CONCEPT MAPPING IN A MULTIMEDIA, WORLD WIDE WEB ENVIRONMENT

by

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B.Sc. (Comp. Sci.) Dalhousie University 1994

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
in the School
of
Computing Science

SIMON FRASER UNIVERSITY
April 1997

0-612-24216-1

Abstract

Traditional educational pedagogies focus primarily on the behaviorist's view of knowledge transfer from the instructor to the learner through the instructor's interpretation of meaning. However, research in education indicates that this method of teaching is not always the most effective one. Students often fail to understand the deeper meaning of concepts and relations using the behaviorist model.

Conversely, the constructivist view focuses on a student's own construction and interpretation of concepts and associated relationships. The constructivist approach requires individuals to organize and structure knowledge in their own manner which leads to "a more complete and coherent understanding" (Scardamalia and Bereiter [6]). This thesis focuses on one specific tool that supports the constructivist method of learning, known as *concept mapping*. The purpose of the concept map is to identify key concepts and the relationships between these concepts in an instructional setting under various levels of abstraction. The learner is encouraged to think reflectively about what they have studied using the concept map.

Concept maps are graphical representations created by learners which consist of polygons (to represent students' concepts and ideas) and labeled lines connected between polygons which represent relationships between concepts and ideas. We will refer to the polygons as "nodes" and the lines as "links". Traditionally, paper and pencil has been used to create concept maps but this method limits students to a flat representation of knowledge is also difficult to edit. A computer-based tool can allow easy modification of concept maps as well as providing high resolution graphics, Internet resources and multimedia to the user.

This thesis will describe the design and implementation of a computer-based concept mapping tool. A small study was conducted to evaluate the ease of user interaction and the effectiveness of the tool in assisting understanding.

Acknowledgements

I would like to thank the many people who made this thesis possible. I would like to stress that many people contributed to this thesis, and that many of their contributions were not scholastic.

First, I would like to thank Chris Groeneboer whose encouragement and diligent efforts were greatly appreciated. She initially hired me on the Virtual University team and it was her help and cheery attitude that kept me going. If everyone was as bright, considerate, strong willed and a great parent like Chris, we wouldn't have problems in society!

I would also like to thank both of my supervisors, Dr. Tom Calvert and Dr. David Fracchia. Both of you have provided enthusiasm and hard work to this thesis and it is appreciated. I would also like to thank the following grad students and professors for their encouragement and interest in my thesis: Sheelagh Carpendale, Dave Cowperthwaite, Andrew Walenstein, Osmar Zaiane, Lori Prodan, Keith Holmes, Lyn Bartram, John Dill and Michael Heinrichs.

However, there's a lot more to life than school, and if I didn't try to get a balance in my life, I would have given up on this thesis a long time ago. First, I'd like to thank my family for their support. Mom, Dad and Ken, thanks for your help!

I would also like to thank others who have inspired me in other ways, although I have never met them. John Olerud, you have overcome a life threatening disease to play for the Toronto Blue Jays. Your strong will is admired by all. Edward Van Halen, you've inspired me to learn how to play guitar! You're the best there is...

I'd also like to thank my friends. Adam Wood-Gaines, I'd like to thank you for entertaining me with your silly puns and vicious games of NHL '95. Mat Wilson should also be thanked for keeping Hamilton Hall interesting. Remember, Darby rules! I'd also like to thank George Colwell for his sense of humour!

Moving to SFU revived my hockey career as well. And what a team we had, six championship teams in three different leagues. The Hot Pink Vipers finally pulled off the double victory when we won the 'A' league and Tuesday league in the same semester. Thanks to Walt Woo for putting the team together with me. Also thanks to my teammates, Keith Allan, Greg Bolli, Kris Erstad, Paul German, Eric Guevremont, Darren Hoem, Darren Kennedy, Malcolm Key, Dan Ko, Joji Kumagai, June Kumagai, Riyaz Maherali, Akbar Manji, Dan Medford, Tony Morabito, Joe Pelle, Chris Reid and Sukh Sumbal.

Finally, I'd like to thank my friends from Halifax, for teaching me that a big heart, character and passion make a great human being; not status, money or anything else. They definitely have more heart than anyone in the world.

Paul Gauthier, thanks for getting me interested in doing well academically and encouraging me to go to grad school. Troy MacDonald, thanks for your attentiveness and eagerness to talk at 4 in the morning. Kenny Conway, I'd like to thank you for the pita bread sandwich recipes! Jerry Wilson, your volunteer work in the Colby Village community is to be commended. You deserve those awards; many young women have had their lives turned around by you!

Matt Riis, you define dedication and perseverance. No one was more dedicated to his studies, and despite peer pressure at your school, you managed to steer clear of alcohol and drug abuse to finish your degree. Pat yourself on the back. Rabih Abdallah, thanks for getting me home safe all those nights...you're the only dependable and safe driver I know! Chris Nantes, we've really become good friends...and I can now better understand those whose alternative lifestyles lead to a great deal of prejudice. Keep on playing that guitar...I could listen to you play Randy Bachman songs all night long!

Finally, I'd like to thank the Andrews brothers, Brent and Sean. You'll never meet two kinder gentlemen. Brent, thanks for keeping me company in Vancouver....just stop being such a neat freak! Sean, I'll always remember how you sacrificed money from your last beer so that another elderly man could buy himself a hot dog. You are such a giving person, who is responsible, insightful, wise and, best of all, punctual!

Chapter 1

Introduction

1.1 Motivation

Many current educational pedagogies are based on transferring knowledge from the instructor to the learner. "Behaviorist transfer" is described as having "limited potential for advancing knowledge and is often not even very effective for purposes of memorization and organization of knowledge" [6]. In many cases the student simply regurgitates formulas or inputs information without getting a full understanding of what concepts are to be learned (e.g. simply plugging numbers into the equation $E = mc^2$ without understanding what impact this formula has on the way the world operates and how it was derived). Students are also devoid in creating their own interpretations of the material which is particularly crucial to those disciplines which require creative thought (i.e. what made *Sunday Afternoon on the Island of LaGrande Jatte* such a great piece of art?).

Recent educational research suggests that a new pedagogy known as "constructivist learning" ([6], [7]) can be more effective. In the constructivist approach individuals organize and structure knowledge in their own manner, building a foundation upon knowledge that they have already constructed. This knowledge building approach is described as "a process towards a more complete and coherent understanding" [6].

Constructivism avoids much of the "copy-delete" regurgitation which occurs in behaviorist approaches [6] and requires the learners to move towards a deeper understanding of concepts and relationships. Constructivists work on building hierarchical models of learning (e.g. building knowledge based on previous knowledge).

This move towards constructivist learning can be applied to online learning as well as in the classroom. The Internet's ability to support education is becoming increasingly important as it can provide flexibility to students who have jobs, allow students from all around the world to take courses from any institution they wish, reduce crowding at the university, and take advantage of Internet online resources. As computers decrease in price and appear in more homes, they can provide a rich, multimedia environment which can support learning ([8], [9]). Many institutions are now providing educational courses online and through the Internet. Examples of such projects include Simon Fraser University's *Virtual U* project [10], University of Illinois' *Cyberprof* project [12], the City University in Seattle M.B.A. program, and the University of Phoenix business-related Master's program.

This thesis will focus on presenting a specific method for building and constructing knowledge, known as "concept mapping". These concept maps encourage a constructivist approach to learning by allowing students to build their own personalized knowledge structures.

1.1.1 What Is A Concept Map?

Concept maps are used to help students and educators see the underlying meanings and relationships between concepts [13]. The concept map appears as a graph-like structure, with nodes represented by polygons and lines joining them together. The nodes represent a central concept or idea, while the lines connecting the nodes represent a link or relationship between two concepts. Nodes are labelled by the concept they represent and the links are labelled according to the relationship between the two concepts they connect. Figure 1.1 displays a concept map for flashbulb memories.

Concept maps can be constructed differently depending on their purpose and the user's own interpretation or preference. Novak and Gowin [13] suggest that concept maps should be constructed by first selecting one subject or concept as the focal point of the concept map. This should be the most general or broadest concept of the entire map and be the root node in the hierarchy. Students can then identify other concepts relating to the key concept and draw them below the key concept. Other representations with different constraints for construction also exist, such as causal interaction maps and semantic maps [16]. The causal interaction map acts as a visual representation for problem solving and uses nodes to represent variables and links to represent input to variables. Causal interaction maps have been used to visualize equations. Semantic maps are used to visually categorize similar concepts and group them together using nodes to represent concepts and using links to

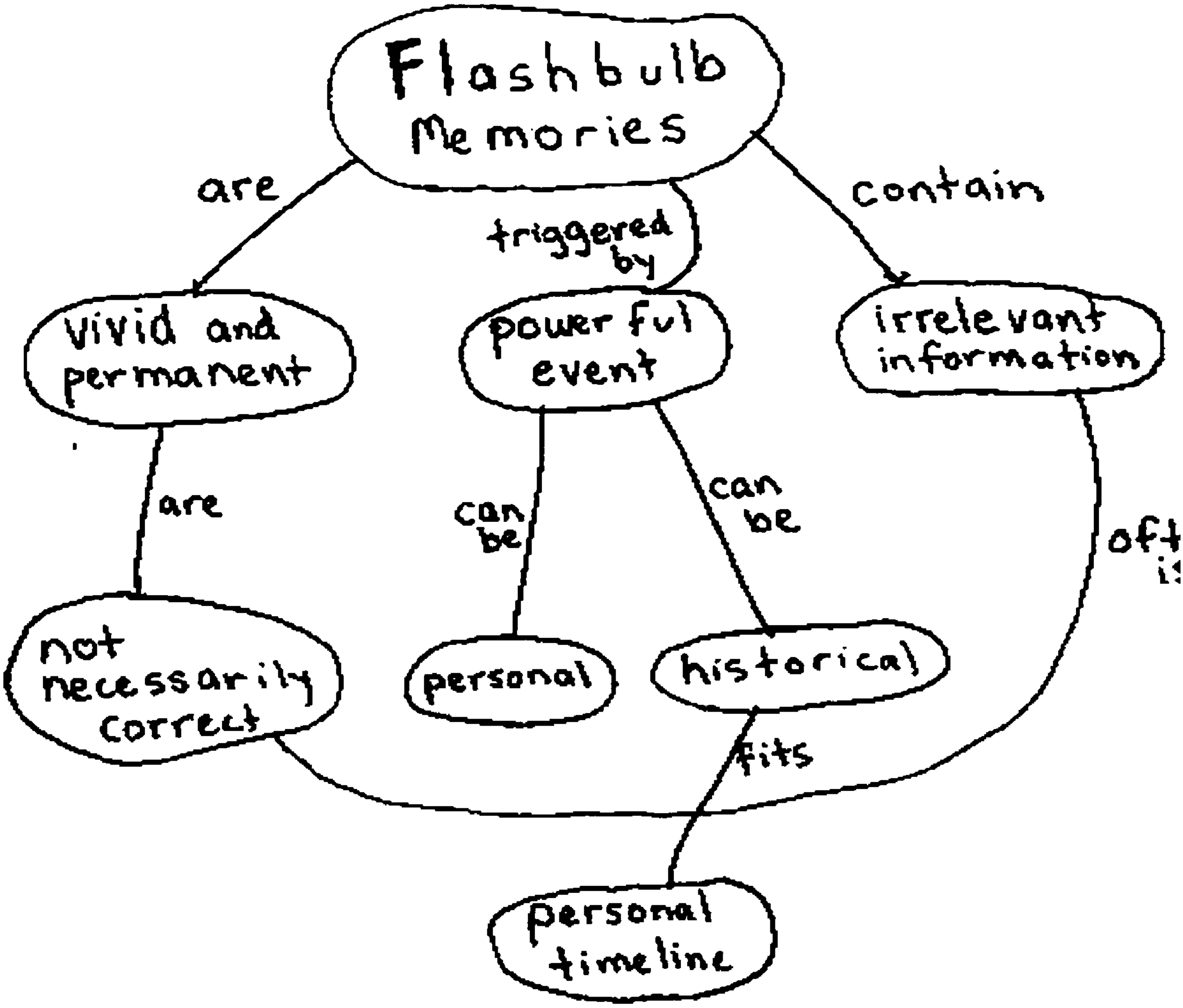


Figure 1.1: Concept map based on "flashbulb memories".

represent some relationship between nodes.

Concept maps have been studied and found to be useful for many applications in education. Novak and Gowin [13] found that they can be used as a method of evaluating students (e.g. draw a concept map to illustrate your knowledge of the moon's rotation), to plan a curriculum (Novak and Gowin used concept mapping to create a course for U.S. Environmental Protection Agency) and to help to extract meaning from textbooks and news articles (e.g. after each chapter in a textbook the class constructs a concept map to create a clear and concise notion of the main ideas of the material they just read).

1.2 Using Computers To Create Concept Maps

One of the main problems with traditional concept maps is the difficulty in modifying and editing them. It often takes several rewrites to lay out the concept map properly. This requires a great deal of time and can be frustrating to the user. Using the capabilities of a computer, it becomes much easier and faster to delete, modify and edit nodes and relationships through simple drawing facilities.

The computer provides a rich, multimedia environment for learning. For instance, let us consider students who are developing a concept map for a group project on different countries in the world. If students wished to mark all countries with its respective flag, as well as providing an audio clip of the national anthem, they would require computer assistance. This would be impossible using only paper and pencil techniques. This can be particularly useful in arts classes, which rely more on audio and imagery rather than text.

The computer can also allow users to colour and shape their concepts and relationships. Colour and shape can be used to provide grouping and classification of objects. For example, we could specify that all relationships between objects which are of type "is an example of" are red. Since it takes little cognitive time to process colour, the user can quickly identify these relationships. The customization of object representation also allows the user to represent objects in a personal manner.

In some respects the computer acts as a graph editor in that it will create nodes and relationships within nodes and draw the representation, but is tailored to provide the user with operations specific to concept maps. For instance, we can extend the idea of a "node" from that of a simple object, to one which can act as a resource for the World Wide Web and hold multimedia information. Concept maps can also allow nodes to contain other concept maps within them, thus allowing for hierarchical concept maps. For example, if a "beaver" concept map was initially created, it could then be imported inside a "rodent" node as an instance of a rodent. The paper and pencil model cannot support hierarchy among different maps without using a piece of paper large enough to support all nodes within the hierarchy and a great deal of time consuming editing.

Concept maps also differ from graphs. The links connecting nodes in concept maps can contain multimedia and textual data to help define what the relationship is between two nodes.

This thesis will also discuss user interface issues, although the user interface is not the primary concern of the research. For the students to take advantage of the richer environment, they will have to learn how to construct the concept map using computer facilitated drawing facilities (not just pencil and paper drawing). In addition, they will have to learn how to use Netscape and understand how URLs work to access World Wide Web materials.

This thesis will not cover problems which stem from lack of screen space as concept maps grow large. This "screen real estate" problem is currently being studied by other researchers ([14], [27], [15]).

1.2.1 Extending the Concept Map to the Internet

There are many reasons to implement the concept mapping tool on the World Wide Web. The first is increased accessibility: students can access the web regardless of platform type from their home. Using Sun Microsystems' new Java^{TM} [1] language, we simply require that users have a modem and a Java^{TM} enabled browser (which is available freely to the public and is available on many platforms).

Another advantage is that the students would have access to resources on the World Wide Web. This allows the student to relate Internet pages to concepts and relationships in their concept map. The World Wide Web provides a wealth of information with text and multimedia for students, resulting in a richer, multimedia environment for displaying and retaining information.

Allowing the concept mapping tool to be run over the Internet will also allow students to share their concept maps with others. For example, if Student A develops a concept map

[1] Java copyrighted by Sun Microsystems

on whales he/she can simply send the concept map to Student B. It is much easier to share resources over the Internet than it is to share books! It should also be noted that Student A and Student B need not be in the same city, nor the same learning institute, to share their concept maps.

The tool described in this thesis allows learners to take advantage of the World Wide Web by allowing direct integration of Web resources into concept maps. Images from the World Wide Web are displayable either as content within a node, or as the node itself. Audio files are also playable and World Wide Web pages directly referenced.

1.3 User Studies

Once a research prototype has been built, subjects will be selected to use the concept mapping system. These subjects will be introduced to the basic ideas of concept mapping and then trained using the computerized system.

Upon understanding the use of the system, subjects will be asked to build a concept map based on a specific topic. When subjects have completed the concept map, they will be asked to complete a brief questionnaire. Evaluation of the system, as well as suggestions for future enhancements, will be obtained by observing the concept maps that subjects build and by analyzing the data from the questionnaires.

The studies will determine the usability of the system and address how the computer interface aids in the creation of concept maps. The studies will show different methods and models that students use to represent their knowledge. Students suggestions from the questionnaire will suggest how to improve the system in the future.

1.4 Thesis Focus

This thesis will describe the design and implementation of a computer-based tool to construct concept maps. This tool will allow easy creation and manipulation of concept map nodes and relationships. It will also allow nodes and links to contain textual and multimedia information. Links will also contain textual and multimedia data as well as definitions of the relationships between nodes. User studies will be conducted to analyze the features provided, to analyze the different models and approaches students have for building concept maps, and to obtain user feedback for future modifications.

Chapter 2

Literature Review

Designing a computer-based concept mapping tool requires research in several different fields. First, one must discuss the learning theories on which concept mapping is based; this draws heavily on education research. Secondly, one must look at research involving pencil and paper concept maps. Once this is complete, it is necessary to examine the translation from pencil and paper concept mapping to a computer interface and look at earlier attempts at providing such a tool.

2.1 Constructivism: The Basis of Concept Mapping

The move towards a new educational pedagogy which features group discussion and places a greater onus on students to interpret and organize material in whatever way they wish is based on the "constructivist" view. The instructor's role is no longer to fully structure lessons and "teach" the material to the students, but to support the students in obtaining resources and attempt experiments so that they construct and interpret knowledge in their own manner. In order to justify the usefulness of the concept mapping tool, it is necessary to address the question of why constructivism is needed and how it plays a significant role in education.

The behaviorist approach is based on the belief that a bridge can be created between the students and the instructor and that learning is created by sending information across the bridge (with appropriate feedback from the student). The performance of the student gauges how well the bridge has been built. One example might be the reading of a textbook, in which the author tries to provide examples, pictures and text to help the student understand a specific concept or idea. If the student cannot connect to the bridge that the author is attempting to build, or crosses the wrong bridge (i.e. misinterprets the author's intent), then the student and author ultimately fail. This type of learning is what takes place in most educational institutions.

The premise of a constructivist approach is that individuals organize and structure knowledge in their own manner. In the following scenario, the student decides how he or she wants to learn material and the instructor's job is to guide and support the student rather than to create and define the structure and scope of the knowledge.

An hypothetical example of constructivism in a classroom is given below:

Instructor:	(demonstrates the compression of a plastic pop bottle by sucking on the open e
Instructor:	Can anyone tell me what happened here?
Adam:	The bottle is smaller!
Instructor:	Why?
Adam:	Because you sucked on it.
Instructor:	So what?
Lance:	The bottle was empty wasn't it?
Tim:	It was clear, but there was probably air or something inside.
Adam:	So what happened?
Dave:	The air went into the teachers lungs, because he sucked on it.
Instructor:	But what if the air disappeared? Why did the bottle crinkle?
Lance:	The bottle crinkled because there's air on the outside.
	The change in the air pressure causes the bottle to implode.

Here one can see the type of interchange that may occur during a constructivist lesson; the instructor allows the students to determine what happened. Although this is a rather simple example, the level of understanding is much greater than if the students had been merely told what happened.

In order to learn new concepts, students must integrate them with previous knowledge to create new knowledge. Often one item must be learned before another can be understood. For example, a student will have to learn how to add, multiply and divide before calculating the cost per square inch of real estate. This requires the learner to master the fundamentals of addition, multiplication and division and then use a constructivist approach to apply those fundamentals to calculate the value of the real estate. It should be noted that this hierarchical method of learning can be integrated into concept mapping.

In "Constructing Scientific Knowledge in the Classroom", Driver, et. al [7] discuss how these basic fundamentals must often be combined with a behaviorist approach before new ideas are spawned through constructivist methods.

> "Scientific entities and ideas, which are constructed, validated and communicated through the cultural institutions of science, are unlikely to be developed by individuals through their own empirical enquiry; learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level. The role of the science educator is to mediate scientific knowledge for learners, to help them to make personal sense of the ways in which knowledge claims are generated and validated, rather than to organize individual sense-making about the natural world."

Constructivism considers each learner's representation of knowledge to be unique. The representation of knowledge is affected by a person's unique perspective of the world based on individual experiences. Thus learning is contextual, cultural and subjective. The goal of the concept mapping tool is to encourage a constructivist learning atmosphere by allowing an individual or group to organize and construct a representation of his/her/their knowledge space.

2.2 Examples of Constructivist Learning

Constructivist learning is used to educate students in many classrooms. Many institutions have also placed constructivist activities on the World Wide Web. Several of these examples are presented below.

2.2.1 Calculus, Concepts, Computers and Cooperative Learning

The C4L program at Purdue University was based on constructivist theoretical perspectives related to the learning of mathematics. The program defines the key aspect of its approach as a "decomposition of each mathematical concept into developmental steps.....based on observation of, and interviews with, students as they attempt to learn a concept" [11].

C4L uses computer-based learning activities to teach students math. These activities are carefully selected so that a mental construction of concepts is created. Exercises are only given to reinforce the activities and not as the standard constructivist method of transferring the knowledge to the student.

2.2.2 The Exploratorium

The Exploratorium [17] is an Internet site which uses constructivist methods to teach science to students. Unlike many of the web sites which exist, the Exploratorium creates an environment for learning which is based on students running their own experiments and building their own knowledge rather than being spoonfed canned textual material.

One example is an interactive program which simulates the dissection of a cow's eye ("Cow's Eye Primer"). Hints and tips are given, but it is ultimately the student who experiences and controls the experiment through a computer interface. The student can download the program for his/her Windows or Macintosh machine.

The Exploratorium also has exhibits which integrate multimedia into learning. An exhibit of the devastation in Nagasaki is featured. Using artistic imagery, the users are led through a historical journey, with commentary provided by people around the globe. Unfortunately, this exhibit suffers from limited user interaction, and could support a more constructivist approach by adding a conferencing session which allows students to exchange their ideas dynamically.

