which appears in this document, it is time consuming and requires a great deal of attention and energy from researchers and participants.

More importantly, it is recognized that maps of the same content material will vary between different subject matter experts. It requires a significant effort in consensus-building to develop a set of complex maps which a variety of experts and users may agree on. This may happen, but it is clearly an exhaustive process.

Not to seem too daunting a task, this group process for building maps is greatly facilitated by the collaborative features which are included in several of the concept map software packages. These features allow for researchers or users across the world to contribute synchronously or asynchronously to building a map. Different people may work on separate sections of a map. A group may work together on a single part of the map;

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changing, editing, and adding nodes until there is consensus that the map is complete. They may also go back later and change the map in an evolving, ongoing process.

This collaborative mapping process requires significant orchestration of participants. Before the advent of the World Wide Web and sophisticated software features for group work, it would have been costly and difficult to schedule a group of scholars to come together long enough to complete maps. Now there are no travel costs, only the coordinating costs of bringing people together online with common collaboration software and a shared vision and purpose for building the maps. This approach is very exciting.

Like all maps, though, those created by such a group will continue to evolve and change over time as new knowledge is created and new ideas suggest new maps.

(2) using the existing thesaurus of descriptors

Instead of creating new maps, a second alternative is to use the ERIC Thesaurus of Descriptors to generate maps that show the thesaurus' listing of search terms and related terms. The version of the thesaurus which the researchers used for their analysis was obtained from Larry Rudner of the ERIC Clearinghouse for Assessment and Evaluation.

The sample thesaurus contains these fields: Term, Use, SN (note or definition), NT (more narrow term), RT (related term), and UF (more breakouts with dates when the term was used in ERIC). The narrow and related term fields have multiple listings in them, separated by semicolons. When each of the fields was analyzed, there were 10,536 unique terms. For each of these, there were up to 2 use terms, up to 4 broader terms, up to 102 more narrow terms, up to 86 related terms, and up to 10 UF terms.

In visualizing how the thesaurus could be used to generate concept maps, it is necessary to understand the model for database-driven maps which was presented in Section D of this chapter. A spreadsheet model may be used to illustrate the use of different fields. The first column is the term, followed by other columns for more narrow and related terms. When the database is used to dynamically create a concept map, the center node or main term is whatever is listed in the first column of the spreadsheet or database table.

Around this main idea, it is then possible using HTML tables to list related terms. Only a fraction of the main terms have more than 20 related terms. Therefore it is possible to list all related terms in a concept map. It is also possible to list, separately, the broader terms and narrower terms for the main idea. These do not have to be portrayed in concept map format, though it is certainly possible. In addition, a designer might wish to provide a button by which users could see a concept map of all broader or more narrow terms.

In moving their way through concept maps, users would have the choice of going one of three directions – sideways to view related terms; up to view broader terms, or clicking on a specific term to see more narrow terms. The following Table 4.1 illustrates how this looks using the existing thesaurus listings for the term "Achievement." No broader

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terms are listed for "achievement," so only narrower terms and related terms are displayed.

Table 4.1: Use of fields for the term "achievement"

Narrower Terms	Related Terms
ACADEMIC ACHIEVEMENT	ABILITY
BLACK ACHIEVEMENT	ACHIEVEMENT GAINS
GRADUATION	ACHIEVEMENT NEED
HIGH ACHIEVEMENT	ACHIEVEMENT RATING
KNOWLEDGE LEVEL	ACHIEVEMENT TESTS
LOW ACHIEVEMENT	APTITUDE
MATHEMATICS ACHIEVEMENT	ASPIRATION
OVERACHIEVEMENT	COMPETENCE
READING ACHIEVEMENT	EVALUATION
SCHOLARSHIP	EXPECTATION
UNDERACHIEVEMENT	FAILURE
WRITING ACHIEVEMENT	FEAR OF SUCCESS
	GIFTED
	IMPROVEMENT
	LEARNING PLATEAUS
	MASTERY LEARNING
	MASTERY TESTS
	MOTIVATION
	NATIONAL COMPETENCY TESTS
	PERFORMANCE
	PERFORMANCE ACTORS
	PREREQUISITES
	PRODUCTIVITY
	QUALIFICATIONS
	RECOGNITION (ACHIEVEMENT)
	SELF EFFICACY
	STANDARDS
	SUCCESS
	TALENT

While some of these terms may seem outdated, the above example suggests what is possible using the thesaurus database to display concept maps. A concept map of this is shown in Figure 4.7 for the narrower terms.