2.2.3 N.J.N.I.E.

N.J.N.I.E. (New Jersey Networking Infrastructure In Education) [18] is an Internet-based site which presents constructivist learning approaches and lessons through interactive models. Like the Exploratorium, N.J.N.I.E. presents several lessons in science based on real world models, and encourages the user to take lessons at his/her own speed. Interactive lessons using multimedia are offered, where possible.

One sample lesson focuses on statistical analysis based on ocean data. Mathematical concepts are presented to students using these real world examples. The students are taught how to find the slope of a line in a graph and are given multiple methods of learning (verbal cues, images, and mathematical formulas). Examples are then given based on verbal and math descriptions of calculations. This site is particularly interesting because it provides multiple methods of learning (verbal, images, etc) and allows the student to select the one he/she is most comfortable with. Unfortunately, concept maps (or similar representations) are not given.

2.3 Mental Models and Knowledge Representation

Constructivist learning requires the student to create, shape and structure his/her own learning space. The concept mapping tool will have to allow and support such mental models in order to be effective.

David Jonassen [19] has examined the different mental models of learners. Jonassen attempted to distinguish mental models in individuals by studying a group of refrigeration technicians. Each subject was given a troubleshooting task and then asked questions designed to extract the type of mental models each subject was using. Jonassen's study concluded that knowledge in the mental models differ within each individual. This study demonstrates the need to provide flexible concept mapping for a learner's specific mental model and further demonstrates the necessity of constructivist learning.

Additionally, there is evidence that mental models have spatial representation. Shepard and Metzler (1971) ran experiments using images of 3-D objects. Subjects were presented a pair of 3-D objects and tried to determine whether the objects were identical but with a differing rotation, or whether the objects were different. The experiment found that the greater the rotation between objects, the longer it took the subjects to discern whether they were the same object or not. The conclusion was that the subject's conceptually rotate the object in their mind.

Another study which supports the theory that mental models have spatial representation comes from Roland and Friberg (1988). Their research measured blood flow in the brain when subjects were mentally rehearsing a jingle and when memorizing directions to someone's house. These processes seemed to stimulate distinctly different flows within the brain, which is evidence that linear and spatial representations are different. Farah, Hammoind, Levine and Calvanio (1988) performed tests on someone who had suffered bilateral temporal damage. The subject performed several tests using spatial assessments and image recollection and found that the two performances differed greatly. It is possible that the spatial portion of the brain was damaged, and could explain the subject's poor performance in that area. This is further evidence that the brain does have separate processing for spatial operations.

This evidence for spatial representation of knowledge within the brain is important to concept mapping. If knowledge is stored internally with some notion of space, it may be useful to view it externally in a spatial representation. Concept maps provide external graphical representation of knowledge within a space.

Many researchers consider mental models to contain hierarchies (which concept maps can support). Biederman (1987) proposed three stages in object recognition:

- object is first segmented into subobjects
- each subobject is classified into one of 36 basic categories called geons (3-d geometric icons)
- the object is then identified based on its relationship between geons

Biederman's justification was based on Biederman, Beiring, Ju and Blickie's (1985) experiment where objects were shown in two forms:

- component deletion: one geon was deleted
- midsegment deletion: complete figure is drawn, but in dotted lines

When subjects were briefly shown (65-100 ms) the two configurations, the component deletion form was easier to distinguish. At longer time segments (200 ms), the midsegment deletion form was easier to distinguish. Biederman argued that for short periods, the subject failed to segment objects into subcomponents, but at longer intervals, the object could be segmented into subobjects and the remainder of the object could be distinguished. This hierarchical representation of knowledge lends itself well to concept mapping, since concept mapping can be hierarchical in design, and the learner can, and is encouraged, to construct his/her knowledge in that manner.

Research also shows that objects which are similar in shape tend to be grouped together. This can be incorporated into concept mapping by allowing similar shapes to represent similar objects. Treisman and Gelade (1980) conducted an experiment creating a "forest" of randomly placed Y and Ts. The subjects were asked to find the single T in a forest. The same experiment was then attempted with a forest of Z and Ts and it was shown that subjects did significantly poorer. Because the Z had more similarity to the T than the Y, the subjects had to do more processing to distinguish the two objects. The processing time to distinguish the two "more similar" objects was increased.

2.3.1 Other Methods of Knowledge Representation

Other forms of knowledge representation, other than concept maps, have been researched. These use graphical representations similar to concept maps, but adhere to more rigid rules and apply to a very specific task. Although the main purpose of the concept mapping tool is to specifically create concept maps, the user may choose to impose rules on the structure. Two other methods of knowledge representation which are similar to concept mapping are discussed - causal interaction maps and semantic maps.

Causal Interaction Maps

The causal interaction map is geared towards problem solving using a graphical representation similar to concept maps. The map mimics simplified mathematical functions. Nodes are used to represent variables, and links are used to represent the input and output of variables. Each node is a function which takes in input and outputs a value based on the computation within the node.

Nodes are represented graphically as circles or squares. Circles represent some value used to solve a problem which cannot be quantitatively defined (e.g. class participation), while squares represent a value which can be quantitatively defined (e.g. number of correct answers in test 3). Students examine different variables which affect a certain result. Typically, this is done in several iterations as the student's understanding of the problem grows.

While concept maps and causal interaction maps are quite similar, they do have significant differences. The relationships between nodes in causal interaction maps are not labelled, and have only one relationship type. Causal interaction maps also specify that nodes must only be circular or square. Thus the causal interaction map is a subset of concept maps.

The sample causal interaction map (figures 2.1 and 2.2) displays a function to determine whether or not a particular person should be hired. The two main criteria for employment are the applicant's skills and character. The company will evaluate these criteria based on job experiences, references, etc.

The causal interaction map remains a simplified view of relationships between concepts

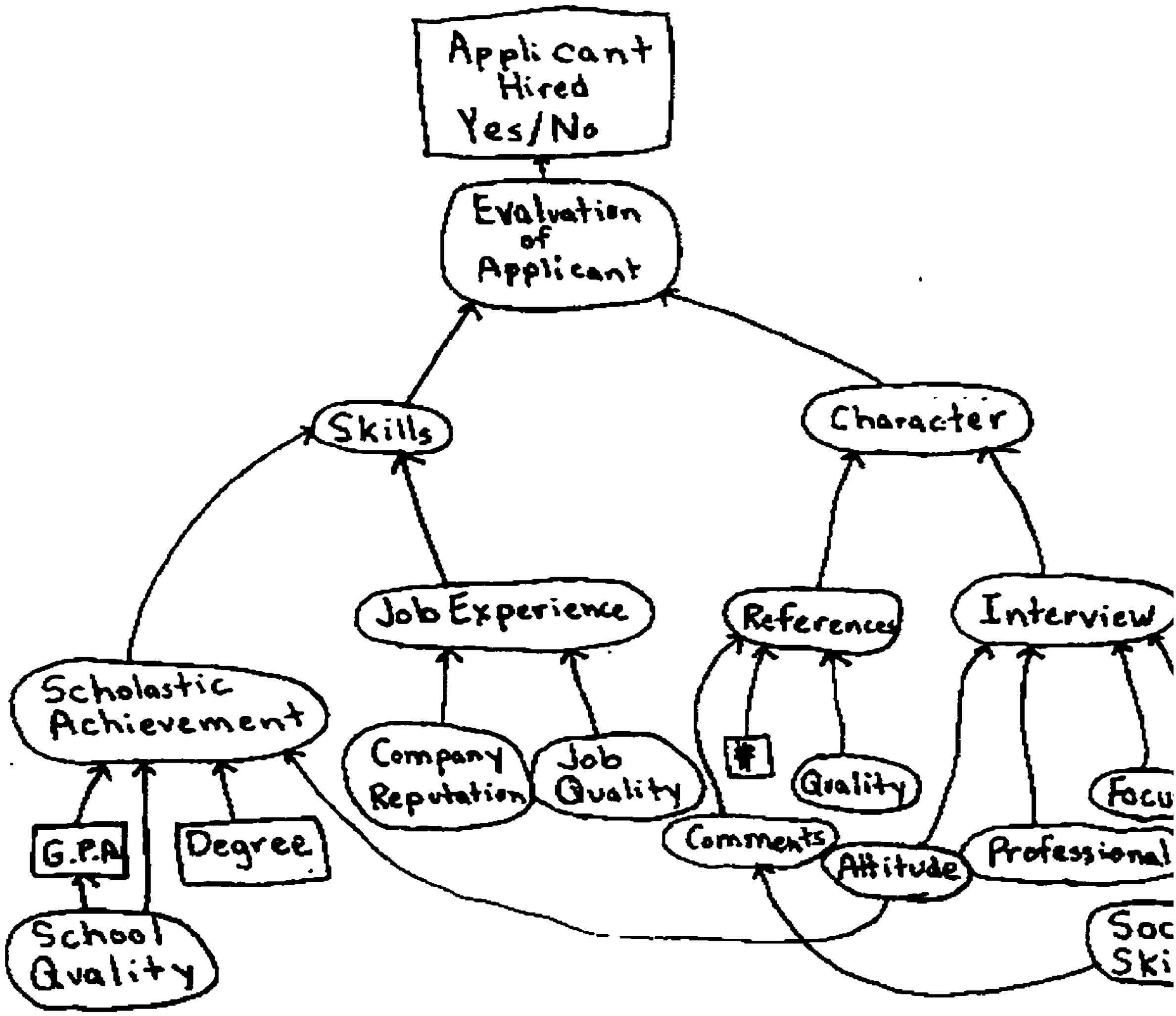


Figure 2.1: An example of a causal interaction map after the first iteration.

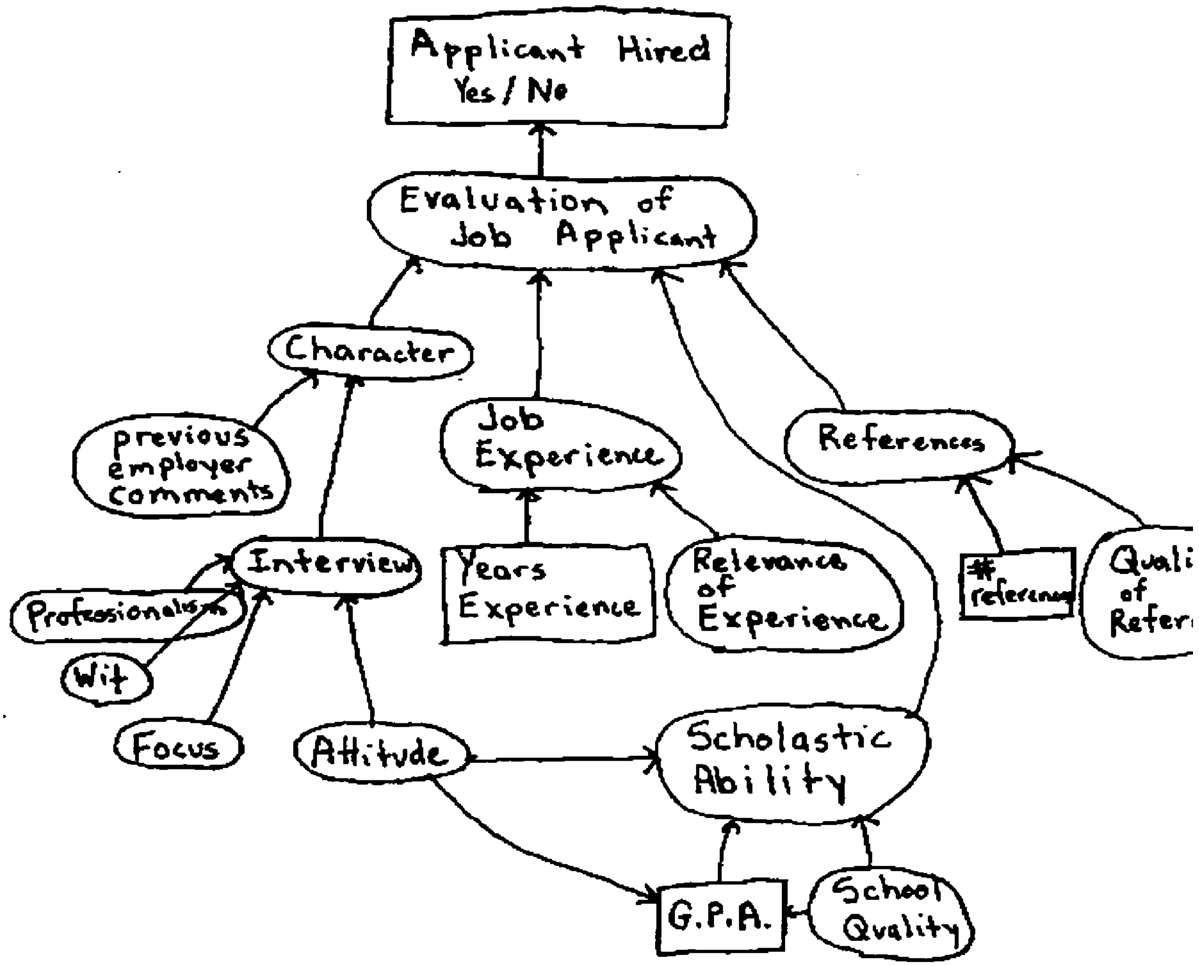


Figure 2.2: This is the finished causal interaction map used to determine the qualifications of a job interviewee.

because it cannot show the different effects of each input variable. Its simplicity and ability to quickly show multiple variables and interactions makes it useful for identifying causal relationships.

Semantic Maps

Semantic maps are another method of knowledge representation designed to build a learner's vocabulary. After a student reads a passage, a semantic map is built to organize and categorize the new vocabulary.

To create a semantic maps, the learner first selects a "key concept". This is represented by writing the concept in the *centre* of the semantic map. Related words are then identified, brainstormed, and categorized. The categories are linked (in a circular fashion) around the key concept and the related words are then placed underneath the categories to which they belong. The structure of the semantic map is fixed; it appears as a ring-shaped topology.

The example shown in figure 2.3 uses the central concept "guitars". This is typically known as a "cluster". Key vocabulary words and headings for each categorization are "Types", "Manufacturers", etc.

Research has shown that semantic maps were significantly more effective in providing vocabulary acquisition than standard techniques (Jones, 1985). In particular, poor learners showed dramatic levels of improvement when using semantic maps (Pittelman, Levin and Johnson 1985). A semantic map is a specialized form of a concept map, with additional rules of structure and a specific application.

2.3.2 Conceptual Graphs

Conceptual graphs are the language which was built from John Sowa's initial work on conceptual structures [30]. Conceptual graphs are quite different from concept maps because they focus on using logic to extract information from a fixed knowledge representation. They are built to provide "strength and flexibility by translating the theoretical formalism into practical applications in different domains" [32]. However, like concept maps, they use nodes to represent concepts and lines to represent relationships between nodes. In between connected nodes are additional nodes, known as "relationship nodes", which help describe relationship types. The graphical representation of conceptual graphs is only used to illustrate the underlying data structure.

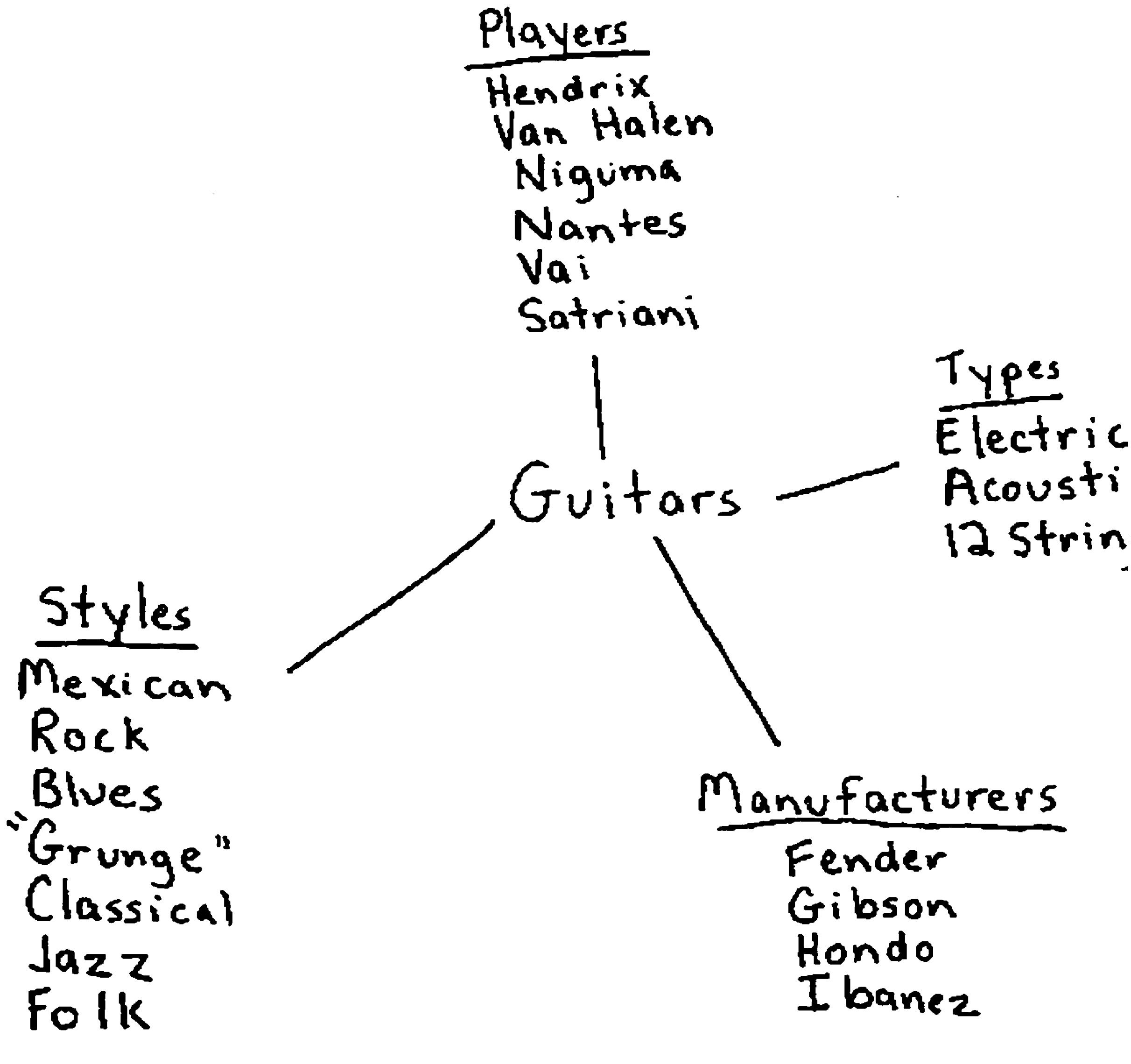


Figure 2.3: This is a sample semantic map based on the key concept *guitars*

Unlike concept maps, conceptual graphs do not focus on the visual aspects of representations. While conceptual graphs are similar to concept maps in that they both try to represent knowledge, the conceptual graph's purpose is quite different since it is a data structure for handling contextual information retrieval. This requires that the conceptual graph have a strongly defined structure (relationship nodes have specific types, it must be a connected graph, etc.) and cannot handle information such as images, sound and colour easily. The purpose of a concept map is to provide a representation which is easily created and understood by the user using visual images, while the conceptual graph's purpose is to provide a representation which can support artificial intelligence applications such as deduction, abduction and inferencing.

Conceptual graphs may be useful for instructors to evaluate learners' concept maps. If a concept map could easily be converted into a conceptual graph, instructors could query the conceptual graph to see what information the student had built. However, the mapping between concept maps and conceptual graphs would require the student to built a rigidly defined concept map which conforms to conceptual graph rules or to automatically convert all natural language, images, sounds into a conceptual graph representation. The former is too demanding on the student while the latter poses a difficult problem.

2.4 Research On Concept Mapping

Now that the need for concept maps has been identified, we can examine work specifically related to them. Concept maps have been studied extensively in classrooms using paper and pencil models. Novak and Gowin [13], in particular, have done numerous studies on the effects and uses of concept mapping within a classroom. This research provides the key fundamentals for creating a concept mapping tool for a computer.

2.4.1 The Purpose of Concept Mapping

The primary goal of concept mapping is to help students and educators build and reflect upon knowledge in a constructivist learning environment by identifying key concepts and the relationships between them. The concept map avoids what David Ausebel refers to as "rote learning" (information memorization and regurgitation) and instead encourages "meaningful learning" through constructivist learning theories.

An initial view of the world is built by experimenting and interacting with the real world (e.g. interpreting voices, depth perception). Once this foundation is built, speech, reading and writing can be mastered. This hierarchical manner of learning (having prerequisites necessary to continue learning) requires building on other knowledge and proceeds most efficiently when notions are placed under broad ideas. Concept mapping facilitates this by using graphical representation.

Concept maps also encourage users to find new relationships between concepts and take advantage of the human ability to process symbols quickly by grouping together like objects. They stimulate reflective thinking by having the user carefully examine relationships between concepts.

2.4.2 Guidelines for Building Concept Maps

Novak and Gowin (1984) present several guidelines on how to build concept maps. The initial step is to define either a key concept which is the most abstract item of the concept map, or to define several concepts and relationships which will be the basis of the concept map (this decision may be based on what the user is trying to accomplish).

The broadest/main concept is placed at the very top level of the concept map. Novak and Gowin state that concept maps should be hierarchical and that the node at the top of the concept map represents the central and general concept. There is usually only one node at the top and we will refer to this as the "key concept". Nodes are represented by some user defined geometrical shape and labelled.

Additional nodes and links are added when a relationship is thought to exist between the current concept(s) and another new concept. For instance, if the key concept is "mammal" and the user remembers that "mammals are warm blooded", a node is created at the level just below mammals and labelled "warm blooded". The "mammals" node and the "warm blooded" node are then connected using a line labelled "are". Concepts which have the same level of abstraction are placed on the same vertical location on the page, making the concept map similar to a tree. Novak and Gowin suggest that lines connecting nodes not be directional, as it adds clutter, and that direction is implied by the hierarchical nature of the concept map.

The concept map should not extend beyond six to eight levels of abstraction. This is partly to reduce the clutter and limited size of paper, but more importantly to limit the scope of the concept map. If the number of levels get too large, the learners may have problems organizing the material. Psychologists believe that the mind cannot handle information "chunks" greater than this number.

It should be noted that Novak and Gowin present these only as guidelines for building effective concept maps. The tool we wish to design will not enforce these structures on the user and will allow alternative structures to be constructed. This will allow greater flexibility to users.