Figure 4.8: Concept map for narrow terms for "achievement"
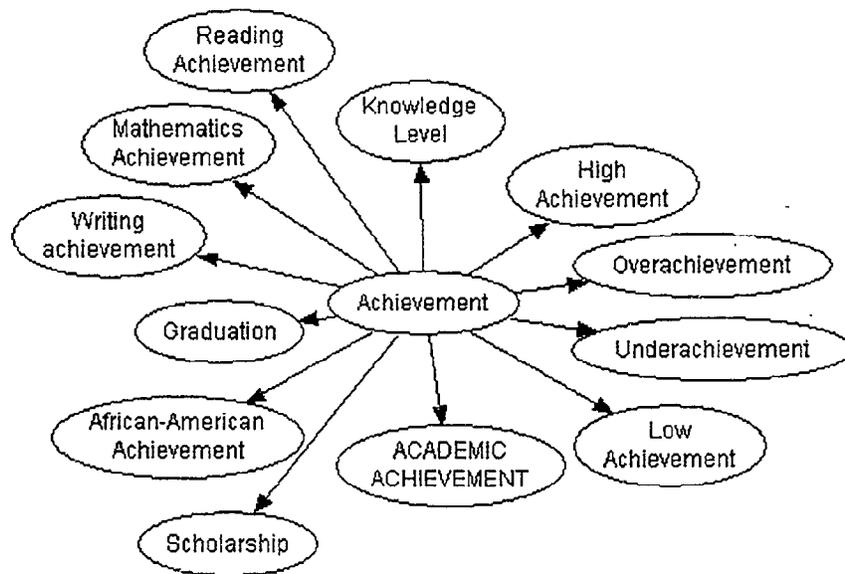
If the user clicks on another node such as "Low Achievement," she/he is then presented with a new map that is driven from the thesaurus. This term has "Achievement" as its broader term, but no more narrow terms. There are 7 related terms for "Low Achievement." Clicking on "Low Achievement" will then produce a map which might look as follows.

Figure 4.9: Concept map of related terms for "low achievement"

For the above examples, the concept maps were drawn using SmartIdeas. As the discussion of hybrid technologies suggested, this is practical for a few maps but quickly becomes unwieldy when there are thousands of terms or nodes that may be displayed.

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Using hybrid technologies

The use of Flash Generator software to dynamically generate actual images on the fly was not tested by the authors due to its prohibitive cost and complexity to use. This would not be a problem for the ERIC system, but the use of this technology does require that users download and install a plug-in Flash viewer. Since ERIC must serve a wide variety of users with many skill levels, this is not a viable approach. The alternative is to use HTML tables, two simple images for the main idea and node, and web database software. This was described generally in Section 4, but will be applied here to the use of concept maps within the ERIC system.

Three coordinating technologies are required for this solution:

> (1) the ERIC Thesaurus of Descriptors is stored in database formats such as Access or SQL Server 7 for NT or mSQL for Unix;

> (2) a web server such as Internet Information Server for NT or Apache for Linux; and

> (3) web database software such as Active Server Pages or ColdFusion.

Choices within each type of technology are driven by the operating system. The authors' recommendation is for ColdFusion web database software, which must be used within Solaris, Linux, or NT. Active Server Pages, Perl, and PHP are all adequate solutions which will produce the same result. However, these require much more substantive programming skills and the resulting code is much more complex.

Regardless of the choice in operating system, the three technologies work the same way together. First, the user selects one or more terms to view in a concept map. These may be presented within its own concept map or be taken from a searchable list of terms. Second, the web server sends this requested term to the web database software. The web database software processes the term and looks it up in the Thesaurus of Descriptors. From this table, related terms are taken. Broad, narrow, or other terms could be listed in the database just as easily. These related terms are then sent by the web database software to the web server, which dynamically creates an HTML table. The table contains an image at the center. This represents the main idea and is overwritten with the text of the term chosen by the user. Around this central idea, related terms are arrayed in the table. The text for each term is displayed over a graphic that represents related nodes.

Issues and constraints

There are some issues and constraints which arise in this proposed solution for using concept maps. These include: (1) the production of graphics; (2) moving from the concept map to bibliographic retrieval of records; (3) the limitations of the thesaurus of descriptors; (4) technology support; and (5) development costs.

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(1) the production of graphics

ERIC wants the best graphical look and feel to the concept maps possible. This is limited somewhat by the reliance on HTML. However, the button images for the primary idea and related nodes may be as fancy as the designers want to make them. The cells within an HTML table may contain other graphics which make it appear visually appealing.

Some confusion on the page may exist if there are 100 different related or more narrow concepts to be presented around a central idea. Table cells may be made small. If necessary, the background image may be done away with entirely, leaving more space for different concepts. Patterns in cell shading, padding, size, and color may be used to distinguish nodes from one another.

(2) moving from the concept map to bibliographic retrieval of records

Once a concept is displayed as the main, related, broader, or narrower term, users may want to get access to online resources or the bibliographic records which are at the heart of ERIC. How does the concept map get to the ERIC search?

The terms which are chosen by a user as she/he navigates the concept map are stored in memory as variables by the web database software. It is relatively simple to pass these variable parameters on as query strings to the ERIC database engine. Instead of using the standard web search pages which are available, the concept map term would be entered into the search page.

In the standard ERIC search engines which are available on the web, a confirmatory page now prompts users of the search engine with the search criteria, asking whether this is what they want. This page would be identical for the concept map page and continue in its existing fashion for presenting the bibliographic results. A special button could be placed on these pages, showing users that the search criteria was generated through the use of concept maps and which would allow users to go back to the map where they started.