2.4.3 Uses For Concept Maps

Novak and Gowin have studied various applications of concept maps. One application is evaluating a student's knowledge on a subject (e.g. as a test question, ask the student to draw a concept map of "arachnids"). This type of evaluation reduces rote learning and also displays possible misinterpretations of concepts by identifying incorrect links. Thus, student errors will be quickly found and the instructor can assist the student. A numerical evaluation was also devised based on Ausebel's learning theories. This evaluation credited students when correct relationships and concepts were identified.

Concept maps are also useful for reviewing previously read text or magazine articles. Novak and Gowin have used group brainstorming sessions to build concept maps on information they had read or studied. These sessions reduced the amount of student misinterpretation. This helps to prevent students from continuing with any misconceptions they may have had about previously covered material. Novak and Gowin also suggest posting these concept maps around the classroom as a constant reference.

Concept maps have also been used by teachers as a means of planning a curriculum or specific lesson. For curriculums it is suggested that broad concept maps are created for an overview of the course and more detailed concept maps are used to describe what lessons will be given on a specific day. Novak and Gowin created a curriculum using concept maps for the U.S. Environmental Protection Agency and Army Corps of Engineers.

Another application for concept maps in education is to guide interviews. Interviews have been used by Piaget as a means of evaluating students, and Novak and Gowin have applied concept maps to provide organized paths for instructors to follow to question students. Concept maps have also been used for interviewing experts to acquire knowledge (McNeese, Zaff, Peio, Snyder, Duncan and McFarren 1990).

Another instance of concept maps is in management systems and decision making ([21], [22]). Arguments have been construed using concept maps, such as in the Graphical Argumentation Scheme [23]. It is believed that visualizing the structure of arguments can provide insight into strengths and weaknesses and allow for more rigorous construction. A specific scheme similar to concept mapping called *QOC* (Questions, Options and Citeria) is presented where nodes are represented either as questions, options or criteria and links are relations between the nodes, which may be directional. The end result was that the QOC was quite effective particularly in clarifying poorly understood design spaces.

Concept maps have also been used in policy studies and philosophy of science as a visual representation of arguments. Other fields such as mechanical engineering (bond graphs), communications (Petri nets) and mathematics (category graphs) use representations similar to concept maps.

2.5 Extending Concept Mapping To The Computer

While Novak and Gowin (1984) have studied concept mapping in depth, they have only studied it using the traditional paper and pencil approach. Moving towards a computer-based, multimedia environment requires careful consideration of how the computer can improve upon the paper and pencil models.

The increased growth of the Internet as a source of information and the capabilities of home computers to present multimedia has prompted research in integrating learning with multimedia. Many researchers advocate using multimedia to increase the richness of a learners environment. We will examine the use of multimedia to aid learning.

We will also examine how to take advantage of the fact that computer based maps are not as constrained as paper and pencil models. Specifically, problems with large concept maps and hierarchical learning which exist in paper and pencil models are examined.

2.5.1 Adding Multimedia to Concept Maps

Strommen [20] stresses the need for a child to be "a self-governed creator of knowledge" and proposes a "child-driven learning environment" (*CDLE*) to promote constructivist learning. Strommen also believes that technology, such as computers and televisions, should be present in a CDLE along with traditional tools (e.g. pencils, paper). Computers, video and other technologies give children the facilities that they are accustomed to using in their everyday lives and provides them with an opportunity to use these facilities in new and different ways other than standard behaviorist methods. Allowing students to create concept maps which can integrate Internet and multimedia objects can act as one component of a CDLE environment.

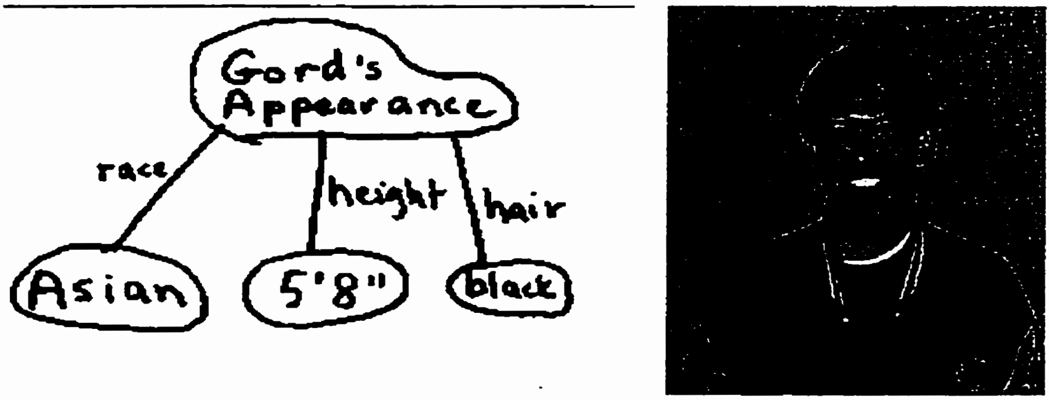
Lawrence Najjar's believed that if multimedia is rich, then people will "elaboratively process information" and make more connections between new concepts and prior knowledge, so multimedia should improve learning. Studies were conducting with subjects from K-12, university and industry. The experiment divided subjects into groups in which some were given multimedia content and others learned using conventional schemes. Generally, about a thirty-five percent reduction with learning time was found in those using multimedia. However, there is considerable question as to whether the multimedia was the reason for the reduced rate or whether the instructional method was the key. The multimedia was also shown to be more "grabbing" to the student and subjects showed a decrease in learning rates after eight weeks of using multimedia.

Multimedia has also been shown to be effective when the media presented is in a form compatible with what we perceive a learner's internal representation of knowledge to be (Kozma 1991). An example is the study in which maps were found superior for learning (using images as a media type) compared to a list (Bartram 1980). Text used in conjunction with pictures was found to help people learn assembly information (Bieger and Glock 1986). Nickerson (1968) stated that visual representations are good for recognition tasks.

The purpose of adding multimedia to the concept mapping tool is to allow the learner to structure information in a personalized way, and thus learn by using their own internal representations of objects. The traditional model of concept mapping cannot easily add multimedia and colour, which hinders the ability of users to personalize their maps.

In the example in figure 2.4 given for "Gord's Appearance", the learner has been forced to create a concept map, where an image would be far more appropriate. Clearly, the concept map is trying to do the job of an image; something you would not ordinarily ask a concept map to do. Allowing the concept map to hold images would solve this problem.

Concept maps are also inappropriate and less effective when dealing with direct information which does not necessarily represent concepts and relationships. In the example of the John Olerud concept map (figure 2.5), which was created from reading a paragraph of text, the information may be more effectively presented as a list or text depending on the user's interpretation of the material. Thus it may make more sense if this concept map is just presented in flat text as the attributes of John Olerud. It may be preferable to consider John Olerud as a single node with properties "hits poorly with runners in scoring position" and



(a) (b)

Figure 2.4: Converting an image into a concept map fails (left) while simply providing an image succeeds (right).

"may improve all aspects of hitting", instead of forcing a reorganization of the information.

2.5.2 Large Concept Maps and Hierarchy

Section 2.3 discussed how knowledge representation is thought to be hierarchical. Problem solving also appears to be hierarchical, with the top level being the actual problem itself and the lower levels of the hierarchies representing intermediate subgoals, which must be solved first (Anzai and Simon 1979, Eylon and Reif 1984). Catrambone [24] also found that learning subgoals helps determine which parts of a problem must be solved first. This hierarchical approach to problem solving and knowledge representation lends itself to creating hierarchical concept maps. The hierarchy can be based spatially within the concept map, or it can be represented by allowing certain concepts to contain different levels of abstraction. On the computer, each node representing a concept may contain another concept map, which has a different level of abstraction from the initial concept map.

When a learner is asked to design a concept map for an area in which they hold particular expertise, it can be very difficult to root through the relevant knowledge and create a concept map. To demonstrate this problem I selected subjects which were both broad and in which I have a good deal of knowledge. They were "guitar playing", "Gord Niguma" and "hockey" (shown in figures 2.6 (a), (b), and (c) respectively).

As can be seen from the examples, the concept maps did not grow because the user had no

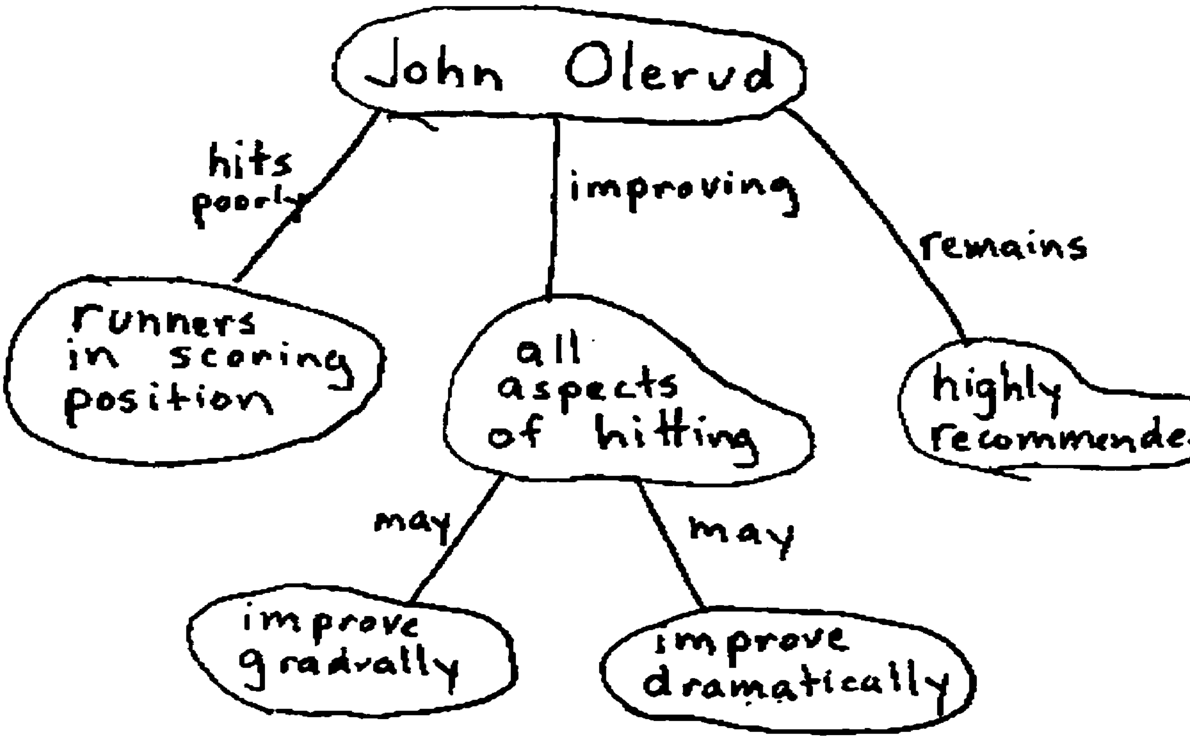
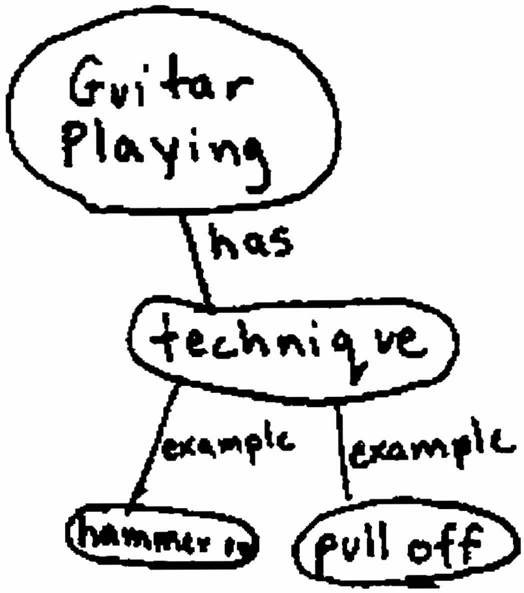


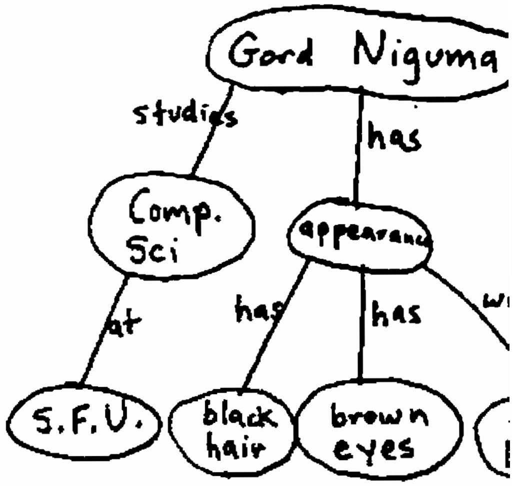
Figure 2.5: View of *John Olerud* through a concept map. A user may prefer to have this information given as a text list.

direction within the large domain. For instance, guitar playing can encompass many things, as can hockey. Hockey could include all of the rules I know about the game, international hockey events, strategies, as well as professional NHL information and players. Constructing these concept maps was frustrating because I realized that all of my knowledge could not be displayed on a single map of reasonable size. What is really necessary in this case is to create concept maps within concept maps. For instance, we could contain a concept map of "Simon Fraser University" in the "Simon Fraser University" node in the "Gord Niguma" concept map. It is suggested by Novak and Gowin that these concept maps remain separate identities and that one can refer back to a "Simon Fraser University" concept map when you encounter it within the "Gord Niguma" concept map. However, this requires finding the "Simon Fraser University" concept map.

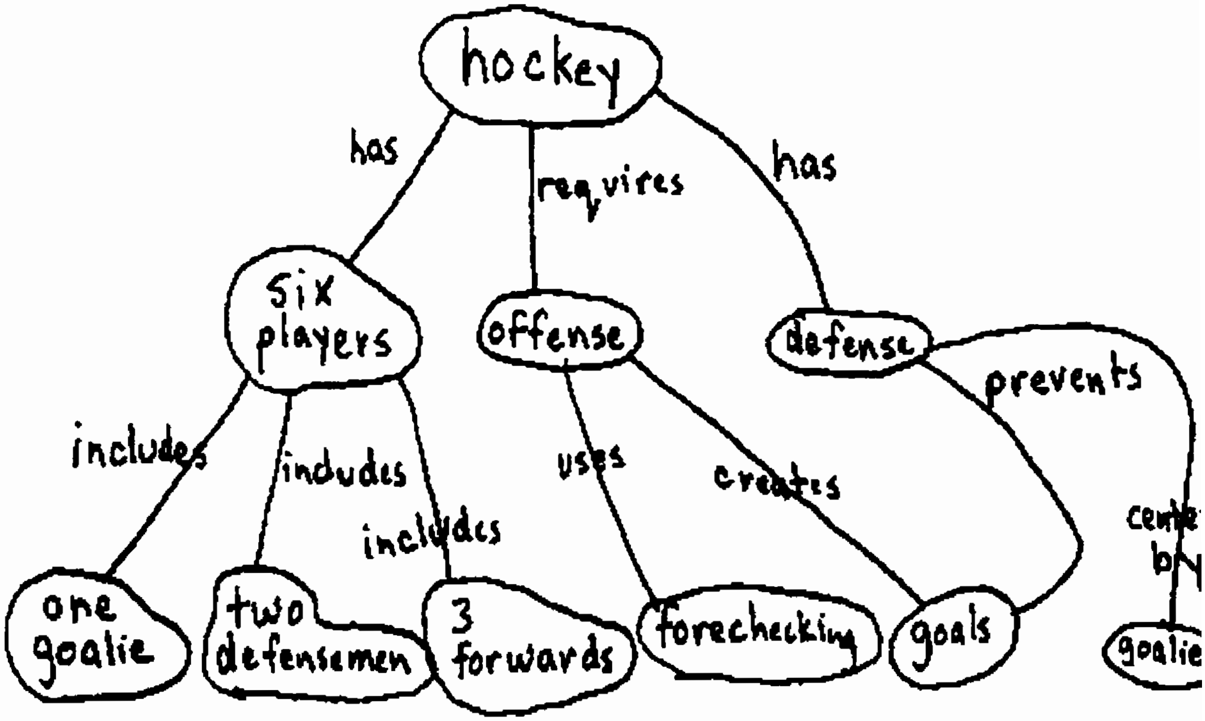
This idea of large concept maps can be dealt with by allowing each node to contain a concept map within itself which can be accessed simply by clicking on a button. This will



(a)



(b)



(c)

Figure 2.6: Concept maps which are not well presented because the domain is too large. Maps (a) and (b) remain incomplete while map (c) is not well done. Allowing us to contain concept maps within concepts in concept maps would be ideal.

save necessary screen space; you will only see a given concept map when it is requested. Furthermore, hierarchical concept maps provide an intuitive means of construction by beginning with broad concepts and adding more detail. Thus, they allow for varying degrees of abstraction.

2.6 Current Concept Mapping Tools

Currently several concept mapping tools exist for computers. They provide some solutions to concept mapping, but still are inadequate in other areas.

2.6.1 Concept Maps For Online Learning

An example of a class using online concept maps is Wayne State University [25]. The course (CSC 811), which teaches concept architecture as applied to software engineering at Wayne State University, provides a text-based presentation of a concept map online. The site simply shows an example of a concept map (built using ASCII characters with hyperlinks) used to outline software design. It is not meant to be an interactive system.

While this is a very simple example, it demonstrates how the interactive concept map editor could be useful in an educational setting. It also demonstrates the deficiencies of such a simple concept map; for example, its ASCII characters make it difficult to group any related nodes together in a cohesive manner, links cannot be labeled, no multimedia content can be stored and it is aesthetically unattractive. It should also be noted that the construction of the concept map would be quite a painful and cumbersome job for the instructor since no tools (other than a text editor) are provided.

2.6.2 Inspiration

Inspiration from Provantage is designed as a project organization tool which supports concept mapping. A gridded field and a 2-D display are used for building concepts. Objects can be of varying colours, sizes, and shapes and act as the "nodes". They can also contain textual information. Links can be used to represent relationships between objects and can be labelled by text and assigned a direction. Typical drawing facilities such as delete and move objects are supported. Groups are only used to move several "grouped" nodes through the concept map. Several templates are available for specific jobs such as "Goal setting" and "Project Planning".

While Inspiration is a useful tool for creating a concept map, it cannot integrate any Internet resources or multimedia for increased learning. Inspiration also lacks the ability to store information in a true hierarchical fashion, as discussed in section 2.3, and also does not allow links between objects to be defined by more than simply appearance and labelling.

2.6.3 WebMap

WebMap is a concept mapping tool for the World Wide Web based on the research of Gaines and Shaw [26]. WebMap was based upon the open architecture of KMap [26] and runs specifically on the Apple Macintosh platform. It allows different concept maps to be defined and loaded. Nodes can be added to WebMap with specific attributes such as types, head, body, colour etc. Links can also be added and may be assigned a direction.

Each node is also programmable so that user actions can communicate with other applications. The user must program in the OpenScript programming language for the Apple MacIntosh. This OpenScript architecture allows the user to program each node to perform a scripting action based on a user event.

KMap works as a client helper to Netscape by defining a MIME type with suffix ".kss" which starts WebMap running on the users local machine. KMap also allows the user to generate concept maps by browsing in Netscape. It creates new nodes when new URL's are visited from Netscape. This functionality is more for navigating the web than creating concept mapping. Similar tools include CZ Web [27].

KMap also can act as a clickable image map on the World Wide Web. A user can upload a concept map to a server and then use it as a clickable image map from the server. This acts as a solution for non-Mac users, as they can view the concept maps and navigate through the concept map, but it does not allow any editing or configuration.

While WebMap is useful, we wish to allow the concept mapping tool to run across all platforms. This flexibility cannot allow students to program the nodes to work with specific applications (if they have an Apple Macintosh computer), but the gain in being able to program nodes is minimal because of the added complexity in having to learn Apple OpenScript. This ability to program nodes only works on Apple machines. Furthermore, it becomes difficult to share concept maps since any user must be using a Macintosh computer and must have the same applications on his/her machine, if the concept map is using programmed nodes to access applications.

Our links also will contain content and defined types for describing relationships between objects, which WebMap does not allow. Since relationships are often used over and over again, templates can be stored in our version. We can also store multimedia data for quick retrieval of Web resources within nodes.

2.6.4 QuestMap

QuestMap [28] is collaboration software for representing the process of making decisions using a graphical map containing icons, text and links. Its purpose is to structure arguments for decision and brainstorming solutions, and, unlike the concept mapping tools, is not geared towards generalized learning.

QuestMap allows groups to modify and edit a minimalized concept map using a set of icons to represent nodes. Each icon takes on a specific meaning and acts as a template. For instance, a lightbulb icon is used as a node representing an idea. The icons are similar in concept to the nodes in the concept mapping tool and are linked together with coloured lines which represent connections between icons. These relationships are not labelled and are only distinguishable by colour.

The user begins by identifying a specific problem and creates a "question icon" (denoted by a ?). Ideas (represented by a lightbulb) are connected to questions using links and pro's and con's (represented as '+' 's and '-' 's) are connected using links to ideas. This is QuestMap's structure for decision making.

While QuestMap's application is more specific than the concept mapping tool that we present, its importance is as an applied version of a concept mapping device. It is limited compared to the concept mapping tool we propose because relationships cannot be labelled, templates (ie. node types) are fixed, structure is not flexible, it is platform specific and the Internet cannot be accessed. Its strength lies in easily used structure, ability to create groups through a network, and shared access to a document.

2.6.5 Open Meeting

Open Meeting [29] was designed as an asynchronous collaboration and conferencing system for Vice President Gore's "Open Meeting on National Performance Review". The goal of the system was to maintain an online meeting with over 4000 participants and allow them to build discussions and arguments through online discourse. Open Meeting provided an environment based on theories that identified the interactions needed for productive discussion and problem solving. It was run over the Internet so that many people could access the system from their home or office computers.

Open Meeting's primary purpose was as an online discussion forum. The National Performance Review (NPR) needed to discuss proposals for reinventing government operations. This required asynchronous methods of discussions for people located across the country.

Many of the repcrts to be reviewed had common structures, so the discussion was represented as concept maps. Each node represented one category or area of discussion, such as *Overview* or *Executive Summary*. Each area of discussion was connected by links to other relevant areas of discussion.

Open Meeting provided an effective environment for discussion and asynchronous conferencing. The use of concept maps was not the prime focus, but is included in this section as an example of using concept maps to enhance and aid in group collaboration and learning. Open Meeting had fixed structures but could be expanded to further to integrate dynamic concept maps to represent conferences.

Chapter 3

Concept Mapping Tool Design

When designing the concept mapping tool, it is necessary to to provide an easy to use computer interface and to extend functionality so that multimedia and Internet resources can be included. This section will discuss the concept mapping tools design and implementation.

The first design decision was to select the programming environment. Currently, the only programming language which allows rich interaction with the user, runs on multiple platforms and is accessible through the Internet, is the Sun Microsystems Java^{TM} language. While Java^{TM} does provide us with the functionality necessary, there are also some problems with the language. Since it can run on many different platforms, Java^{TM} uses the lowest common denominator available to all machines. For example, since the MacIntosh^{TM} computers have only one mouse button, all Java^{TM} user button-press and button-lift events can only come from one source button. This affects the user interface design. Another problem is that the Java^{TM} language is interpreted and not fully compiled, which makes the execution slow.

Even with these constraints, Java^{TM} provides us with the necessary tools to create concept maps. It provides support for audio (au files only at this point), and images (currently only gif format) as well as providing full colour graphics support and user interface tools.

3.1 Creating Concept Maps

The concept mapping tools interface design was based on commonly used tools such as Superpaint^{TM} and Photoshop^{TM} [1]. All of these tools provide the user with two main

[1] Photoshop and Superpaint copyright Adobe Systems Designers

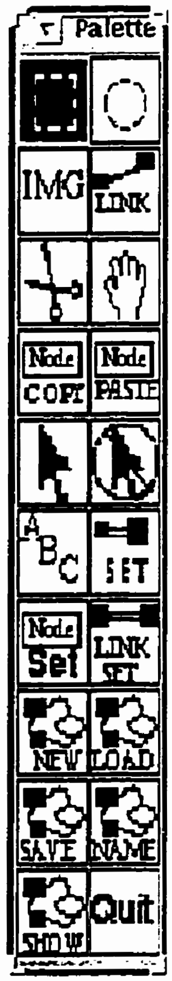


Figure 3.1: The palette frame is where the user selects which mode or tool is active.

window types to create objects:

- **Palette window**: The palette window is filled with graphical icons which change to a dark shade when selected. Here the user selects which tool or mode he/she wishes to use by clicking on an icon. Only one icon can be selected at a time (figure 3.1). The icons respresentations were based on similar operations on typical drawing platforms (e.g. both Superpaint^{TM} and concept mapping tool use a "hand" to represent a "move" operation).

- **Drawing window**: This is where all of the nodes and links are graphically drawn. It acts as the "paper" for the concept map (figure 3.2).

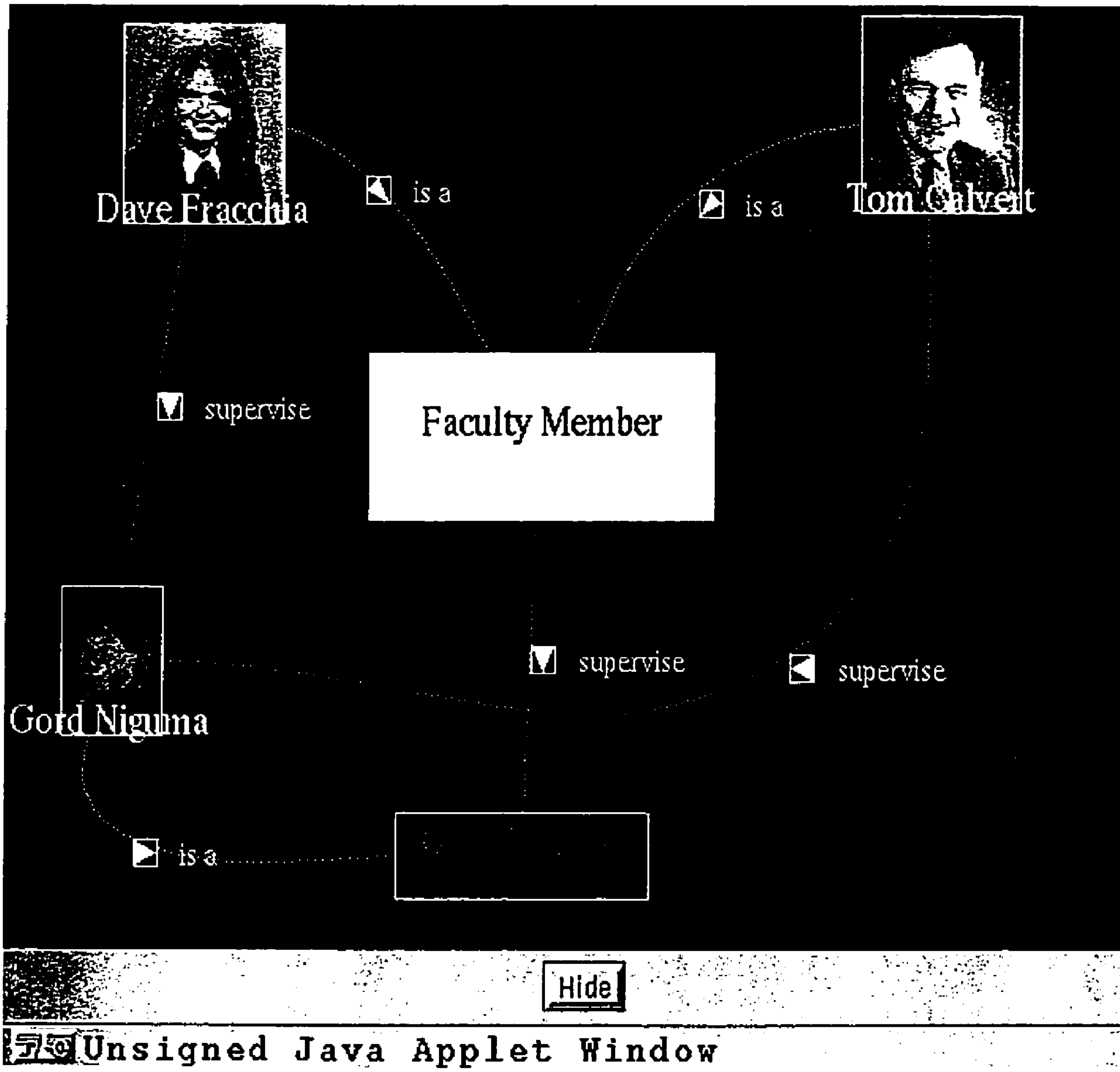


Figure 3.2: An example of a concept map. This window is known as the drawing window.

The drawing window is initialized to a black background so that it would contrast with the user's screen. The palette window is to control all user operations and the drawing window to handle all created objects.

3.1.1 Starting A Concept Map

Concept maps can be created, loaded and saved using the Palette window and each map can act as a separate entity. The user can click on the Palette Window button marked "New" to create a new concept map or on the button "Load" to load a concept map from a file. The user gives each new concept map a name, which acts as the concept map's ID. When a new concept map is created, it has no objects in it and is named "Unlabelled". When a new map is loaded, the previous names and objects appear. The user can save these concept maps, hide them or rename them, through the Palette Window. Multiple concept maps can be open and manipulated at the same time.

All files and information is loaded and stored through the remote server file system. Java^{TM} allows the execution of CGI scripts to run on the remote server. The concept mapping program uses Java^{TM} code to read and write to an input or output stream and Perl code is then executed to read and write from this stream to the local server [2]. Since Java^{TM} applets are currently not allowed to write to hard drives, this was the simplest way to implement the reading and writing of files.

3.1.2 Adding Graphical Objects to the Concept Map

The user can add graphical nodes or links to a concept map. Nodes can be represented either by a rectangle, ellipse or an image from the Internet (gif files only). Rectangles and ellipses were the only shapes allowed in the concept mapping tool because they were the simplest to draw, manipulate and determine if a mouse was clicked inside them. This reduces the amount of computation time, which will be important. Images were allowed to take advantage of gif files on the World Wide Web. In the future, the user should be allowed to created their own polygons.

To create a node, the user simply selects which type of object he/she wishes to draw by clicking on the appropriate icon in the Palette window. By clicking and holding on the appropriate display panel at the desired location, the user then drags the mouse to control

[2] When this program was written, it was advised that using a CGI script was the simplest method of reading and writing to files on a remote server.

the size of the node. This procedure is similar to the drawing of objects in typical drawing programs such as SuperCard^{TM} [3]. The initial prototype for the concept mapping tool required the user to click on an area and a node of default size was drawn. This method was rejected because the users immediately resized the object upon creation and this caused unnecessary mouse operations.

Links are created by selecting the link icon in the Palette window, then clicking on the appropriate "root" node, dragging the link onto the "destination" node (while holding the mouse button down) and then releasing the mouse button. After clicking initially on the "root" node, the concept map will display a line from the centre of the "root" node to the current position of the mouse cursor. This is designed to give the user a clear understanding of which "root" node was selected and where the mouse is currently positioned. When the link is successfully made, a line between the centre of the two nodes will appear along with a "control point" positioned midway between the two nodes. This control point is used to label and position the link (moving of the links is further discussed in section 3.2).

It is important to note the distinction between being the first, or "root" node selected, and the second "destination" node selected. If the link is to be uni-directional, then the relationship will exist *from* the "root" node *to* the "destination" node. Such links will be displayed with an arrow pointing to the "destination" node. The arrow cue is very useful for displaying direction in three-dimensional worlds [3] and should be effective in two dimensions.

Setting Default Values For Nodes and Links

When a node or link is first created, default values are given for colour, name etc. These default values can be changed within the concept mapping tool and allow the user to make several nodes of the same type without changing the individual nodes' properties. To change the default properties of a node, the user can click on the "Node Set" icon on the Palette window. This window will allow the user to change the name of the node, the colour, the font type, the font style, and the font colour for the node. If the node is an image, the user can change the URL which acts as the source of the image. When satisfied, the user can click on the "Apply Changes" button, which will force the next node to inherit these properties and alter all currently selected nodes to inherit these properties.

[3] SuperCard copyrighted by Adobe

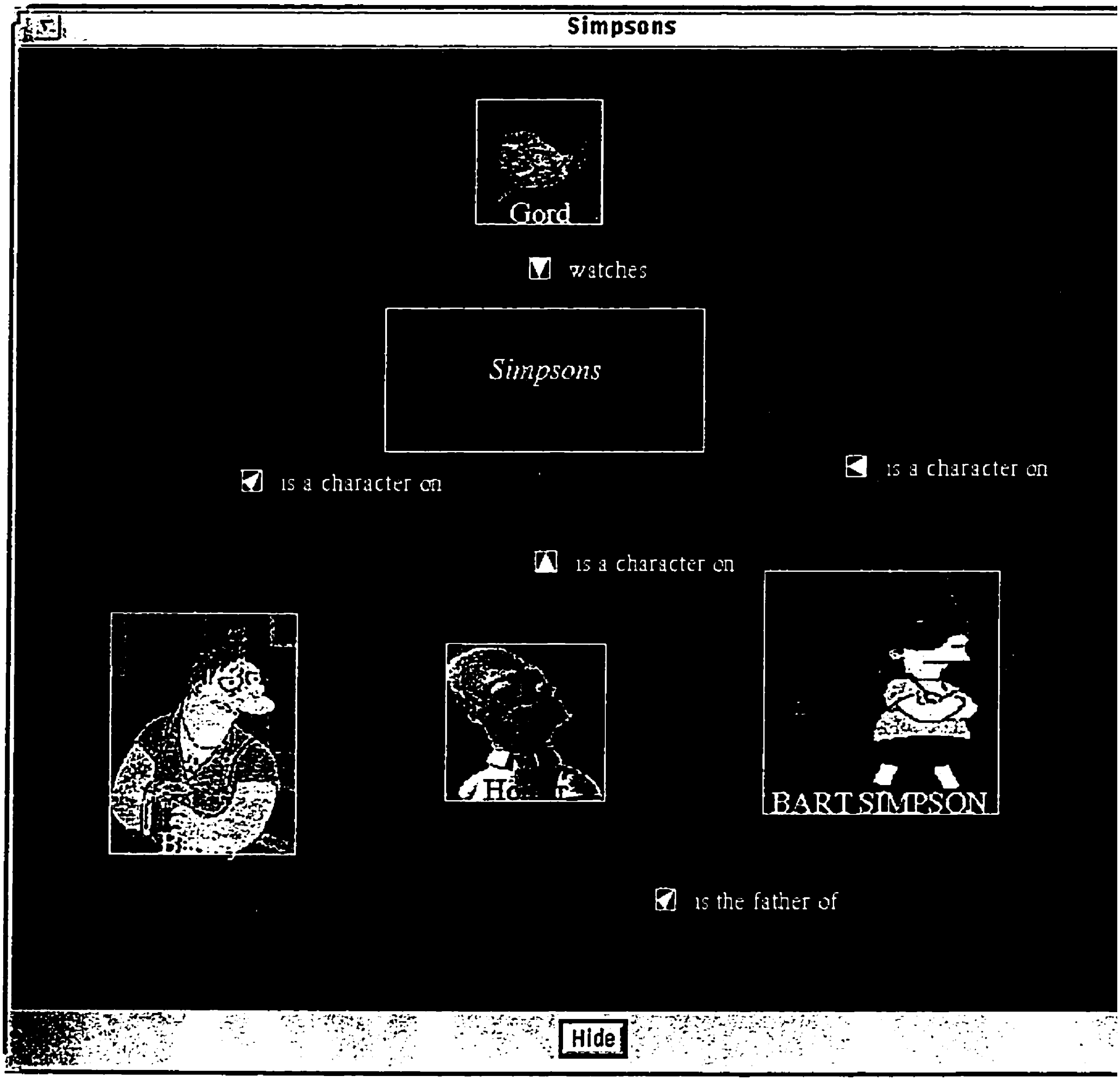


Figure 3.3: An example of a concept map.

A user can control all physical properties of a link as well as the contents within the link. To bring up the window to change these properties, the user clicks on the "Link Set" icon in the Palette window. The window allows the user to fill in the text area, add sounds, images and URLs as default settings, as well as to control the links' physical appearance, such as name, colour and direction. The links can also be saved and loaded as templates, so they can be reused. The user can click on the "Apply Changes" button to force all selected nodes to inherit the given properties.

Relationship links in concept maps are generally used more than once within a concept map, and thus the ability to duplicate and replicate relationships is quite important.

3.2 Manipulating Objects Within A Concept Map

Objects can be deleted, moved, resized, and copied in a manner similar to other popular drawing programs.

Delete Node or Link

To delete a node or link, first select the "scissors" icon in the Palette window. If deleting a node, simply click on the node to delete it. The node will be deleted, along with all links to which it is currently connected. To delete a link, click on its control point. While it may be easier to click anywhere on a link to delete it (rather than on the control point), it was too computationally expensive to determine if a mouse directly hit a point on a link.

Move Node or Link

To move a node or link, select the "hand" icon from the Window Palette. To move a node, the user simply clicks and holds the mouse button on the appropriate node and moves it to a new position. Links move based on the new position of the node. The links control point will not move, but the connecting line from the control point of the link will. To move a link, the user clicks on the link's control point and moves it to a new position. To avoid confusion, connected nodes do **not** move.

The initial design of the concept mapping tool used straight lines between connected nodes. The centre of each of the two connected nodes was found and lines were connected based upon the simple linear equation $y = m * x + b$. As nodes were moved in the concept

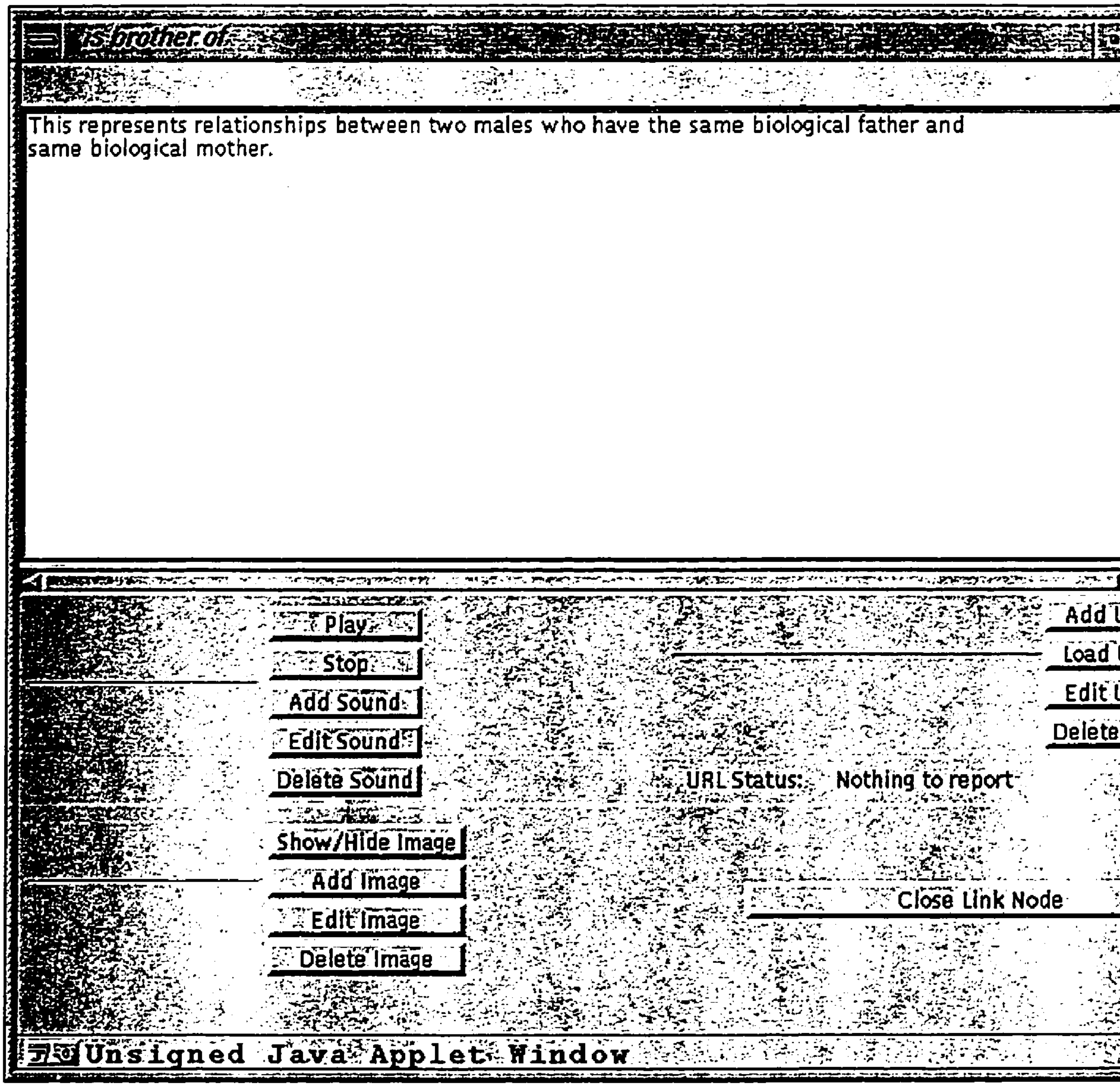


Figure 3.4: An example of setting a links' properties.

map, the links would repaint themselves based on the new position of the centre of the connected nodes.

There were serious problems with this simplistic model. The inability to create curved lines caused a great deal of overlap between links and nodes which led to a very confusing concept map. In order to avoid this problem, the user had to keep nodes and links quite far apart from each other and avoid crossing links, which was quite limiting. Examination of pencil and paper concept maps showed that curved lines were commonly used to connect links for precisely this reason.

Several options were considered. One option was to design an algorithm to display the links to minimize intersections. However, this could possibly reorganize nodes in such a way as to be unintuitive and confusing to the user and be computationally expensive. The second option was to allow the users to interactively move the links and have the links "curve" accordingly. The initial model was created using a Bezier spline with three control points. The three control points consist of the centre of the two nodes which are being linked together and a central control point. The curvature of the link can then be controlled by moving the control point. However, the curve does not intersect the control point, which can cause confusion.

The option finally implemented uses two CTB cubic curves [5]. Creating two connected CTB curves requires three control points. The first and last control points are both at the centre of one of the two nodes. The second control point is initialized as halfway between the two control points. This control point is user controlled and acts as the location for the link's label (i.e. the relationship type between the two connected nodes). It acts as the last point in the first CTB curve and the first point in the second CTB curve.

The continuity, tension and bias are fixed (bias is 0.0 for all control points, tension is -0.45 for all control points and continuity is 0.0 for all control points except the fourth). These values were chosen experimentally. The precision represents the number of lines drawn to comprise the link. This is dynamically generated based upon the distance between the two connected nodes - the further apart, the greater the number of lines are drawn (the more lines are drawn the smoother the "curve" will appear).

The CTB curves provide the flexibility necessary in altering links to avoid crossings and hiding of information.

Resizing Nodes

To resize a node, the user first has to "select" the appropriate node to be resized. If the node is not currently selected, the "select" icon must be clicked on the Palette window, and then the node must be clicked. A node is marked as selected when four white dots appear at its corners. The user must then click on one of the four white dots and drag and drop it to a new location. The node's size and shape will change automatically as the mouse is being dragged. This is similar to many drawing programs.

Links are not resizable.

Copying and Pasting Nodes

Nodes can be copied and pasted within the same concept map or in different concept maps. The user clicks on the "node copy" icon and then simply clicks on the node to be copied. The program then makes a copy of the node and stores it internally, until the user selects "node paste" in the Palette window and clicks on the copied node's new location. Links cannot be copied but templates can be created, saved and loaded so that the same relationship can be used in different concept maps.

3.2.1 Manipulating Other Physical Properties of Nodes and Links

Once an object is created with default values, the user may decide that certain aspects of the appearance must change. Each node and link can have its label altered by selecting the "ABC" icon in the Palette window, clicking on either the node or the link's control point, and typing in the new label. The user can also change more than just the label of the object by selecting the "(node or link) Set" icon in the Palette window and then clicking on the appropriate node or link control point. This will bring up a window which allows the user to adjust the object's physical appearance.

Nodes and links can also have their appearance changed as a group, instead of changing object properties one at a time. First, the user selects all nodes or links that they wish to change (multiple objects can be selected by holding down the shift key while selecting objects). Then the default values for nodes or links are configured using the default settings discussed above, and the "Apply Changes" button is clicked. This function is particularly useful for grouping similar concepts or relationships together.