(3) the limitations of the thesaurus of descriptors

The utility of a hierarchical thesaurus is a hot topic of debate among librarians, especially as the web has enabled full-text searching and non-linear, hypertext as new modes of query. It is not the purpose of this project to comment on this debate, except to state that the display of concept maps is not designed to be hierarchical. Some concept map software presents the results in a hierarchical, linear fashion. Certainly, the terms must be stored in fields of data that are somehow related to each other. But the database-driven display of hypertext concept maps allows something which the existing use of the thesaurus does not - movement between, among, and around terms in a fashion which does not force users to think about the hierarchy.

With concept maps, users are led to see patterns in the nature of knowledge. They may move horizontally or vertically in many paths of terms and ideas. Also, concept maps may be redundant in the listing of terms, so that a keyword may show up in many different places, not just in its prescribed hierarchical placement. To truly implement this vision, the nature of the thesaurus must be expanded to allow for more redundant listings of terms.

(4) technology support

The underlying technology for the proposed hybrid solution includes a web server, database server, web database software, and HTML. Scalability, load, and support issues arise in any large scale solution. What should be anticipated if the proposed hybrid technologies were implemented for ERIC?

For this analysis, Dr. Milam studied the level of web server and web database software hardware and software solutions already used at the National Center for Education Statistics within the Office of Educational Research and Improvement, an agency comparable to the National Library of Education and ERIC in scope and in the demand on Internet services. NCES houses two Pentium level machines running NT operating system software for the web server and one comparable machine running SQL Server for the database server. A second set of machines is used for the development of programs before they are transferred to the production servers. These boxes get millions of hits and the site statistics, available from NCES, reviewed by Dr. Milam for another research project which he is currently directing.

If the concept map site gets too many hits for the existing ERIC servers, then the site needs to be mirrored. Issues of security will be dealt with through the same methods used by NCES, with built-in levels of security from the NT operating system, the web database software, and by keeping the data on a separate and secure database server.

The NCES hardware and software configurations suggest that this is a relatively inexpensive solution from the non-personnel perspective. It is assumed that ERIC and EDRS would provide comparable support of the same level of servers and that the production use of concept maps would not significantly impact the service or efficiency of these ERIC web servers.

What is perhaps most important to the success of implementing this recommended hybrid approach is vision - the vision to leverage existing, relatively inexpensive hardware and software in a new and exciting web application for the future of ERIC.

(5) development costs

If the recommended hardware and software strategy is incorporated and the ERIC system wished to move forward, what would it cost? It is unnecessary to duplicate the production server environment maintained by NCES just for a single web app. This may

be done on desktop machines by programmers, with presentations for review, and testing on the production site before final announcement to the public.

The cost of hardware for the primary web server and for the database server is estimated at approximately $20,000 with half going to each server for dual Pentium III Zeon processors, 512MB of Ram, redundant power supplies, RAID level 5 with hot swappable SCSI hard discs (3 required with mirroring, at least 9 gigabytes each). Software would include NT Server, ColdFusion Professional or ASP, and SQL Server 7. It is assumed that an IP address and Internet host site already exists within the ERIC system with 24/7 monitoring, support, and power backup capability.

Summary

This proposed solution for leveraging a hybrid mix of technologies to build web-based concept maps for ERIC is not vaporware. All aspects of the technology have been tested as part of this research. Furthermore, it is a relatively inexpensive and still elegant solution. The key to its implementation is in whether it meets the vision of the ERIC system for a new user interface that incorporates concept maps. The technology is there and the solutions are straightforward.

V. Discussion

Concept maps for web navigation

The literature on concept maps suggests that they are becoming more widespread in their application to such varied purposes as instruction, creativity, writing, and research. However, the literature is at times contradictory and confusing, with different recommendations about such key features as the relationship between symbols. Users must seek a consensus that is not available by adopting the work of one or more theorists in the context of one or more fields of study.

There are also implicit assumptions behind choices for software used to build and view concept maps. These packages have undergone significant changes with the advent of the web, with exciting new features such as collaborative groupware and cross-platform use of Java. However, none of the evaluated packages offered the researchers exactly what they were looking for, particularly in sharing concept maps without the use of "plug-in" software to view levels of linked Internet resources.

While concept maps may be quickly created by one or more persons, the resulting maps may not adequately "map the knowledge base" very well. Even with clear assumptions and good qualitative research methodology, there are a myriad of ways to create a single type of map of the same content. It is important to either involve a group of scholars in developing a map and/or to recognize that the resulting map is simply a pattern for documenting the links between complex ideas. The groupware features for the collaborative creation of concept maps have great potential for developing these consensual maps and need to be explored further within an education context. The use of groupware for creating maps is already being implemented in other fields.

This technical report has much to offer discussions about the ERIC system on a number of levels, from the advantages of concept maps to specific recommendations about leveraging existing, relatively inexpensive website technologies to improve navigation. Still, no single, concept mapping software package currently offers a clear and evolving navigation scheme for a website based on the use of concept maps. A hybrid approach is needed.

While it would be invaluable to conduct further research to create concept maps that are based on a consensus of scholars, this is impractical. Due to the rise of full-text, Boolean searching, the existing ERIC Thesaurus of Descriptors has been perceived as a product of another era. The use of concept maps breathes life into the nature of the Thesaurus and provides a rich tool for transforming the nature of bibliographic retrieval.