A user must be very careful when using the "Apply Changes" button because all selected nodes or links will be affected, and it is quite possible to accidentally change the contents of the nodes. Another button to unselect all nodes is added to clear any selected nodes so that the user can start selecting nodes from scratch.

3.3 Manipulating Multimedia Data Content Within Links and Nodes

In typical paper and pencil models, students are unable to carry any information about a specific node, other than tiny textual notes they can jot on the concept map. The only other option is to carry any information which is to be a reference to a node and try to index it to the specific node in the concept map. For example, if there is an accompanying newspaper article to a node the student will have to somehow index the newspaper article to a specific node. This is very cumbersome.

The computerized concept map allows each node to contain sound, text, images, pointers to other web resources, and other concept maps. Links may also contain sound, text, images and pointers to other web resources. The contents of nodes and links are displayed in a separate window which can be opened by clicking on a selected link or node while in "select" mode. Using separate windows allows the user to conserve screen space when not editing contents. The window acts as a control to display other multimedia items on command. It is also closed with a simple click of the "Close Node" button to maximize screen space when node/link contents are not required.

3.3.1 Node Content Windows

Node content windows (e.g. figure 3.5) are titled based on the name of the node from which they are derived and the title of the drawing frame to which the node belongs. This helps to keep context of where the information belongs. Each node content window has a text area into which users can type information. A typical use for text may be for a student's own personal notes, or perhaps a "cut and paste" text note from another URL. The node content then has four different lists for sounds, URLs, images and concept maps. The lists for sounds, URLs and images, allow the user to add, delete or display based on buttons and selection of menu items. Concept maps are also allowed to be embedded and can be saved, loaded, renamed and displayed/hidden.

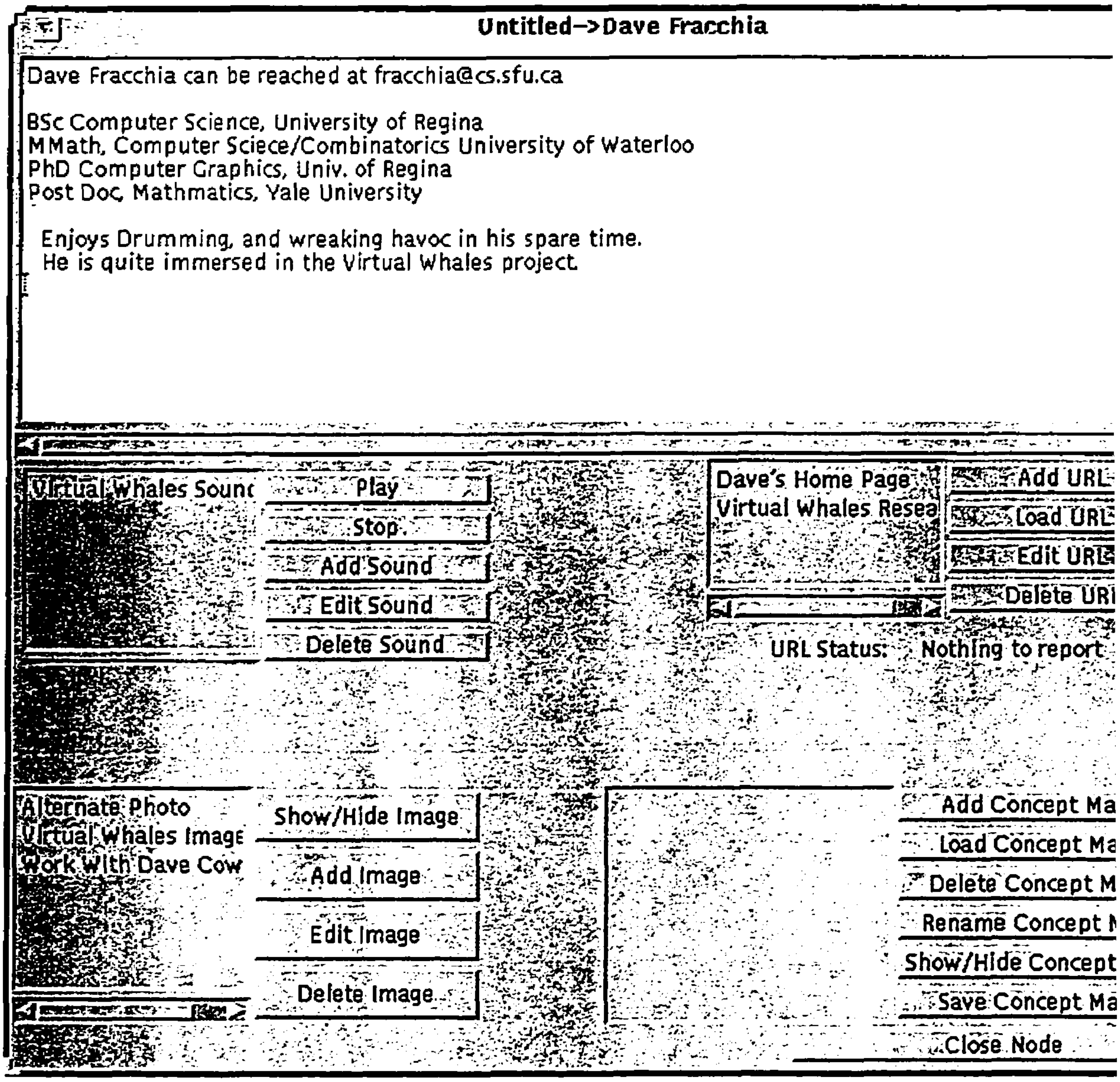


Figure 3.5: An example of a node's contents.

3.3.2 Link Content Windows

Link contents are quite similar to node contents with the exception that they cannot hold separate concept maps and are titled by the name of the relationship. The title name of the link is simply the relationship name.

3.3.3 Problems With Objects Window

Several problems exist with respect to the object's contents. The first concern is that users will have to understand what URLs are and how to use the Internet if they wish to take advantage of the multimedia aspect of the system. Unfortunately, at this time it is not possible to simply point at a sound, URL or image in Netscape, and then automatically have the URL stored in a buffer. The user has to explicitly specify the URL of the resource and must understand not only how to find resources, but how to find the URL of an object within an HTML page. Another problem is that only certain file formats are allowed in Java^{TM}, so the user must understand which files can be accessed.

The second concern is that the sound, audio, URL and text information is not integrated in a homogeneous fashion, as in HTML. All of the information is stored by media, which is not recommended [4].

3.4 Embedding the Concept Map within Netscape

Allowing the user to browse the Internet while using the concept mapping tool requires that the Java^{TM} program be run as an "applet". The applet or Java^{TM} code is embedded within a Hypertext Markup Language (HTML) page and served to the Internet. The concept mapping tool is presented within an HTML file with two "frames", or divisions, within the HTML page. The top frame is used for loading URLs from the concept mapping tool, while the bottom frame is used to provide navigation to help pages. Netscape currently has a problem loading an URL from an applet when the applet's URL source has been changed.

3.5 Other Technical Details

The concept mapping tool currently double buffers each concept map before displaying it. This reduces the screen flicker dramatically, but makes the program much slower to run on lower end machines.

3.6 Comparing Computerized Concept Maps to Paper and Pencil Concept Maps

The computerized concept mapping tool takes advantage of the home computer and Internet. The old paper and pencil models are difficult to edit and share. Furthermore, paper and pencil maps have difficulty adding separate resources such as images, sounds and text. Hiding information is also not possible.

The following table compares the main advantages and disadvantages of the computerized model:

Objective	Paper and Pencil	Computerized
Learning Curve	small- requires only use of paper and pencil	must learn software inter
Quick Sketches	requires only paper and pencil	must have access to com and load program
Editing and modifying	requires redrawing and/or erasing..."messy"	able to move and delete n will automatically move delete connected links nodes
Allowing images and coloured nodes within concept map	cumbersome and very difficult to edit	yes
Allowing nodes to contain text annotations	must write directly on concept map (consumes large amounts of space)	can open up "node con and store text
Allowing embedded concept maps	not easy	supports embedding co map within node for mu mensional concept map
Access to Internet URL's	not possible	runs directly with Int browsers with Java capab
Adding images	cumbersome to cut and paste into map	specify URL
Adding audio	not possible	specify URL
Sharing concept maps	may have to be FAX'ed	can be shared over Intern
Collaboration	only possible if students are at same location	students can share via I net, potential exists to co orate asynchronously

Chapter 4

User Studies For The Concept Mapping Tool

Following development of the concept mapping tool as a research prototype, it was evaluated by a number of test subjects.

Once the concept mapping tool was developed, it was necessary to evaluate it as a useful system for creating concept maps. User studies were done on a number of test subjects and their comments and recommendations are discussed in this chapter. These comments serve as a basis for future changes and provide insight into what features could be added.

Before experiments can take place, it is necessary to determine what information is to be obtained. It was decided that the studies' focus would be on the usefulness of the computerized concept maps, specifically on the features which are not available in the paper and pencil models. Test subjects were also asked for feedback for future enhancements of the system. The various strategies and mental models used were also examined. User interface issues would be examined but not be the primary focus of research.

Once the task is determined, consideration must be given to the type of subjects involved, what their actual task must be, and how the information should be compiled. This chapter discusses the selection of subjects, creation of an appropriate task, and the analysis of the experimental results.

4.1 Developing A Task

In order to receive useful information from test subjects, it is necessary to create a reasonable task for subjects to perform. It is important to carefully select a task which is neither too broad, nor too specific. If the task is too broad, the subject will have difficulty pinpointing a direction to take and become frustrated. If the task is too specific, the subjects may be too constrained and limited in their responses. The task selected must be of a reasonable length. If it is too long the subjects will be unwilling to participate, and if it is too short then producing useful data may be difficult.

It is also necessary to select a task which will directly relate to the area which we are trying to study. Since this research project focuses on the benefits of extending a concept mapping tool to a computer-based environment, the task focuses on building a concept map on a computer and discussing how and what was built (as opposed to direct user interface issues).

It was decided that the subjects task would be to create a concept map based on the mechanisms of a toilet. The toilet was chosen because most subjects will have some familiarity with toilets, without having a complete understanding of the internal mechanisms. This task requires subjects to think carefully on the focused topic. The task is reasonably specific, but not so rigid that the subjects cannot experiment and construct original concept maps. The task is not so broad that they have no idea of how to build the map and become frustrated. The toilet also lends itself well to a concept map because there are many "parts" (i.e. concepts) which relate to each other.

Before the subjects can perform the task, they must be trained on the basic principles of concept maps. Subjects will be taught how to create their own concept maps using paper and pencil techniques after being shown some sample concept maps. It is important that subjects get an understanding for constructivist learning techniques and the ideology behind concept maps. It is also important that subjects understand how to create good concept maps, however, they will not be required to create their own concept map on paper and pencil because it would be too time consuming to produce a map which contains thought and restructuring of ideas. Figure 4.1 is given as an example of a simple, yet effective paper and pencil concept map.

The subjects will then have to understand the operations to create their own concept map using computer software. They will be given a sample computer concept map so they can create, edit, delete and move nodes through an already existing concept map. This will allow them to see and test functionality of the system as well as to become accustomed to the user interface. The example concept map represents the SFU-Computing Science department (figure 4.2). It provides a topic familiar to users and contains images, sounds, URLs and embedded concept maps. It is crucial to demonstrate all features to the user or a bias towards one feature may be created. The subjects will be allowed to edit this concept map to familiarize themselves with the interface. There is no specific time allotment for this phase of the experiment; users can take as little or as much time as they feel necessary to learn the system. Additional online help is available while the subject is performing the task.

Once the prerequisite tasks are completed by the users, the main task of creating their own concept map begins. The subjects are given a URL (*http://www.toiletology.com*) which has an online tutorial for the plumbing of toilets. This URL consists mostly of images and accompanying text. Sounds are not available at this site. Subjects are encouraged to go to other sites to examine toilet information. The subjects are free to construct their concept maps. They are recommended to spend at least fifteen minutes on their concept map, but may spend more time if they wish.

It should be noted that this task still contains biases. The lack of availability of other URLs and the relative uselessness of sounds in this domain (as opposed to music or dance) will affect the user's judgement in evaluating the importance of these features. Virtually any task selected will have some bias towards one feature or another.

The formal task description is given in Appendix A.

4.2 Selecting Experimental Subjects

Eventually, the concept mapping tool will be designed as a complete product readily available and accessible to all students. However, at this stage the concept mapping tool is a research prototype and thus it is necessary to carefully select a group of subjects who can look beyond its current limitations.

While it is hoped that the concept mapping tool will eventually reach any student with a computer and Internet access, the preferred environment of the concept mapping tool is on faster, more powerful machines that typically are not available to students. Thus, it was necessary to provide hardware to our subjects. With security being another issue, it was decided that face-to-face tutorials with subjects would be given rather than allowing them open access to the tool. These constraints required the study to consist of a small number of subjects, but this allowed the experimenter to carefully monitor their progress and watch for any problems or bugs they may experience. The extensive amount of time needed to perform the task also restricted the number of subjects, but this allowed for a more thorough test.

The concept mapping tool also has limitations related to the young age of Java^{TM}. Inexperienced Internet and Netscape users may find that the concept mapping tool is too difficult to use because:

- Objects used in concept maps must be referred to by their unique URL. This requires the user to understand what a URL is and how an object's URLs can be retrieved and referenced. In the future, it may be possible to drag and drop objects into the concept mapping tool.

- Java^{TM} currently only understands certain image and sound formats (gif files and au files). This adds extra burden to the users as they have to understand which file suffixes will be understood and which will not.

Furthermore, experienced computer users will be more comfortable using a mouse to draw objects and be more familiar with the user interface of the tool, since it follows the UI's of many popular drawing tools. If the user is completely Internet and computer naive, it will require a great deal of extra effort to learn the user interface.

The subjects selected for this experiment were not only computer literate, but experts in navigating through the Internet. Using a scale of one to five (where one is a novice user and five is considered an expert user), ninety percent of participants claimed they were at least a four. Five participants responded that they were expert users. Furthermore, ninety percent of users selected a minimum of four on a scale of five, of how often they used Netscape (the minimum response was a "three" for both questions). It is clear that the respondents were familiar with Netscape and navigating through the Internet.

All respondents claimed they were familiar with different file types for images and sounds and had used computer software for composing and drawing graphics. This should reduce problems users have when creating graphical objects through a mouse and keyboard interface and when accessing Internet objects.

The subjects were much less familiar with teaching and concept mapping. On a scale of one through five (with one representing "no experience" as a teacher and five representing an "educator") half of the respondents placed themselves as a "three" or lower. Respondents agreed with the constructivist method of learning, as ninety percent categorized themselves as constructivists as opposed to behaviorists (with the final ten percent simply remaining neutral), but the respondents did not use concept maps frequently. The subjects also felt that the Internet was going to act as an important resource of information for education purposes. On a scale of one to five where a one represented "not important" and five represented "important", ninety percent of respondents gave either a four or five rating. There may have been some bias as the participants were familiar with Netscape and used it frequently. Please refer to Appendix C for full results.

It is clear that the majority of the subjects selected for this experiment will create a bias in evaluating the system. The concept mapping tool is a research prototype which should be evaluated for its potential rather than its current beta state which could not be released as a product. Before the experiment, known interface problems existed as well as problems caused by the immaturity of the Internet and Java^{TM} programming language. It was important for the subjects to be able to look beyond some of these problems and evaluate the system as an educational tool and examine its strengths and weaknesses, rather than become overloaded with interface and speed problems. This bias will be noted when evaluating the users' results.

It should be stated that the computer and Internet expertise of the subjects may be required as the Internet develops. Students will require the skills to use computers and the Internet as computers play a larger role in education.

4.3 Developing a Questionnaire

Upon completing the task, subjects are asked to fill out a questionnaire based on their experiences. This questionnaire, as well as observations of the concept maps created, will form the basis of evaluating the concept mapping tool.

The questionnaire is divided into three separate parts:

- Background information
- Interface issues

- Concept Map issues

Background information is used to determine the expertise of the user (this has already been discussed in section 4.2). Users who are novice to the Internet may have greater difficulty using the concept mapping tool and finding resources for concept maps. The questionnaire also queries the user on their knowledge of concept maps and whether they have experience as an educator. This section is designed to confirm in a quantitative manner that the subjects selected are expert Internet and computer users.

The Interface issues section examines the user's ability to create concept maps using computers. Questions query the user on the difficulty of performing a specific operation. The questionnaire also directly asks the user what advantages the computer has over pencil and paper and what disadvantages it has.

Concept mapping issues are the most important area of the questionnaire. The questions focus on the importance and usefulness of the extensions of this concept mapping tool. The questionnaire also asks for recommendations on which branches of education the concept map is most useful for.

See Appendix B for the actual survey.

4.4 Experimental Results

This section discusses the results of the ten subjects who were selected to perform the experiments. The results are divided into several sections. The first discusses the user interface issues and the advantages and disadvantages of using a computerized concept mapping tool over the traditional pencil and paper model. The second section discusses the added functionality (such as access to Web resources and multimedia) of the computer environment and whether these extensions are useful. The third section examines the separate concept maps that the subjects created. Use of different features and mental model types are examined.

4.4.1 User Interface Design

While the user interface was not the prime focus of the concept mapping tool, it was important to assess the interface to see if it interfered with learning. Judging by the respondents, the user interface had some serious problems which need to be addressed before the concept map software can be easily used by naive users. One subject remarked, "The UI is critical.

I found the basic concepts useful, but the actual UI really awkward". Fortunately, most of these problems are easily solved. It should also be noted that the results to the "Interface Evaluation" (Appendix C.1.6) of the questionnaire is biased because the subjects were very familiar with drawing programs and the Internet, thus would have less difficulty performing tasks than inexperienced users.

Users evaluated several aspects of the user interface on a scale of one to five, where one represented difficulty in performing an operation and five represented no difficulty in performing an operation (see Appendix C). The features most similar to typical graph and drawing programs were the easiest to use. The use of a palette which contains icons was rated a four or five in ease of use by seventy percent of users. The main complaint with the colour palette was that it was inconsistent. Some icons would highlight to display which tool was being used, while clicking on some icons would simply pop up a window. Consistency is needed, and adding pull-down menus for certain operations will provide a superior interface. In typical drawing programs, operations such as "file open", "save" and "save as" are presented as pull down menus.

Function	Mode	Mean
Add rectangles, images and ellipses	5	5.0
Add relationships between nodes	5	4.7
Move and resize objects	5	4.5
Change the physical appearances of ...	5	4.3
Change the location of links...	5	4.1
Add sound, images and URLs into a node or links contents	3	4.1
Understand and control the colour palette	5	4.0
Open a nodes' or links' contents to view information	5	4.0

† Not all respondents answered every question.

Table 4.1: Ease of Use for Concept Map Interface Options

Other typical interface issues such as adding a node, adding links, and resizing nodes provided few problems to users. This is because the subjects had all been exposed to drawing packages before, and the operations are quite similar. It should be noted that naive users may have greater difficulty performing these operations simply because they have no prior experience with drawing programs.

Difficulty began to surface when users attempted to do things unique to the concept mapping tool. The use of CTB splines and a central control point to move links was not intuitive to the users as three subjects graded the difficulty of moving links as three or lower on a scale of one to five. Ideally, the subjects would have been able to grab any point on a link and move it appropriately, however that would be computationally expensive. Perhaps it was not clear that the control point was the centre of all link operations. Other options could be examined in the future, but the CTB splines seemed a reasonable solution for the task.

Changing the the physical appearances of nodes and links also proved cumbersome. The confusion was created by having to select the correct mode to open the physical properties of a link or node. The distinction between physical properties of nodes and links and their content proved quite confusing. Improved methods of changing physical properties and content should be addressed. The concept mapping tool currently allows users to set the physical properties of one specified node, all selected nodes, or the default node properties (see figure 4.3). A major problem with this method of changing nodes is that all properties of a node must be changed at once. If the user wants to change several nodes, and not their fonts, they would have to change each node individually.

Users also had difficulty adding URLs, sounds and images to nodes, as only half rated it a four or five in ease of use while three did not even attempt it. Having to understand file types and URLs introduces an even greater degree of difficulty for novice users. Some users may not have tried to add multimedia simply because they did not have enough time or could not find proper resources. In the future it may be possible to drag and drop objects into the concept mapping tool. This will remove the confusion surrounding file types and URLs.

User interface modifications also dominated the "Comments and Suggestions" portion of the questionnaire (see Appendix C.3.16). The most common complaint was the lack of an "Undo" button, which would allow users to return to the previous state of a concept map after making an alteration. This feature should be added in the future.

Another common complaint was the "flickering" display of the concept map. The concept mapping tool did not double buffer information as it was too slow ("alot [sic] of blinking due to repaint"). There are some problems with the Java^{TM} language in terms of execution time, but the new "just in time" compilers (Java JIT Compiler) may help. Currently it is only available as a Beta release on Solaris machines, but plans are to have a Macintosh, Windows NT and Windows 95 release. The downside is that the JIT compiler's biggest speedup is in applications which are computationally intensive, so the advantage may be minimal.

Several users also asked for immediate access to multimedia objects inside the nodes instead of having to open the object's contents and then access them from there. A related complaint was that all link and node objects had to be opened to find all the multimedia files. A suggested solution was to display an icon beside the given node or link in a concept map to indicate that the given node or link had multimedia information inside. Specifically, the type of media in each node should be displayed.

Other disadvantages mentioned were the "constraints on shapes of nodes, ... where links go" and "lack of flexibility". Allowing learners to create their own node shapes by drawing their own polygons is possible, but was not implemented in this version. Several suggestions were made to allow greater customization of the concept map objects. These could be added in later versions, but were a low priority for the initial prototype.

With all of these problems, none of the participants preferred using the paper and pencil model over the computer method. Sixty percent of participants outright selected the computer over the pencil and paper model while three said that it depended on the situation. It appeared, from further comments, that if a small, quick sketch were required, the pencil and paper model was preferred. One respondent did not answer the question.

The main advantage to using the computer as an interface to create a concept map (versus a pencil and paper interface) is the ability to redraw and edit existing concept maps. Eighty percent of respondents made some reference to this, such as "making modifications to an existing map is easy", and "easily modifiable - important!". One subject stated that the biggest advantage was

> "incremental modification and creation: since I evolved the map over time, wholesale changes could be made without redrawing by hand. The redrawing affected further creation. Important were link and node movement and group attribute settings".