With a strong sense of this vision of transforming ERIC with concept maps for web-based navigation, the authors recommend that continued work is warranted on this project. The next step is for ERIC to evaluate whether this vision merits further exploration and, if so, to take the next steps which are outlined above.

VI. Annotated Bibliography

Anderson-Inman, Lynne, & Horney, Mark. (1996-1997). Computer-based concept mapping: Enhancing literacy with tools for visual thinking. *Journal of Adolescent & Adult Literacy, 40* (4), 302-306.

This article describes two prewriting strategies (brainstorming and synthesizing information), and discusses practical issues related to computer-based concept mapping for classroom use.

Berg, Gary A. (1999a). Community in distance learning through virtual teams. *WebNet Journal, 1* (2).

Although not about concept mapping, this article contains an excellent example of a complex concept map on page 36, displayed as a series of concentric circles.

Berg, Gary A. (1999b). Concept mapping in instructional delivery and assessment. *WebNet Journal, 1* (3), 5-6.

Concept mapping is based on meaningful relationships between ideas in memory and has often been used for assessing learning outcomes for students. The problem is that there may be multiple right methods to mapping. An example is provided that was created with Inspiration software.

Beissner, Katherine. L., and others. (1993). *Using and selecting graphic techniques to acquire structural knowledge.* ERIC No.: ED362151. 23 pages. In Proceedings of Selected Research and Development Presentations at Convention of Association for Educational Communications and Technology.

This paper covers nine graphic techniques such as networks, pattern notes, and semantic maps that may be used to examine relationships between concepts. Implications for research and instructional design are included. The author proposes a model of different effects of graphic techniques depending on the cognitive processes elicited in order to construct the graphic.

Bousquet, Woodward S. (1982). *An application of Ausebel's learning theory to environmental education: A study of concept mapping in a college natural resources management course.* ERIC No.: ED216900. 330 pages. PhD dissertation, Ohio State University.

This study looked at the use of concept maps to help students at Ohio State University identify relationships between new concepts and those already known. Students were divided into high and low knowledge groups based on pretests. Each student constructed three maps of environmental concepts during the course and took a posttest at the end of the course. Results showed that prior knowledge and reasoning ability showed little relationship to students' ability to construct concept maps.

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Carley, Kathleen, & Palmquist, Michael. Extracting, representing, and analyzing mental models. *Social Forces, 70* (3), 601-636.

The authors describe a computer-based method used to extract mental maps from written and spoken texts, and to analyze and compare concepts within the maps. The method is illustrated using data on an undergraduate writing class.

Chou, Chien, & Lin, Hua. (February, 1997). *Navigation maps in a computer-networked hypertext learning system.* ERIC No.: ED403882. 24 pages. Paper presented at Annual Meeting of Association for Educational Communications and Technology.

A Taiwan study looked at the effects of navigation maps on first year college student performance in a hypertext learning course on Introduction to Computer Networks. The navigation map type had a significant effect on students' search steps and search efficiency. Map type did not have a significant effect on search-task completeness or estimation of course scope.

Concept Mapping Home Page. (Retrieved March 4, 2000). Available: http://www.to.utwente.nl/user/ism/lanzig/cm_home.htm

This site contains a brief description of concept mapping, tracing its origin to Joseph Novak at Cornell University in the 1960s. An example is provided of a concept map.

Diekhoff, George M., & Wigginton, Phil. (April, 1982). *Using multidimensional scaling-produced cognitive maps to facilitate the communication of structural knowledge.* ERIC No.: ED218245. 12 pages. Paper presented at Annual Meeting of Southwestern Psychological Association.

Structural knowledge is knowledge of how ideas, events, and principles are related. Cognitive maps provide a graphical display of the structural relationships among ideas. Student judgments of the strength of the relationship among ideas may be analyzed through a technique called multidimensional scaling, in which highly related ideas are grouped closely together and less related ideas further apart.

Ferry, Brian. (1996). Probing personal knowledge: The use of a computer-based tool to help pre-service teachers map subject matter knowledge. *Research in Science Education, 26* (2), 233-245.

This article covers a HyperCard-based tool used by pre-service teachers to create concept maps for science instruction.

Ferry, Brian, Hedberg, John, & Harper, Barry. (Retrieved Nov. 6, 1999). How do pre-service teachers use concept maps to organize their curriculum content knowledge? Conference presentation, ASCILITE, December 1997. Available: http://www.curtin.edu.au/conference/ascilite97/papers/Ferry/Ferry.html

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This article suggests that teachers may use concept mapping to create and modify maps about curriculum content knowledge, and that it enhances skills in planning instruction. The authors define concept maps as two to three dimensional spatial or graphic displays that make use of labeled nodes to represent concepts and lines or arcs to represent relationships. The software used was HyperCard for Mac computers.

Flores-Mendez, Roberto A. (Retrieved 4/15/2000). Java concept maps for the learning web. Available: http://www.cpsc.ucalgary.ca/~robertof/publications/edmedia97/

The "learning web" is a vision of a society in which individuals are engaged in lifelong learning. Concept maps may help to support the communication and sharing of knowledge among each member of a community. This article discusses work by the Knowledge Science Institute to develop a concept mapping tool using the Java programming language. jKSImapper and jKSImapplet are systems designed to enable the viewing of concept maps by multiple viewers over the Internet.

Gaines, Brian R., & Shaw, Mildred L.G. (Retrieved March 4, 2000). Concept maps as hypermedia components. Available: http://ksi.cpsc.ucalgary.ca/articles/ConceptMaps/

The authors discuss interactive concept mapping using the Mac and the Web. It is possible to integrate concept maps with the Web for indexing and retrieval by using software called KMap in conjunction with HyperCard for text annotation. KMap is used as a WWW client helper through Netscape. KMap may receive information of user interactions with the Web, build a concept map of linked documents, and use this to provide a graphic "hot-list." (Note: KSI is the Knowledge Science Institute at the University of Calgary.)

Grasha, Anthony F. (1996). *Teaching with style.* Pittsburgh: Alliance Publishers.

Cognitive mapping is based on the premise that information organized in a personal scheme for an academic discipline will be retained better. The procedure includes: 1) developing a list of key terms, concepts, events, principles and ideas broad enough to cover the major issues; 2) organizing them into a scheme that helps one to understand the connections among parts of the information; and 3) showing connections among ideas within a category and across categories. Maps done by students may be evaluated and assigned points for grading.

Hall, Richard H., & Sideo-Hall, Maureen A. (1994). The effect of color enhancement on knowledge map processing. *Journal of Experimental Education, 62* (3), 209-217.

Color was shown to increase learning acquisition of material presented through either a knowledge map or text information in a study of 84 college students.

Herl, Howard E.; O'Neil, Harold F., Jr.; Chung, Gregory K.W.K.; Dennis, Robert A.; & Lee, John J. (1997). *Feasibility of an on-line concept mapping construction and scoring*

system. ERIC No.: ED424233. 27 pages. Paper presented at Annual Meeting of American Educational Research Association.

This report focuses on the feasibility of administering and scoring concept maps online to assess learning. Middle school and high school student subjects used Hyper-Card concept mapping software developed for the study to complete individual and collaborative online concept mapping tasks. Descriptive statistics were generated for the number of terms used and the number of links. Group concept map scores were based on expert criteria.

Horney, Mark. (December, 1992). *Data maps: A hypertext technique for visualizing, analyzing, and presenting qualitative data.* ERIC No.: ED352628. 14 pages. Paper presented at Annual Meeting of National Reading Conference.

Data maps are diagrams of the relationships among data. According to Horney, computerized hypertext techniques make the creation of such maps more feasible. This report describes how EntryWay, a hypertext editing program, was used to create data maps based on qualitative data from eight different research projects. Data maps make it possible for researchers to display their data, and may be used as aids to navigation, as prompts, to demonstrate relationships, and as cognitive supports.

Jonassen, David H., Beissner, Katherine, & Yacci, Michael. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge.* Lawrence Hillsdale, NJ: Erlbaum Publishers.

Jonassen writes about what he calls "structural knowledge," based on the work of Novak (1977) at Cornell University and Ausubel's 1968 theory of learning. He describes many different types of concept maps and includes drawings of each. Types include concept maps, pattern notes, spider maps, networks, cognitive maps, and others.

Jonassen, David H., & Grabowski, Barbara L. (1993). *Handbook of individual differences, learning, and instruction.* Lawrence Hillsdale, NJ: Erlbaum Publishers.

Jonassen is one of the leading authorities on concept maps in education. This book contains an excellent example of a concept map on page xi.

Jonassen, David H.; Reeves, Thomas C.; Hong, Namsoo; Harvey, Douglas; & Peters, Karen (1997). "Concept mapping as cognitive learning and assessment tools." *Journal of Interactive Learning Research, 8* (3/4), 289-308.

This article provides a conceptual framework for concept mapping and discusses some of the confusion that has emerged from the differing accounts of concept mapping. Jonassen claims that due to the technique's newfound popularity, the rationales and results of concept mapping are being "exaggerated and distorted by many accounts." The article contains a list of criteria for evaluating concept maps and a thought-provoking discussion on the limitations of concept mapping.

Kommers, Piet, & Lanzing, Jan. (1997). Students' concept mapping for hypermedia design: Navigation through world wide web space and self-assessment. *Journal of Interactive Learning Research, 8* (3/4), 421-455.

This article lists four major ways to use concept mapping to improve students' learning processes: (1) as a structural scaffolding technique before and during the development of hypermedia; (2) as a navigation device to explore hypermedia documents on CD-ROMs or the Internet; (3) as a knowledge elicitation technique; and (4) as an authentic knowledge assessment tool.

Kremer, Rob, & Gaines, Brian R. (Retrieved April 18, 2000). Embedded interactive concept maps in web documents. Available: http://curry.edschool.virginia.edu/aace/conf/webnet/html/164/164.htm

This article discusses the use of SmartIdeas software to develop concept maps. The authors have found that most people easily learn to create and modify concept maps. With SmartIdeas, computer-supported concept mapping may be developed by groups using a shared workspace and collaborating on their topic area. The nodes in the concept maps are used as a navigational tool, i.e., double-clicking on a node may lead to an associated document. The authors suggest that, in the future, a tool be built to automatically generate a concept map given an HTML document as the starting point.