With larger tasks, the computer advantage in editing becomes more important as students can build hierarchical models and restructure their concept maps without increased paper clutter.

Another commonly cited advantage of the electronic concept mapping interface was its ability to integrate web resources, such as text and multimedia, with the concept mapping tool. This was mentioned by fifty percent of subjects. This is significant considering that several users had difficulty adding this multimedia and thus may have shied away from it, and the fact that the task given did not lend itself well towards the integration of Web resources since there were not many Web resources/images/sounds available. If another task involved objects with easily accessed multimedia files or required more use of sound and/or images, the importance could have increased.

Other advantages mentioned included the ability to integrate different colours into the concept map (e.g. "colours, shapes aid in visualization"). This helped with aesthetic gains ("Resulting concept map is much prettier").

Thirty percent of users pointed out that quick sketches or initial drawings were far easier to construct using paper and pencil. One respondent claimed "If all you want is a rough sketch to get the general idea, then pencil and paper is the way to go." The learning curve was also cited as a disadvantage that the computer concept mapping tool has to the pencil and paper model. However, as maps increase in size, the advantage in editing would make it worthwhile to both learn the software and input the information on computer. Consider that a small database may be maintained simply by pencil and paper or memorized, but as the database size and number of transactions increase it becomes far more preferable to use a computerized database. Another solution, which allows quick sketching, is to switch the input device from a mouse and keyboard to a laser pen.

Overall, the subjects certainly preferred the computer version of concept mapping over the pencil and paper model for anything but the smallest tasks. The main advantages of the computerized version were its ability to add Web resources and relative ease in editing concept maps. The subjects also suggested many interface changes which will improve the ease of use of the concept mapping tool.

4.4.2 Evaluating the Extensions to the Concept Mapping Tool

When moving to a computerized environment, the concept mapping tool was able to provide extra functionality to the user, such as interaction with Web resources and the ability to store and retrieve information within nodes and links. Subjects were asked to rank the usefulness of these extensions by giving them a rating from one to five, where one was considered "not useful" and five was considered "useful". This portion of the questionnaire was used to determine if the subjects found the extensions to traditional paper and pencil models useful or not. The rankings for the extensions are listed in Table 4.2.

Most of the subjects found the extensions to the concept mapping tool to be very useful. The ability to add image files and particularly sound files were considered the least useful

Function	Mode	Mean
adding text comments to nodes and links	5	4.7
ability to connect URLs to nodes	5	4.6
ability to embed concept maps within nodes	5	4.5
ability to represent nodes as images	4.5	4.2
ability to add image files to nodes	5	4.1
ability to add sound files to nodes	4	3.2

Table 4.2: Value of Concept Map Extensions

extensions but this may well relate to the task. Certainly the sound files were not particularly useful for developing a concept map for toilet plumbing and resources were not readily available, so subjects were unlikely to use this extension. However, if the task was to create a concept map for teaching one how to sing, sound files would be invaluable.

The questionnaire also asked subjects how effective concept maps were in the following scenarios:

A. Getting instructors to create concept maps as learning modules for students.

B. Helping students to construct their own knowledge.

C. Organizing and grouping useful information together.

D. Method of navigating through a personalized web space.

These results are given in the table 4.3.

Function	Mode	Mean
B. Students constructing knowledge	5	4.6
C. Organizational tool	5	4.4
A. Instructor tool	4	3.9
D. Navigating the Web	3	3.3

Table 4.3: Responses to Concept Map Applications

Subjects felt that it was a better tool for personalized use than for teaching or navigating through a web space. This may not be surprising given that most subjects considered themselves constructivists and one of the main constructivist views is that knowledge is based and created on an individual's personal knowledge. The task also put the subjects in the role of a "student" who constructed knowledge, so it is not surprising that the users considered B the most useful.

The concept map's flexibility also led to a wide range of responses to the question "Which types of educational training do you feel this is most effective for?" The question was designed to allow as broad or as specific an answer as the respondent wished to give.

The common thread among respondents was that the application had to have clear relationships between objects (eg "representing info as concepts and relations between concepts"). Another related comment was the application's use in "analyzing the technical experiment ... the procedure of starting the car engine" and "logic" (this task requires many intricate relationships between car engine parts). Some respondents gave specific fields which they felt were ideal (e.g. "physical sciences", "education", "biology") while others were more abstract in their answers. One response felt that "sex education" was ideal because "students could find out info about stuff they may be too embarrassed to ask." (For full results, see Appendix C.3.13.)

While the above question created quite diverse responses, the followup question, "What types of educational training do you feel this is least effective for?", had less varied responses. Not surprisingly, comments such as "practical applications typically learned by apprenticeship", "religious training" and "Spoken Languages" were mentioned. Activities which require physical activities (e.g. swinging a baseball bat or "pottery making") make concept mapping ineffective. Mathematics was also mentioned by two respondents.

One subject had a particularly interesting response, stating "Anything which is based mainly on a transfer of facts from teacher to students (I have taken many psych courses like this)". This is not surprising since it is a clear reference to "behaviorist" learning. Naturally, the concept map tool cannot perform behaviorist learning well, since that is not what it is designed for (See Appendix C.3.14).

Users were also asked to make "Comments and Suggestions" as well as suggest "additional features". These two questions seemed to yield similar responses: most of the features for concept mapping are already in the system but the user interface needs some work!

Overall, comments were very positive. One subject stated, "I really think using something like this could encourage learning" while another said "This is excellent work!". While the system is still a prototype, the feedback suggests that the potential exists for a very useful concept mapping tool. Several suggestions were made for improving the system. The following outline the most common suggestions and comments.

Problems with Java^{TM} Technology

Several complaints that were made were directly related to Java^{TM} and current Internet technology. Two subjects complained of the long refresh time and speed of their machines. One subject complained that "Java was way too slow on the machine I was using, so this made things a bit tedious". Java^{TM}'s speed over the Internet is a real problem to web developers and this limits the feasibility of large scale applications running effectively over the oversaturated World Wide Web. These problems are faced by other developers as well.

Another suggestion made was to drag and drop objects from the browser into the concept mapping system. Currently, Netscape does not allow users to embed sound and image files into other applications in the same seamless manner that text can be cut and paste from one application to another. With the growth and development of JavaBeans^{TM} [1], IIOP and CORBA, the reuse and recognition of different object types will eventually allow the user to drag and drop file types from Netscape into an application.

One other suggestion was "using alternate mouse button to edit nodes." However, Java^{TM} suffers from "lowest common denominator" disease and since MacIntosh machines has only one mouse button, Java^{TM} restricts user interfaces to use one mouse button.

Suggestions For Future Implementations

Many users commented on added features they would like to see implemented. These suggestions, while useful, would require a great deal of research before being implemented.

One suggestion was to create a three-dimensional concept mapping system. In the original design phase, three-dimensional graphics were being considered but were discarded because of the poor performance of graphics in Java^{TM} and the lack of libraries available for three-dimensional graphics. However, there are many reasons for moving towards a three-dimensional concept map. These are outlined in greater detail in section 5.1.1.

Several users wanted to specify groups and sets of nodes. Some users simply wanted "group motion" which is available on most drawing packages. However, the ability to place nodes and links in a group is more powerful than simply moving a set of links or nodes to a

[1] JavaBeans^{TM} is trademark of Sun Microsystems

new position. One subject requested Meta Nodes, where nodes could contain other nodes. Currently, the concept mapping tool supports this, but the internal nodes within a node remain hidden from the other levels. Another called this a "disjoint hierarchy" because nodes which are internal to another node's content cannot interact with nodes which are in a different level. The subject

> "found that things didn't neatly order themselves into disjoint hierarchies. e.g. A key interacts with the components of a lock but if I put the lock components into groups of concept maps, I want the key to be related to both the upper level (the lock) and the lower levels (groups of components, the components themselves)."

This issue is discussed in section 5.1.3.

Other suggestions were made for making concept mapping a better navigational tool by merging it with CZ Web [27], which is an interface tool for navigating through the World Wide Web, in order to avoid the "lost in cyberspace" syndrome. The main problem with the concept mapping tool as a navigational tool are the numerous windows, cumbersome interface and the lack of knowing what context one is in. The subject claimed, "Somehow we need to combine CZ Web and concept mapping to get the best of both." This remains outside the scope of this thesis.

4.4.3 Evaluating Subject Concept Maps

Perhaps the most interesting data obtained during the experiments were the individual differences and approaches to building concept maps. Participants quickly understood the purpose and capabilities of paper and pencil concept maps after seeing an example. Most of the subjects did not need any confirmation of what a concept map is or what it represents. Most did not require/desire any user interface training session for a "practice" concept map and they were eager to begin work immediately. Judging by their concept maps, all of the participants grasped the theory of concept maps and applied them successfully. This ease of training was likely due to the backgrounds of the subjects involved. In a typical classroom where students would not have as much computer and Internet training as the subjects, greater problems would arise.

Only one subject struggled and this was because his/her task became too broad. Due to technical problems with the Internet, the toilet web site could not be accessed and thus the task had to be changed. The subject was encouraged to select another domain of which he/she had interest in, but could not decide on a specific task. The end result was an overly broad view of a subject ("Information about Drumming") which the user had a great deal of expertise in. This broad task led to a lack of direction, which led to disinterest. The end result was a fragmented concept map which acted as a web site navigator rather than a learning tool. The concept map is shown in figure 4.4.

Originally, the concept map creation was to take only fifteen to twenty minutes of the subjects' time but it is clear that this was too short a period for users to create a meaningful concept map for this particular task. Many subjects voluntarily stayed over this time and seemed to enjoy the experience. One subject described the process as "alot [sic] of fun."

The enjoyment in creating the concept map was also seen in the concept map design. Constructivist pedagogies were demonstrated within the various strategies and approaches the subjects took. One subject took it upon himself/herself to make a stand against the environmental problems created by sewage (figure 4.5) by creating a node "Lake Lovelylake" and commenting:

> "Lake Lovelylake used to be shiny and blue, a good source of water and fishes for all those who live on the Island of Tranquility. Since the advent of the toilet (otherwise known as "the john"), however, Lake Lovelylake has lost much of its luster and its fishes. Lake Lovelylake now sports the nickname "Lake John" by a social groups and others concerned about the health of their once beautiful waters. *sniff* *sob*"

Another subject provided social commentary on the modern day advances and uses of the toilet. The humour of the student is evident when he/she states from the toilet node's content:

> "The Toilet.
>
> The toilet is one of those modern conveniences that we take for granted in modern life.
>
> But really, ask yourself, what would you do without a toilet.
>
> I guess you'd find a wooded area and do your thing there, but that could get cold in the winter.
>
> Especially with snow on the ground."

This subject also introduced the cultural implications of toilets (figure 4.6). Another subject took a more direct and straightforward approach to the concept map by outlining each part of the toilet and its relation to other parts which help the toilet flush (figure 4.8). It is clear that these subjects allowed their own experiences and interests to shape the development of his/her concept map. This creativity and lack of a singular "right answer" are fundamental to a constructivist environment.

Subjects not only interpreted the task in a subjective manner, but they also went into different levels of abstraction to create the concept map. One subject used nodes to represent physical objects inside the toilet such as "pipe" and "tank" as well as to describe "gravity pressure" and "line pressure". Another subject created an abstract node for "cultural norms". Most subjects did not deal with specific parts which construct the toilet. The number of nodes in each concept map varied, but this is largely due to variations in the time spent and the structure of a subjects' concept map.

Subjects had instituted different schemes to represent their understanding of the concept map. One subject (figure 4.6) used a central node and a star shaped topology to build his/her concept map. This is in direct "violation" of Novak and Gowin's [13] theories of constructing concept maps. Perhaps the hierarchies which exist by embedding concept maps within nodes affected the subject's willingness to build in a hierarchical manner.

However, several students did decide to use a hierarchical approach (figures 4.4 and 4.7) with the top node representing the most abstract node ("Information about Drumming" and "Toilet") and the creation of clear "levels" of abstraction based on its physical distance from the top or "key" node (see figure 4.7). Other subjects preferred to use no hierarchy and no central or "key" node (see figure 4.8).

Different colour schemas were also recognized in some concept maps. Some used colour to represent an object's colour, such as using a brownish hue for "waste" nodes (figures 4.6 and 4.9) and using blue nodes to represent "Water" nodes. Another subject used colour encoding to show whether or not a particular node had a concept map embedded within the node. Another subject (figure 4.8) effectively used node colour and label colour to indicate different node types. Both "Gravity Pressure" and "Line Pressure" were represented by grayish nodes (but differing slightly), while red labels represented warning signals to the user (nodes "Low Water" and " Clogs"). One subject also used differing link colours to distinguish relationship types (figure 4.9).

Another major structural difference was whether one large concept map was built, or whether hierarchies were built by embedding concept maps within nodes of other concept maps. One subject started with only three nodes representing the toilet tank, the pipe and the ballcock. Inside the ballcock node was a more detailed concept map containing the workings of the different parts of the toilet.

Another subject also had a similar, disjointed hierarchy. The top level view of the hierarchy is shown (figure 4.10). Using this top concept map as the highest level of abstraction, the subject went into greater detail by embedding a concept map in the node labelled "repairs" and embedding a concept map into the node labelled "operation" (figure 4.11). Other subjects tended to avoid internal concept maps and displayed everything on the same, top level concept map.

In a classroom environment where knowledge is built over large periods of time, embedding concept maps within nodes of other concept maps becomes more useful. The task presented is fairly short and all of the knowledge is built within a twenty minute to one hour time frame. If a task such as the following had been given:

- Build a concept map of the toilets drains
- Build a concept map of how a bathtub drains
- Build a concept map of how a sink drains
- Build a concept map of a schema showing how a bathroom with toilets, bathtub and sink can be drained

The final step could import the toilet, bathtub and sink concept maps into a top level concept map discussing how the toilet, bathtub and sink nodes interact.

Although subjects clearly promoted the usefulness of multimedia in the questionnaire (see Appendix C), for the most part they shied away from integrating these objects in their concept maps. This had alot to do with security exceptions built into Java^{TM}. Other contributing factors were:

1. Having seen only paper and pencil methods and being very new to concept mapping, they may have wanted to avoid "advanced features".
2. The task did not lend itself well to multimedia (if a dance study or music lessons were the task, sound and imagery would have become more significant pieces).

3. There were very few resources available for this particular task.
4. The difficulty in the user interface for integrating these items.
5. Time constraints (not enough time to find resources).

Subjects did not vary in their use of links. No subject used the link content to describe a relationship between two nodes. No subject used link templates to save relationship types, either. Links were almost always used in a uni-directional way, with exceptions existing in figure 4.6 (the relationship was between "the toilet" and "excrement" and the link name was "the purpose"). Several subjects used colour coded links to denote specific relationship types. The ability to store information to describe a relationship may not be a useful extension to concept mapping. In this particular application, users may have had only simple relationship types which did not need clarification and the link content was simply unnecessary. It is also possible that users, new to concept mapping, wanted to avoid advanced features.

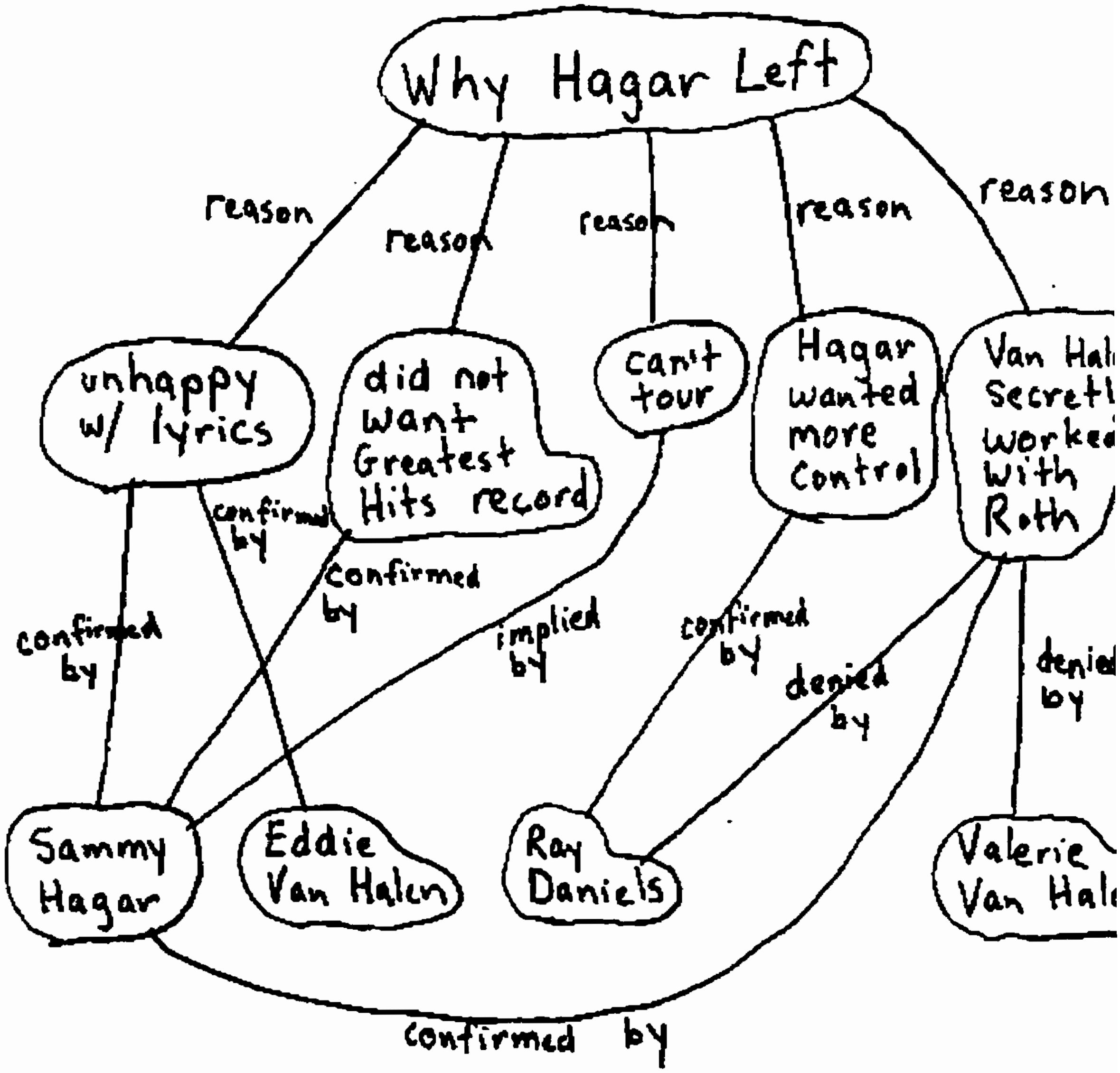


Figure 4.1: A pencil and paper example shown to subjects of a good concept map.

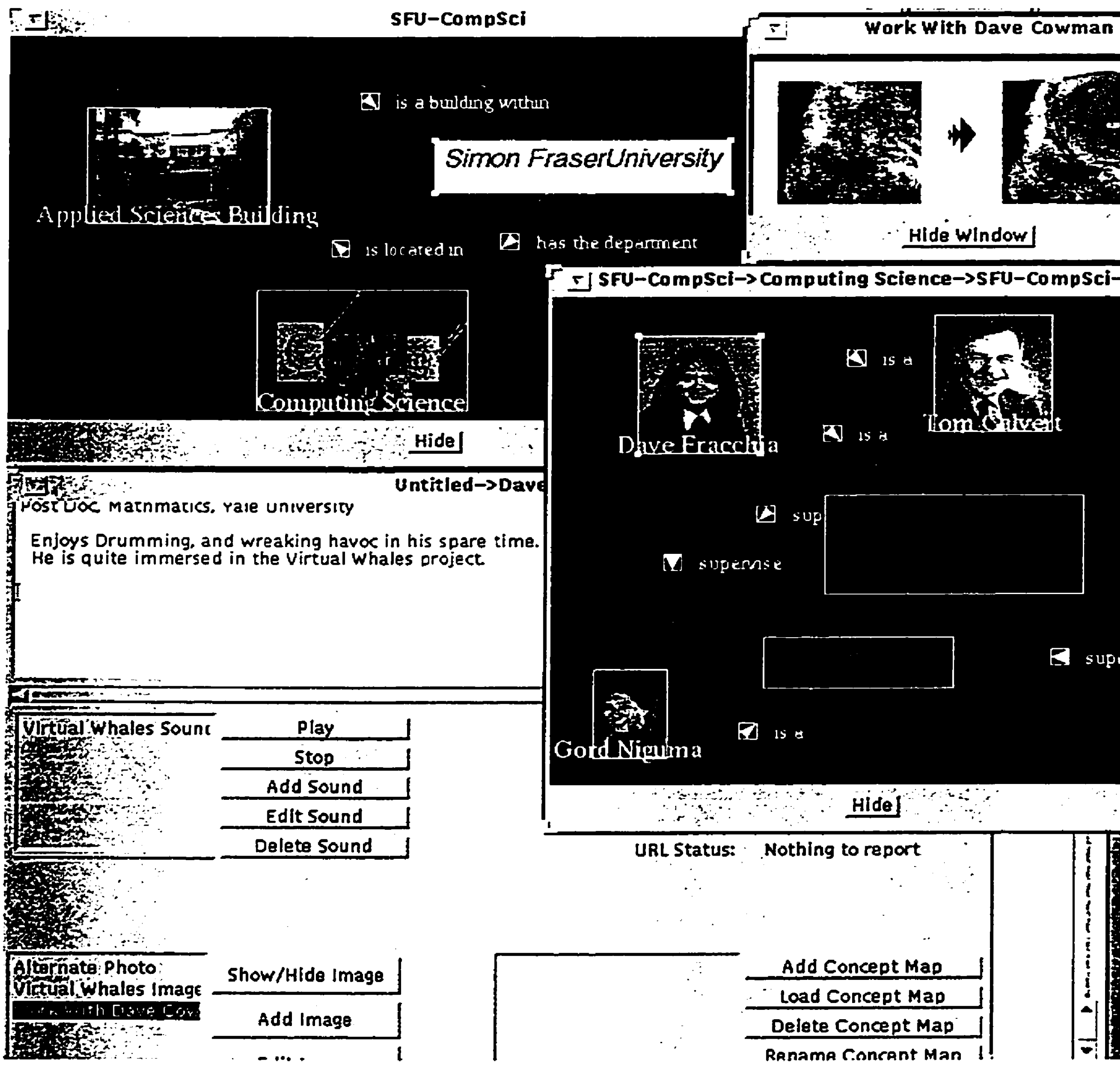


Figure 4.2: An example shown to subjects of a computerized concept map. It shows how several windows are used to display multimedia, node contents and embedded concept maps.