Lanzing, Jan W.A. (Retrieved April 18, 2000). Concept mapping model for hypermedia design. Available: http://www.to.utwente.nl/ism/linhyp/phases.htm

This article discusses the special considerations involved in designing hypertext and suggests using concept mapping to design the conceptual structure of a hypertext document. The model proposed divides hypertext design into three phrases: 1) conceptual design, in which the content is determined, and all concepts and their relations are described; 2) structural design, in which concepts are clustered to form units that may be described in hypertext paragraphs; and 3) navigational design, in which a navigational structure is added. The concept map itself may serve as a navigation tool if it is included in the hypertext as a visual overview with clickable areas. It is the author's hope that new tools will be developed for building concept maps, including tools that may generate a map from a series of hypertext pages.

McAleese, Ray (1998). Coming to know: the role of the concept map--mirror, assistant, master? ERIC No.: ED 429968. 15 pp.

The author provides a framework for the process of creating, managing, and maintaining concept maps, using reflection as a focus. Section 1 defines concept mapping and structural knowledge, provides an example of a concept map, and discusses "associationism." Section 2 describes how self-regulation makes individuals goal-directed and helps lead them to intentionality. Section 3 explains that the limited capacity of working memory leads to a process known as off-loading. Section 4 looks at

phases in the construction of a concept map. Finally, Section 5 discusses implications for learning and instructional design.

McAleese, Ray. (April, 1988). *From concept maps to computer-based learning: The experience of NoteCards.* ERIC No.: ED299954. 24 pages. Paper presented at Annual Meeting of American Educational Research Association.

Research in knowledge acquisition and representation for computer-based training is discussed. The hypertext system NoteCards may be used to provide a learner-based interface to training applications. Visual examples of concepts may be placed on a videodisc attached to the workstation that runs NoteCards.

McCagg, Edward C., & Dansereau, Donald F. (1991). A convergent paradigm for examining knowledge mapping as a learning strategy. *Journal of Educational Research, 84* (6), 317-324.

This article shows how student-generated knowledge maps improved college student performance on recognition and recall tests, based on gains over time.

Miles, Mathew B., & Huberman, A. Michael (1994). *Qualitative data analysis: An expanded sourcebook,* 2nd ed. London: Sage Publications.

Cognitive maps display a person's representation of concepts in a particular domain and the relationships among them. A good display will show the complexity of an individual's mind, yet minds are not always organized hierarchically as in taxonomies. Miles and Huberman suggest this process: 1) premapping interviews (2 hours) to get at key concepts; 2) mapping to arrange concepts and write descriptive text of the map and how it should be organized (3-4 hours); and 3) feedback to show the map and text to the respondent, in which the person may fill out a response form or redraw the map (3-4 hours). In creating a concept map, it is important to consider the issue of idiosyncrasy vs. comparability (i.e., using displays across several persons).

Moen, Ed, & Boersma, Kerst. (1997). "The significance of concept mapping for education and curriculum development." *Journal of Interactive Learning Research, 8* (3/4), 487-502.

The authors explore the functions which concept mapping may serve in education and curriculum development, and discuss rules that lead to effective concept maps. Finally, they examine why educational institutions fail to make systematic use of concept maps for their students.

Novak, Joseph D. (1998). *Learning, creating, and using knowledge: Concept maps™ as facilitative tools in schools and corporations.* Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

The book focuses on five factors that are always involved in educational events: the learner, teacher, knowledge, context, and evaluation. Concept maps are used to illustrate and give examples of learning theory, theory of knowledge, and instructional theory. Novak also discusses why rote learning is ineffective for achieving the knowledge goals of today's society, and shows how effective management is dependent on the same factors as effective teaching.

Novak, Joseph D. (Retrieved April 19, 2000). *The theory underlying concept maps and how to construct them.* Available: http://cmap.coginst.uwf.edu/info/printer.html

This excellent article by Novak summarizes his theory of concept maps, which was based on cognitive psychology. Learning takes place by assimilating new concepts into existing frameworks of knowledge. Concept mapping makes it possible to achieve synthesis of knowledge, the highest level in Bloom's taxonomy. An example of a concept map is included, as well as steps for constructing a concept map. Novak concludes by expressing the wish that achievement exams use concept mapping as a tool to evaluate learning.

Novak, Joseph D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27* (10), 937-949.

Concept mapping is described as a tool for science educators. The author also makes suggestions for additional research on the representation of knowledge.

Oldfather, Penny, and others. (1994). Drawing the circle: Collaborative mind mapping as a process for developing a constructivist teacher preparation program. *Teacher Education Quarterly 21* (3), 15-26.

This article discusses the relationship of collaborative mind mapping to constructivism, types of mind maps, and how to use mind maps in developing constructivist teacher education program.

Peterson, Anne R., & Snyder, Paula J. (1998). *Using mind maps to teach social problems analysis.* ERIC No.: ED424882. 73 pages. Paper presented at Annual Meeting of Society for the Study of Social Problems.