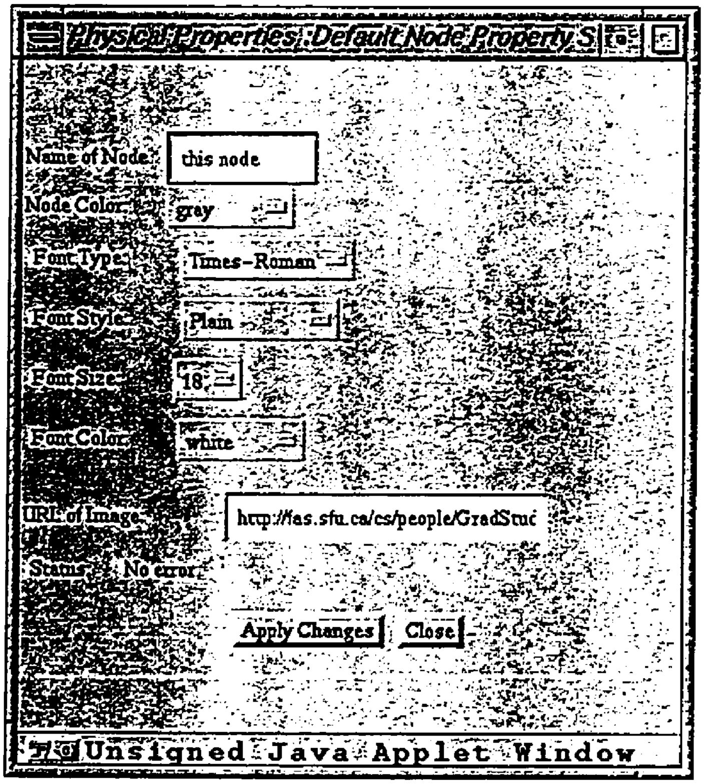


Figure 4.3: Confusion was created when trying to change the physical properties of a node

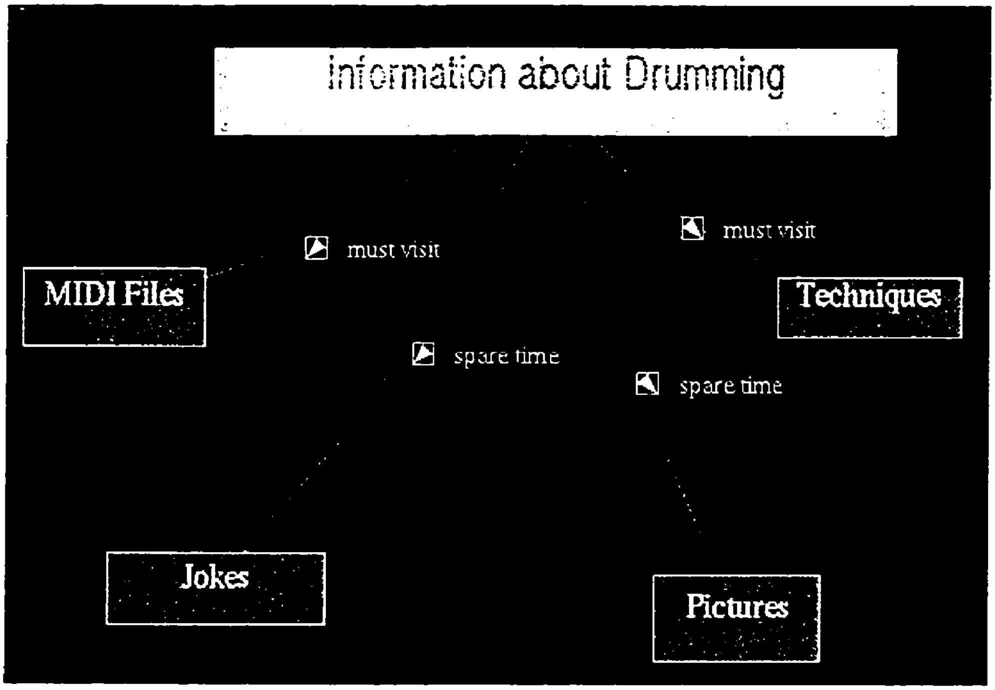


Figure 4.4: One subject struggles with a loosely defined task.

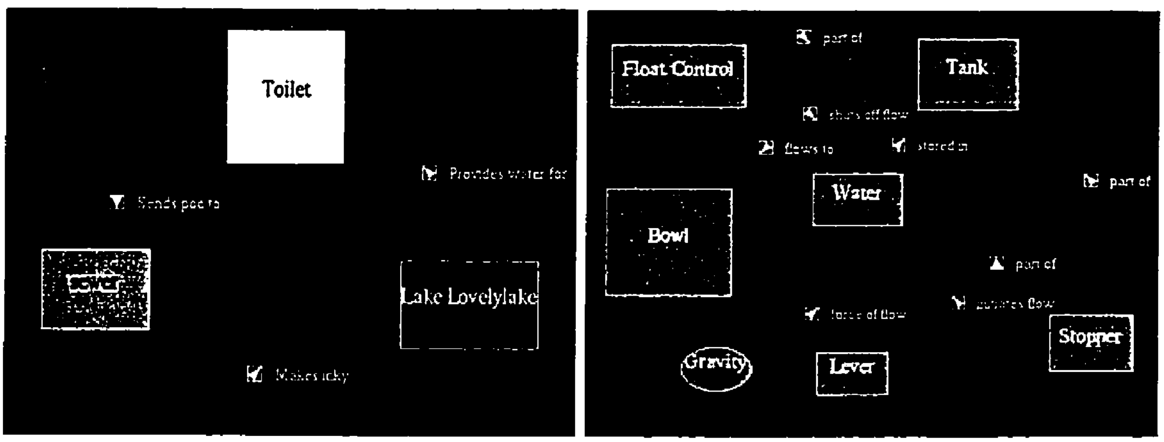


Figure 4.5: One subject makes references to environment in top level of concept map (left). Inside the "Toilet" node, another concept map is embedded (on the right).

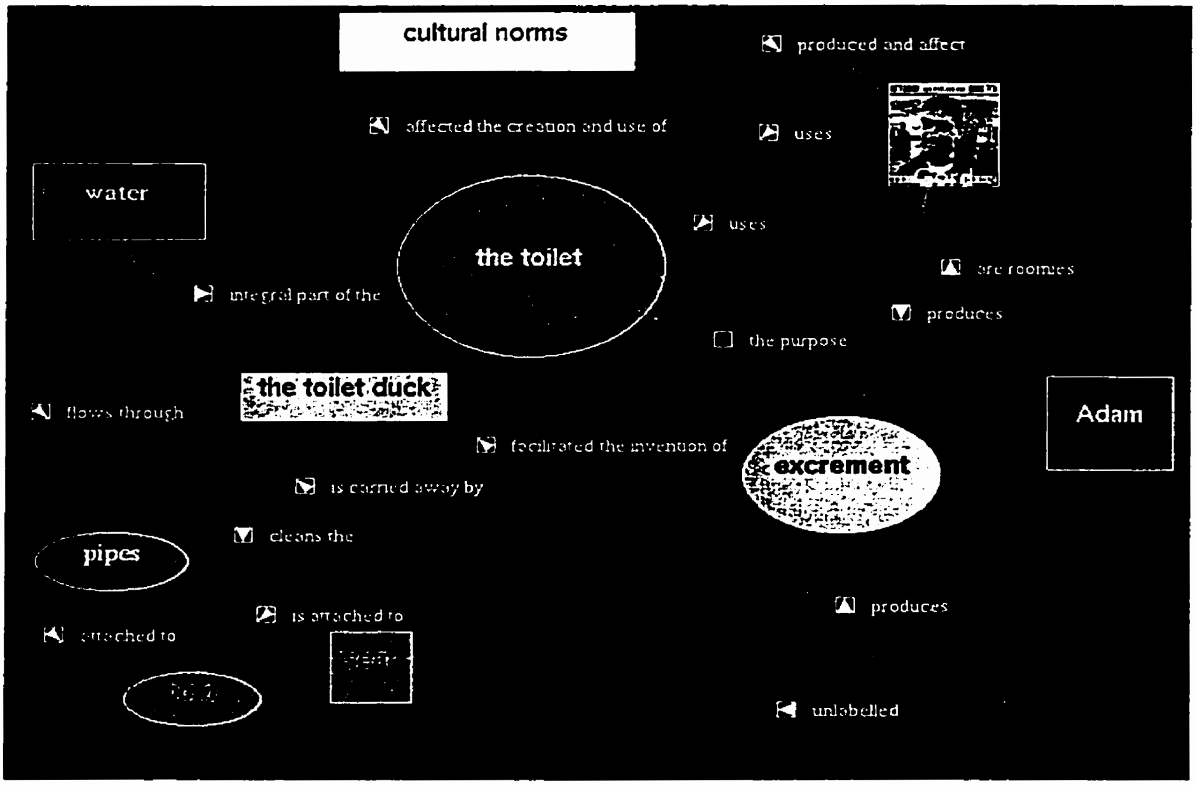


Figure 4.6: One subject makes references to the environment and effect on culture.

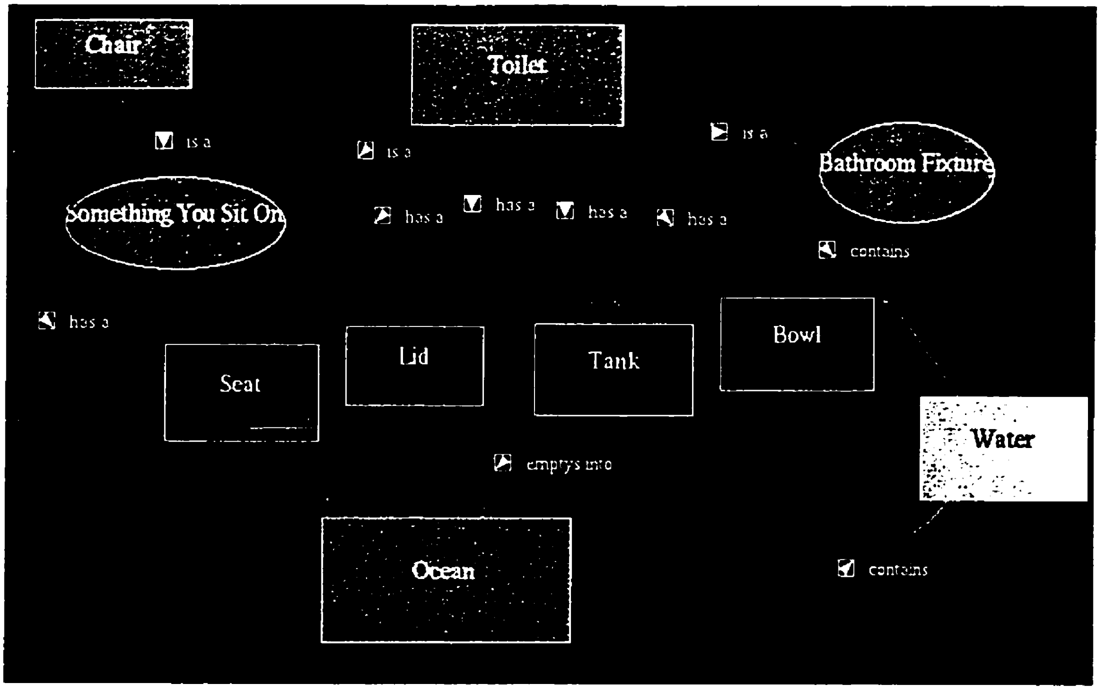


Figure 4.7: This subject uses a top-down hierarchy.

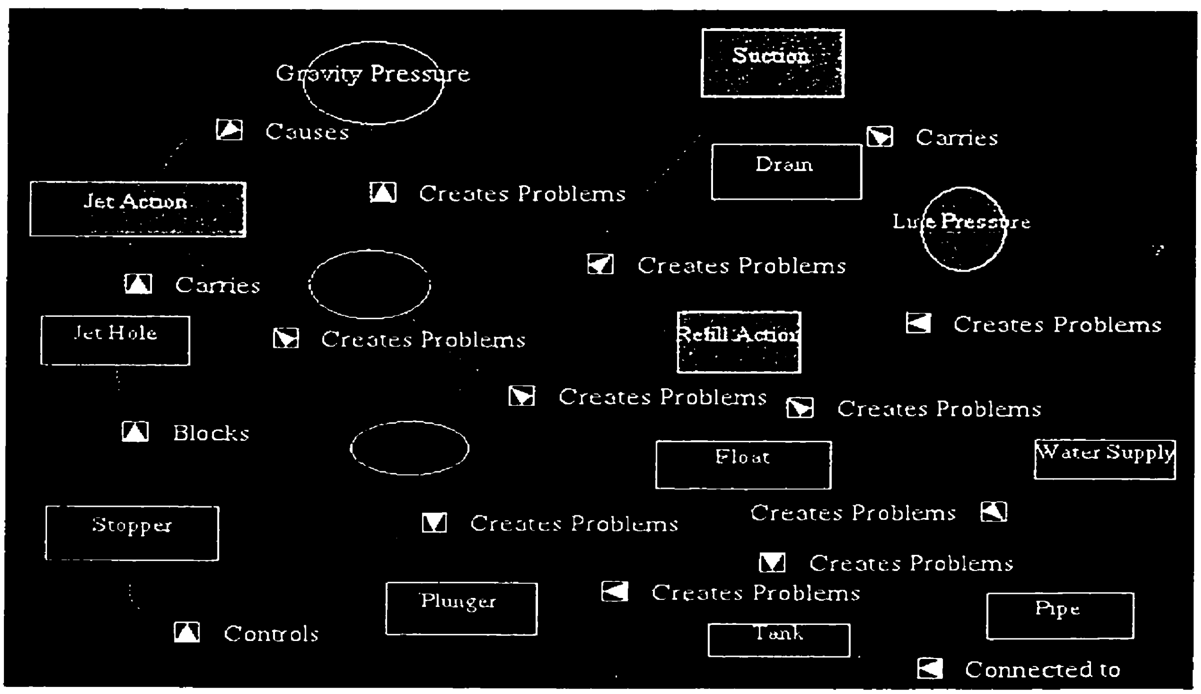


Figure 4.8: This subject approaches the task in a practical way.

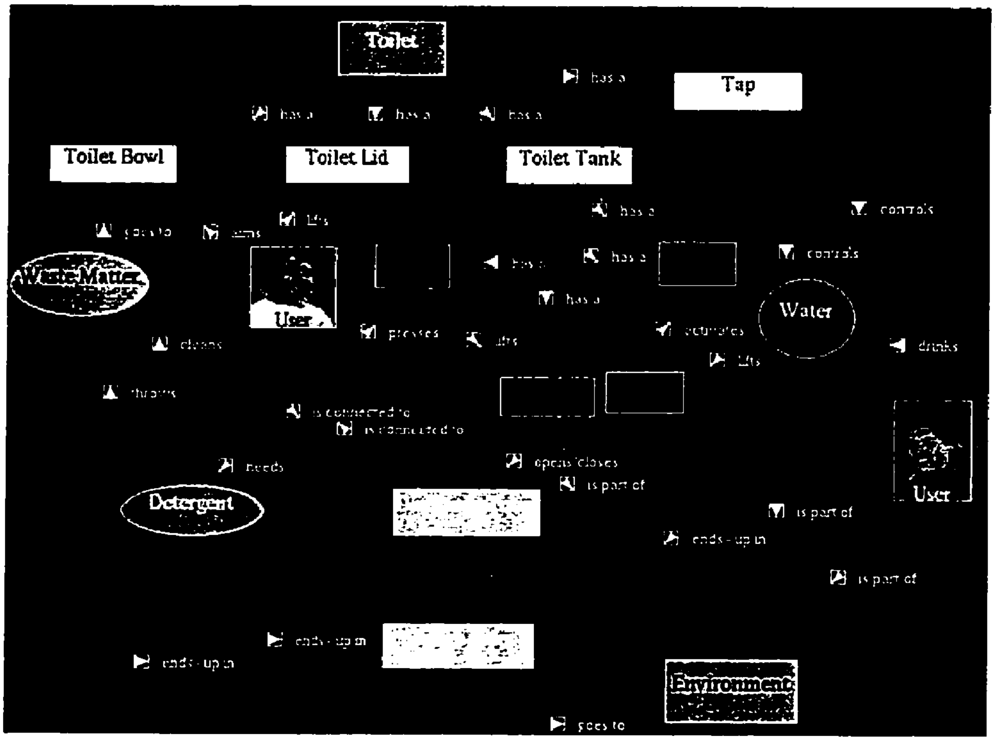


Figure 4.9: Subject E uses colour to symbolize "Water", "Environment" and "Waste". Different link colours also represent different link relations.

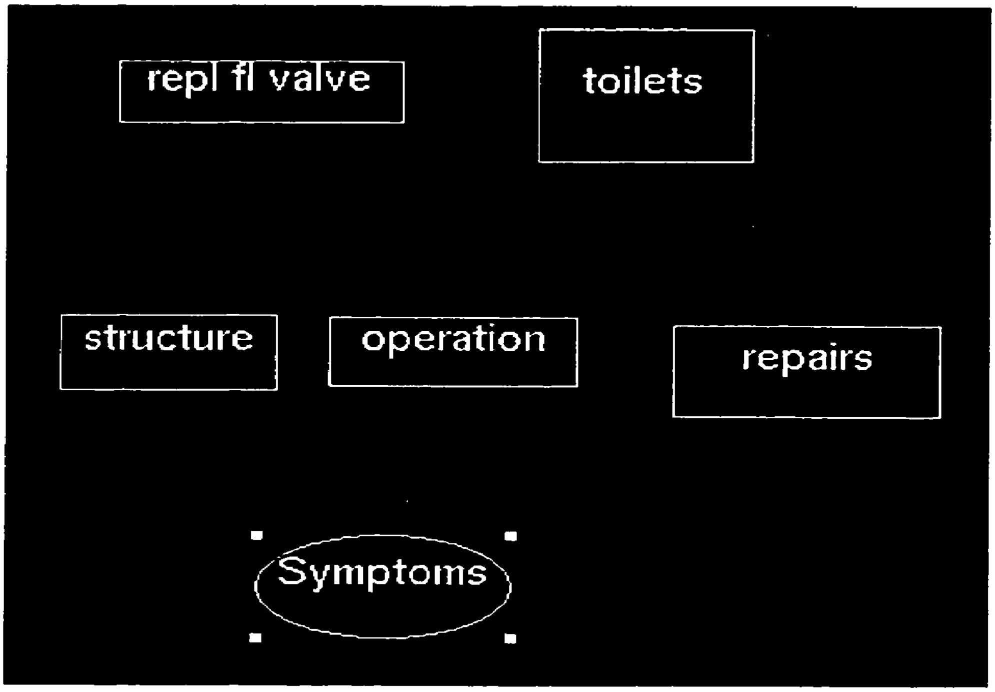


Figure 4.10: One subject uses a top level map with internal concept maps embedded within the "operation" and "repairs" nodes. This is a "disjoint hierarchy" structure.

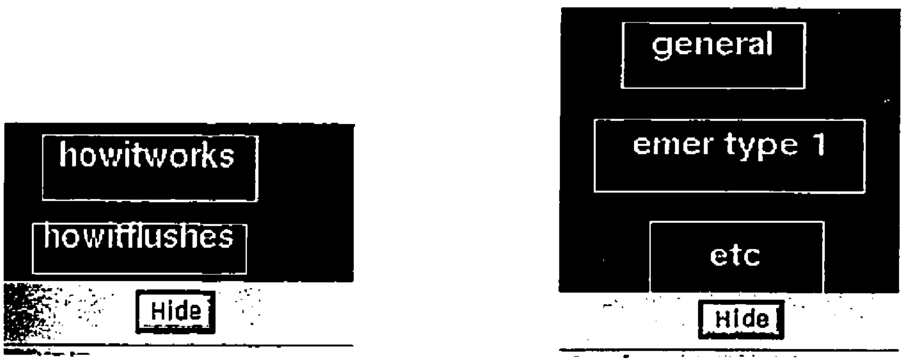


Figure 4.11: A subject embeds two concept maps inside the "operation" node and "repairs" node from the top level map given in figure 4.10.

Chapter 5

Summary and Conclusions

The concept mapping study provided positive feedback for the tool's potential. As the Internet matures, the concept map can be integrated into classrooms and serve as a valuable educational tool.

This thesis acts as the first step in the examination of a computer-based, concept mapping tool. This chapter summarizes the research and discusses future enhancements to improve the system.

5.1 Future Enhancements on Concept Mapping Systems

As an initial research prototype to a computerized concept mapping system it is important to discuss how the system can be further improved on the basis of user feedback. This section examines the possibilities.

5.1.1 Moving Towards a Three Dimensional Concept Map

Subject A suggested that "3D concept map for meta-constructs" would be useful (see Appendix C.3.16). Moving the structure to a three-dimensional view may be easier for the user. Colin Ware and Glenn Franck [1] examined whether network graphs were easier to view in two-dimensions or three dimensions. They focused on path detection between two highlighted nodes. Their results found that the percent error vs. the number of nodes was constantly growing as the graph grew larger (not surprising), and that a head mounted system coupled with stereo viewing was three times as effective as a two-dimensional graph of the same size. This leads us to consider three-dimensions in concept maps; it would also reduce screen clutter and increase cognitive ability to distinguish objects by shape, however, this study focused only on finding paths between two nodes (not a common feature in concept maps) and does not account for the extra cognitive load in *making* a concept map (a three-dimensional graph drawing tools interface would be more complex to use than a simple two-dimensional interface).

Ware and Franck [3] also discuss how three dimensions can use form, lighting, texture and wireframe effects to add more cognitive contrast between objects. Three-dimensional networks can also display a greater number of nodes than typical two-dimensional displays.

However, most of Ware and Franck's work focused on graph/network structures, which have different operations and needs than concept maps. One important difference is that Ware and Franck only examined navigation through a graph structure and not the construction of a graph. If the interface for three-dimensional concept maps overloads the users cognitive capabilities, it will distract from learning. Furthermore, the computational power needed to produce three-dimensional graphics far exceeds the two-dimensional concept map, and may make the typical students hardware incapable of running such a tool.