Mind maps may provide a visual representation of students' thinking patterns. Four steps are recommended to construct a mind map: 1) preparation, 2) brainstorming, 3) revision, and 4) presentation. The results of using mind maps at Columbus State Community College for a Social Problems course are discussed.

Pinkerton, David K. (1998). Network similarity (netsim) as a method of assessing structural knowledge for large groups. *Journal of Interactive Learning Research, 9* (3-4), 249-69.

The "KNOT" computer program uses a network similarity index (NETSIM) to compare the concept maps of novices and experts. Three high school physics classes were used to investigate the reliability and validity of the software.

Plotnick, Eric (1997). *Concept mapping: A graphical system for understanding the relationship between concepts: An ERIC digest.* Syracuse, NY: ERIC Clearinghouse on Information and Technology. ERIC No.: ED407938. 4 pp.

Concept mapping, a technique for conveying information visually, may be used for brainstorming, communicating complex ideas, aiding the learning process, and assessing understanding or diagnosing misunderstanding. Concept maps have certain advantages over text: 1) visual symbols are quickly recognized; 2) minimum use of text makes it easy to scan for a general idea; and 3) visual representation leads to a holistic understanding that words alone cannot convey. Computer software for concept mapping may facilitate adaptation and manipulation, dynamic linking, conversion, communication, and storage. "Inspiration" is given as an example of one of the most popular software programs now available for educators.

Reed, W. Michael, & Oughton, John M. (1998). The effects of hypermedia knowledge and learning style on the construction of group concept maps. *Computers in Human Behavior, 14* (1), 1-22.

The authors analyze students' concept maps related to the term "hypermedia" to determine whether group membership influenced the maps. Students were put into groups based on a mixture of learning styles or a mixture of hypermedia knowledge. Learning style seemed to explain the results more than hypermedia knowledge did.

Rico, Gabriele L. (1983). *Writing the natural way: Using right-brain techniques to release your expressive powers.* New York: Jeremy P. Tarcher/Putnam.

This book is about using concept maps (which the author refers to as "clustering") to aid in the creative writing process. Extensive examples are provided. The author's viewpoint is that creating visual maps, as opposed to text outlines, may free people from the mental blocks that prevent good writing.

Roshan, Visa, & Dwyer, Francis. (1998). Effect of embedded graphic mapping strategies in complementing verbal instruction. *International Journal of Instructional Media, 25* (4), 389-98.

This study examined the instructional effect of different mapping strategies (spider maps, frame maps, and semantic maps) on helping college students achieve different educational objectives, as well as how much time the students had to process the information presented in each type of map.

Russel, Peter (Retrieved March 4, 2000). Mind maps. Available: http://www.peterussell.com/mindmap1.html

This site contains "how to mind map" tips such as starting in the center of the page, making the central image the theme, using color to represent associations, using arrows and icons to indicate links, putting ideas down as they occur, and going on to another branch if stuck. MindManager software was created for this approach.

Shaw, Mildred L.G., & Gaines, Brian R. (Retrieved March 4, 2000). Comparing conceptual structures: Consensus, conflict, correspondence and contrast. Available: http://ksi.cpsc.ucalgary.ca/articles/KBS/COCO/

This site points out a problem in eliciting knowledge/concepts from experts, which is that they may use the same term for different concepts, different terms for the same concept, or different terms and different concepts. The authors suggest having multiple experts brainstorm as a group, using different viewpoints to develop a rich framework. Do not force a false consensus on the assumption that there is some "correct" conceptual framework, but make the differences available for discussion.

Spradley, James P., & McCurdy, David W. (1984). *The cultural experience: Ethnography in complex society.* Chicago: Science Research Associates, division of IBM.

According to Spradley, all knowledge depends on categorization. Different kinds of questions may reveal categories. Structural questions help determine what fits into a conceptual category, for example: What are kinds of ___? What are ways to ___? Contrast questions relate what something means to what it does not mean. Attribute questions look for pieces of information to distinguish differences. To determine the differences among related categories, Spradley suggests asking, "What is the difference between ___ and ___?"

Spradley, James P. (1979). *The ethnographic interview.* New York: Holt, Rinehart, & Winston.

This book uses a linguistic approach to ethnography. Spradley defines language as a tool for constructing reality and sees ethnography as a search for the relationships among symbols. The elements of an ethnographic interview with an informant include: having an explicit purpose, explaining the reason for the project, asking descriptive and structural questions, expressing interest, asking contrast questions, restating by using the informant's terms, encouraging expansion by phrasing and repeating, and asking questions in different ways.

Stanton, Neville A. (1992). Maps as navigational aids in hypertext environments: An empirical evaluation. *Journal of Educational Multimedia and Hypermedia, 1* (4), 431-444.

A study of college students at Aston University (United Kingdom) looked at whether cognitive maps were an appropriate aid for searching in a hypertext environment. Data

studied includes task performance, previous computer use, and system u.:e. Implications for hypertext system designers are discussed.

Trochim, William M.K. (Retrieved March 4, 2000). Concept Mapping. Available: http://trochim.human.cornell.edu/kb/conmap.htm

Trochim views concept mapping as a group brainstorming structured process guided by a facilitator. The group determines content and produces an interpretable pictorial view of ideas. This site describes the author's recommended procedure: 1) prepare project; 2) generate ideas; 3) sort ideas; 4) compute maps; 5) interpret maps and 6) use maps.

Trochim, William M.K. (Retrieved March 4, 2000). An introduction to concept mapping for planning and evaluation. Cornell University. Available: http://trochim.human.cornell.edu/research/epp1/epp1.htm

This article contains a detailed description of a concept mapping project that used brainstorming followed by multivariate statistical techniques (multidimensional scaling and cluster analysis) to generate maps. Trochim says that concept mapping encourages groups to stay on track and results in a conceptual framework in the language of participants.

Wandersee, James H. (1990). Concept mapping and the cartography of cognition. *Journal of Research in Science Teaching, 27* (10), 923-936.

The author takes facts, concepts, and principles of cartography and uses them as a metaphor for concept mapping. Included is a discussion on how the concept map may be used to represent scientific concepts.

Watters, Carolyn & Wu, Zhou (1999). Interactive lateral maps: Using the web for collaborative analysis. *WebNet Journal, 1* (3).

Concept maps are a visual language for representing and communicating knowledge within a community. They may be used either to begin a task or as result of an analysis. The technique works well when there is an agreed upon set of relationships and well-defined types of nodes, but it's not so good if concepts are vague.

VII. References

Anderson-Inman, Lynne, & Horney, Mark. (1996-1997). Computer-based concept mapping: Enhancing literacy with tools for visual thinking. *Journal of Adolescent & Adult Literacy, 40* (4), 302-306.

Berg, Gary A. (1999). Concept mapping in instructional delivery and assessment. *WebNet Journal, 1* (3), 5-6.

Boettcher, Judith (1999). What does knowledge look like and how may we help it grow? *Syllabus, 13* (2), 64-65.

Buzan, Tony (1993). *The mind map book: Radiant thinking—the major evolution in human thought.* BBC Publications.

Ferry, Brian, Hedberg, John, & Harper, Barry. (Retrieved Nov. 6, 1999). How do pre-service teachers use concept maps to organize their curriculum content knowledge? Conference presentation, ASCILITE, December 1997. Available:
http://www.curtin.edu.au/conference/ascilite97/papers/Ferry/Ferry.html

Grasha, Anthony F. (1996). *Teaching with style.* Pittsburgh: Alliance Publishers.

Jonassen, David H., Beissner, Katherine, & Yacci, Michael (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge.* Lawrence Hillsdale, NJ: Erlbaum Publishers.

Jonassen, David H.; Reeves, Thomas C.; Hong, Namsoo; Harvey, Douglas; & Peters, Karen (1997). Concept mapping as cognitive learning and assessment tools. *Journal of Interactive Learning Research, 8* (3/4), 289-308.

Lincoln, Yvonna S, & Guba, Egon G. (1985). *Naturalistic inquiry.* Newbury Park, California: Sage Publications.

Maxwell, Joseph A. (1996). *Qualitative research design: An interactive approach.* Thousand Oaks, CA.: Sage Publications.

McAleese, Ray (1998). *Coming to know: the role of the concept map--mirror, assistant, master?* ERIC No.: ED429968.

Miles, Mathew B., & Huberman, A. Michael (1994). *Qualitative data analysis: An expanded sourcebook,* 2nd ed. London: Sage Publications.

Novak, Joseph D. (1998). *Learning, creating, and using knowledge: Concept Maps™ as facilitative tools in schools and corporations.* Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Novak, Joseph D. (1993). How do we learn our lesson?: Taking students through the process. *The Science Teacher, 60* (3), 50-55.

Novak, Joseph D. (Retrieved April 19, 2000). The theory underlying concept maps and how to construct them. Available: http://cmap.coginst.uwf.edu/info/printer.html

Patton, Michael Quinn (1990). *Qualitative Evaluation and Research Methods, 2nd Ed.* Newbury Park, CA: SAGE Publications.

Pfaffenberger, Bryan (1998). *Microcomputer applications in qualitative research.* Newbury Park, CA.: Sage Publications.

Plotnick, Eric (1997). *Concept mapping: A graphical system for understanding the relationship between concepts: An ERIC digest.* ERIC No.: ED407938.

Russel, Peter (Retrieved March 4, 2000). Mind maps. Available: http://www.peterussell.com/mindmap1.html

Shaw, Mildred L.G., & Gaines, Brian R. (Retrieved March 4, 2000). Comparing conceptual structures: Consensus, conflict, correspondence and contrast. Available: http://ksi.cpsc.ucalgary.ca/articles/KBS/COCO/

Spradley, James P. (1979). *The ethnographic interview.* New York: Holt, Rinehart, & Winston.

Trochim, William M.K. (Retrieved March 4, 2000). Concept mapping. Available: http://trochim.human.cornell.edu/kb/conmap.htm

Trochim, William M.K. (Retrieved March 4, 2000). An introduction to concept mapping for planning and evaluation. Cornell University. Available: http://trochim.human.cornell.edu/research/epp1/epp1.htm

Watters, Carolyn, & Wu, Zhou (1999). Interactive lateral maps: Using the web for collaborative analysis. *WebNet Journal, 1* (3).

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