5.1.2 Integration of Media Types

One major problem of the current concept mapping system is the organization of multimedia based on the media type (e.g. text is separate from audio and image rather than integrating them together seamlessly). Margaret Recker [4] has studied multimedia systems and how media types affect the ability to teach:

Text	Abstract Principles
	Specific Instruction
	Explanations
Animations	Dynamic interactive representation
	Constructive visualization
Pictures	Examples
	Graphical display of relations
Sound	Voice over text
	Warnings
	Summaries

The table shows that different media types have different purposes and should be integrated together to create a lesson plan. Recker states that,

> "Multimedia systems instead should facilitate access to information and activities that support effective knowledge construction and learning by students. Designing such a system requires research into how students will actually use such systems, what kinds of usage actually improves learning and what types of educational materials these systems should provide."

Recker's research ultimately found that objects should not be placed together by media types, but rather by lesson or instruction. The current model of concept mapping separates objects by media type instead of integrating all media types together (such as HTML). A better interface to the node content area would be a significant advance to the system.

5.1.3 Grouping and Hiding Nodes and Links

Several users addressed the need for grouping nodes of like properties together. By placing similar nodes in groups based on some criteria (where nodes can belong in 'x' number of groups), queries can be made on concept maps to only show relevant nodes. Simple queries such as "belongs to A and B but not C" could be used to show users only relevant nodes and links and help reduce screen clutter.

Grouping of nodes could also allow group movement (moving an entire group of nodes together) and group modifications (e.g. changing all nodes which belong to some group into a certain colour). Ideally, nodes within a group could be represented by a node which represents the group of nodes within a concept map. The user then has the option of opening a group node to see all of its contained nodes.

5.1.4 Integrating Concept Maps With Other Applications

The concept mapping tool is flexible and, given minor modifications, can be placed in specific applications. One possible use for the concept mapping system is as an organization tool for instructors.

An example is a conferencing system. Conferencing systems have been integrated into learning environments [2] to provide asynchronous communications between parties. Within the Virtual University Project at Simon Fraser University, a tool named VGroups provides online discussion groups. The concept mapping tool could be integrated into this system to facilitate navigation or organization of the discussion. One option may include creating tools for instructors to examine a specific student's work in a course. A wrapper function could access all messages from a particular student and all messages to which the student had responded to from the VGroups' database and convert them into a concept map. The resulting concept map would act as an organizational tool for an instructor to navigate through a student's progress. Another option would be to provide a representation of a conference's structure within a concept map. This graphical aid may help in navigating through messages and seeing relationships build between discussion threads.

One suggestion in the "Comments and Suggestions" was to integrate concept mapping within CZ Web [27], which is a graphical, 2D road map used when surfing the World Wide Web. A hierarchical structure of Web pages is built from the set of sites visited and reduces space for all pages, as well as maintaining the context of pages. This allows users to return from and go to web sites previously visited with minimum difficulty. CZ Web could take advantage of some of the relationships between sites and integrate these into its tool. Users may wish to create different structures of their web site using a concept map and take advantage of CZ Web's screen saving methods and context handling.

5.1.5 Improving User Interface Design

One large problem in the early stages of concept mapping was the user interface design. The difficult interface caused some users to become frustrated. The user surveys reflect the importance of the interface to the concept mapping tool. To convince students and educators to adopt the new pedagogy presented to them, we must reduce the amount of overhead needed to learn how to use the tool. While the larger interface issues are outside the scope of this thesis (such as the screen real estate problem), several changes have been made from the initial prototype to improve interface design and increase usability.

Pull down menus are now used in addition to a floating palette. This was done because palette windows are not useful for one time, immediate events on one specific map, such as "Save File", "New", etc. Clicking on a palette window now exclusively changes the "mode" of the concept mapping tool. For example, when a user clicks on the "Rectangle" area of the tool palette, no immediate event occurs, other than the notification to the user that the "Rectangle" tool is now selected. The initial version often popped up windows from the

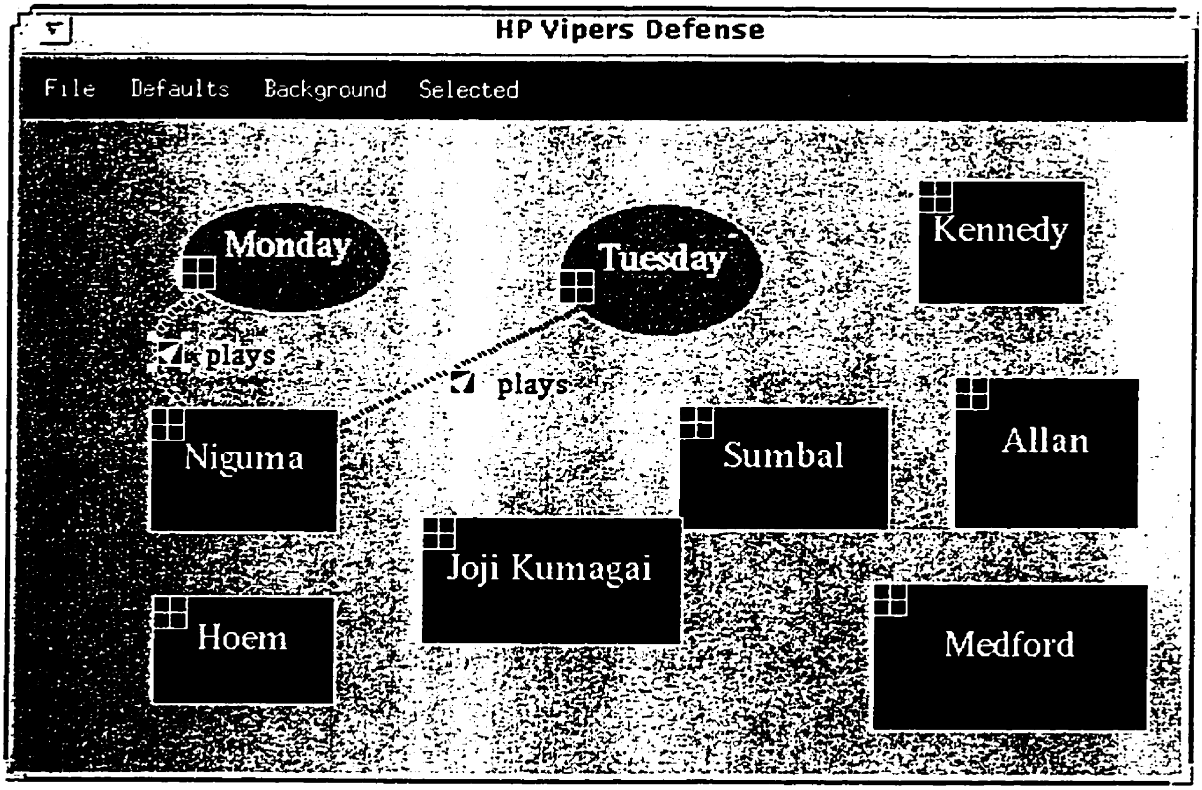


Figure 5.1: The user is now able to change the colour of the background, the links' label colour and each node displays in its top right corner an indicator of whether multimedia is contained in the node or not.

palette window.

Users are now able to select a specific attribute (e.g. node colour, link colour, node font) and apply it to all selected items in a concept map by using a pull down menu. The initial version required the user to change all attributes at once.

Several other features were added which were suggested by users. Links are drawn "thicker" so they could be more easily identified and are able to change the colour of their label. The concept map's background was also changeable, instead of always being black. The new version is illustrated in 5.1.

A greater number of prompts was also provided. Immediately after a node is created, a prompt window is generated for the name of the node. This is useful because the user's first agenda upon creating a new node is usually to name it. Windows are also opened closer to the user's cursor rather than letting the Java^{TM} compiler decide where to put the new windows. Figure 5.2 shows the new window which prompts the user to input a node name.

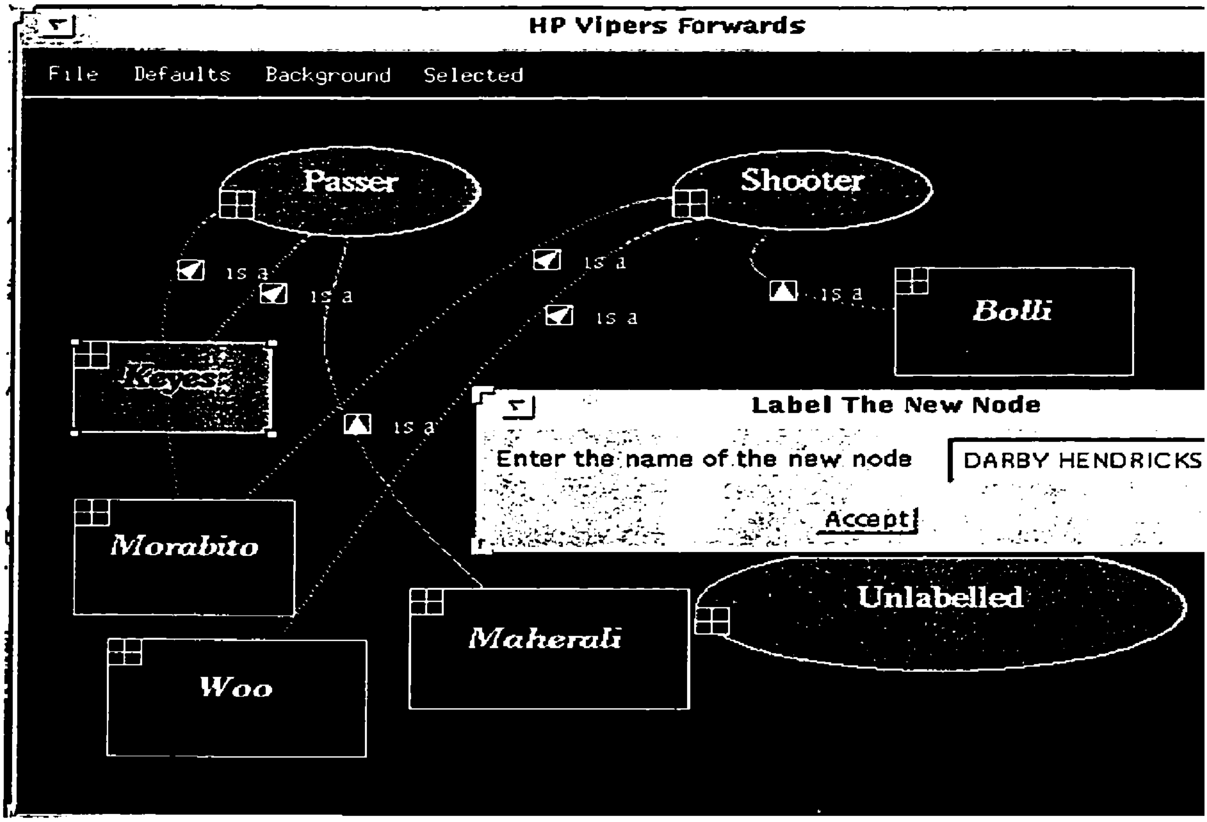


Figure 5.2: The user is prompted for a node name when adding a new node. This was added since most users typically change a node's name immediately after it is created.

Concept maps were also drawn to give some notion of what was inside its node's contents. One user had complained that he/she had to open all nodes to see if a sound, image, URL or concept map was embedded inside. The new concept mapping tool draws nodes with boxes containing either checkmarks or blanks to show the user that a given node has sound, image, URL information or an embedded concept map. This is shown in figure 5.2.

One major improvement to the concept mapping tool would be to switch the input device from a mouse to a laser pen. This would further reduce the overhead in learning the interface (similar interface as pen and pencil model) and allow concept maps to be sketched out quickly.

5.1.6 Using Concept Maps to Evaluate Knowledge

Concept maps are drawn to represent a learner's knowledge space and to demonstrate the amount of knowledge present in a given domain. If concept maps could be evaluated in some objective manner rather than purely subjectively, it would allow for an automatic grading system for students. This would reduce the time required by instructors to grade the maps and remove some of the confusion a student has on why a concept map is "bad". It would also encourage students to grade their own maps and continuously build and improve them.

One possible method of evaluating maps is using conceptual structures. The Peirce group [31] has written software to develop a GUI based conceptual structure creation tool which supports databases. Many features are being planned. However, problems exist when moving from conceptual structure to a concept map (discussed in section 2.3.2).

A better method to evaluate maps is to create an algorithm to determine how many key concepts and relationships were identified and give them weight according to their importance. This marking could be partially automated and would require some intelligence to understand the context of the domain studied and allowing synonyms for concept and relationship names. Other portions of the current concept map, such as text, images, URLs and sounds, would have to be graded for their relevance by the instructor.

5.1.7 Concept Maps as Groupware

Currently, the concept mapping tool has no mechanism for editing a map by several users concurrently. While concept maps may be readable to many users, editing amongst several people is not yet possible.

One useful feature which could be added is to allow users to "share" a concept map with others and observe changes in real-time while receiving text suggestions from other students. For example, Student A may add a link between two concepts while Student B looks on. Student B could see the change suggested by Student A and send comments back (e.g. "I don't think those two concepts are related. I think the relationship between these two other concepts are more relevant"). This change creates a groupware environment between users.

5.2 Conclusions

Moving the concept map to a computerized environment has improved the capabilities of typical paper and pencil concept maps. Subjects stated that they liked the ability to add URLs, sounds and images to concept maps and that they preferred the computer model to the paper and pencil. Many subjects also took advantage of the ability to build hierarchical concept maps, which is not possible in paper and pencil models. Although changes are still required to make the system more usable (user interface design changes, robustness and more mature Java^{TM} and Internet applications), the situation should improve as development continues.

The studies have also uncovered the variance in learning approaches taken by subjects. Different mental models and approaches towards problem solving were seen in the students' concept maps. By using a constructivist approach, subjects were also able to create unique concept maps that relied on a broader, fuller understanding of the subject matter.

The user study conducted in this thesis was small and limited. More research on a wider array of subjects with varied tasks is needed. Ideally, several classes at several institutions would adopt concept maps and allow students to experiment and share concept maps, but there are still many logistical problems behind this, such as providing enough computers with network accessibility to students, acceptance of instructors of new constructivist pedagogy, ethics issues, etc.

This thesis has succeeded in developing and evaluating a multimedia, Internet capable concept mapping tool which can run on many platforms. The user study gave evidence that the features unique to the computerized version were useful.

Appendix A

Official Task Description

Procedure For Concept Mapping Study

Subjects will be selected from a group of graduate students, faculty or research assistants. None of these subjects selected will be under eighteen years of age. Approximately a dozen subjects will be selected.

Each subject will be given some verbal training on concept mapping and they will be introduced to the building of concept maps through concepts and relationships. They will be shown several hand drawn concept maps as examples.

The subject will then be introduced to the computer software which aids in generating concept maps. The concept mapping tool runs along with Netscape and provides drawing facilities and integration of Internet resources. A demonstration will be given to subjects on how to use the computer software to generate their own concept maps. The subjects will work with the experimenter on viewing and extending several pre-made example concept maps.

Once the subjects are familiar with the softwares interface and functionality, they will be required to create their own concept maps, using various text, URL's and multimedia files they will have available to them. They will optionally be allowed to surf the web to find other information.

Once this process is complete, they will be asked to fill out a questionnaire on their Internet experience and their opinions on the software.

Appendix B

User Survey

Background Information

Where do you rank yourself as an Internet user?

novice 1 2 3 4 5 expert

How often do you use Netscape?

never 1 2 3 4 5 everyday

Are you familiar with different file types for images and sounds (eg. .au, .jpg, .gif)?

Yes No

Have you ever used computer software for composing or drawing graphics (eg. Xpaint, PhotoShop, Superpaint)?

Yes No

Do you have any experience in teaching?

no experience 1 2 3 4 5 educator

How familiar were you with concept maps before today?

didn't know what they were 1 2 3 4 5 use them frequently

Interface Issues

How difficult was it to

- understand and control the palette (used for changing modes etc)

difficult 1 2 3 4 5 not difficult

- Add rectangles, images and ellipses

difficult 1 2 3 4 5 not difficult

- Add relationship links between nodes

difficult 1 2 3 4 5 not difficult

- Move and resize objects

difficult 1 2 3 4 5 not difficult

- Change the location of links to the specific location that you wanted

difficult 1 2 3 4 5 not difficult

- Change the physical appearances of nodes and links

difficult 1 2 3 4 5 not difficult

- Open a nodes or links contents to view information

difficult 1 2 3 4 5 not difficult

- Add sound, images and URL's into a node or links contents

difficult 1 2 3 4 5 not difficult

Which interface do you prefer (consider operations which apply to both pencil and paper and computer models such as adding nodes, deleting nodes, moving nodes, coloring nodes, resizing nodes)?

pencil and paper computer

Did the difficulty using the computer interface affect the creation of your concept map?

Yes No

What advantages does the computer aided concept maps have over paper and pencil model?:

What disadvantages does the computer aided concept maps have over paper and pencil model?:

Concept Map Issues

A constructivist believes that students build knowledge by constructing concepts to old knowledge and building relationships between them to create a greater understanding. A behaviorist believes that knowledge occurs when information is transferred from an instructor to a student. Do you agree with :

behaviorist 1 2 3 4 5 constructivist

How important do you think the Internet will be as a resource of information for education in the future?

not important 1 2 3 4 5 important

If you were in an educational setting as either a teacher or student how useful would you find

- adding text comments to nodes and links?

  not useful 1 2 3 4 5 very useful

- the ability to connect URL's to nodes?

  not useful 1 2 3 4 5 very useful

- the ability to add sound files to nodes?

  not useful 1 2 3 4 5 very useful

- the ability to add image files to nodes?

  not useful 1 2 3 4 5 very useful

- the ability to represent nodes as images?

  not useful 1 2 3 4 5 very useful

- the ability to embed concept maps within nodes?

  not useful 1 2 3 4 5 very useful

How effective would concept maps be in the following scenarios:

getting instructors to create concept maps as learning modules to students

Not effective 1 2 3 4 5 Very effective

helping students to construct their own knowledge

Not effective 1 2 3 4 5 Very effective

organizing and grouping useful information together

Not effective 1 2 3 4 5 Very effective

method of navigating through a personalized web space

Not effective 1 2 3 4 5 Very effective

Which types of educational training do you feel this is most effective for (be as specific or unspecific as you like)?

Which types of educational training do you feel this is least effective for (be as specific or unspecific as you like)?

What added functions would you like to see made to the concept mapping tool?

Comments and Suggestions:

Appendix C

User Survey

These are the results from the ten subjects that participated in the study. Each subject was given a letter in the alphabet which represents their response to given questions. The subjects are alphabetized from a-l, with no "f" subject or "j" subject, because they did not complete the experiment.

C.1 Background Information

C.1.1 Where do you rank yourself as an Internet user?

novice 1 2 3 4 5 expert

Responses			
Rank	Value	Subject	# Responses
Novice	1		0
:	2		0
:	3	a	1
:	4	bcgl	4
Expert	5	dehik	5

C.1.2 How often do you use Netscape?

never 1 2 3 4 5 everyday

Responses			
Rank	Value	Subject	# Responses
Never	1		0
:	2		0
:	3	g	1
:	4	l	1
Everyday	5	abcdehik	8

C.1.3 Are you familiar with different file types for images and sounds (eg. .au, .jpg, .gif)?

Yes No

Responses		
Response	Subject	# Responses
Yes		0
No	abcdeghikl	10

C.1.4 Have you ever used computer software for composing or drawing graphics (eg. Xpaint, PhotoShop, Superpaint)?

Yes No

Responses		
Response	Subject	# Responses
Yes		0
No	abcdeghikl	10

C.1.5 Do you have any experience in teaching?

no experience 1 2 3 4 5 educator

Responses			
Rank	Value	Subject	# Responses
No Experience	1		0
:	2		0
:	3	adghi	5
:	4	bck	3
Educator	5	el	1

C.1.6 How familiar were you with concept maps before today?

didn't know what they were 1 2 3 4 5 use them frequently

Responses			
Rank	Value	Subject	# Responses
Didn't Know What they were	1	bi	2
:	2		0
:	3	acdeghk	7
:	4	l	1
Used Them Everyday	5		0

C.2 Interface Issues

How difficult was it to

C.2.1 understand and control the palette (used for changing modes etc)

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2	h	1
:	3	el	2
:	4	bcd	3
Not Difficult	5	agik	4

C.2.2 Add rectangles, images and ellipses

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2		0
:	3		0
:	4		0
Not Difficult	5	abcdeghikl	10

C.2.3 Add relationship links between nodes

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2		0
:	3		0
:	4	cel	3
Not Difficult	5	abdghik	7

C.2.4 Move and resize objects

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2	l	1
:	3		0
:	4	ek	2
Not Difficult	5	abcdghi	7

C.2.5 Change the location of links to the specific location that you wanted

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2	h	1
:	3	ek	2
:	4	c	1
Not Difficult	5	abdgi	5

* One respondent did not answer this question (l).

C.2.6 Change the physical appearances of nodes and links

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2	b	1
:	3	h	1
:	4	k	1
Not Difficult	5	acdeg	5

* One respondent (l) claimed that this was "not applicable".

C.2.7 Open a nodes or links contents to view information

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1	l	1
:	2		0
:	3	ek	2
:	4	dh	2
Not Difficult	5	abcgi	5

C.2.8 Add sound, images and URL's into a node or links contents

difficult 1 2 3 4 5 not difficult

Responses			
Rank	Value	Subject	# Responses
Difficult	1		0
:	2		0
:	3	k	1
:	4	gh	2
Not Difficult	5	bcd	3

* Three respondents did not respond (a,i,e), stating it was "not applicable" or they "didn't have time to try". Another respondent (l) placed this somewhere between 2 and 3.

C.2.9 Which interface do you prefer (consider operations which apply to both pencil and paper and computer models such as adding nodes, deleting nodes, moving nodes, coloring nodes, resizing nodes)?

pencil and paper   computer

Responses		
Response	Subject	# Responses
Pencil and Paper		0
Computer	abchik	6
Depends	agl	3

* One respondent (d) did not answer.

C.2.10 Did the difficulty using the computer interface affect the creation of your concept map?

Yes   No

Responses		
Response	Subject	# Responses
Yes	abdhikl	7
No	ceg	3

C.2.11 What advantages does the computer aided concept maps have over paper and pencil model?:

Remarks	
Subject	Comments
A	depends on what you are trying to do. This was very convenient when working with info already on the web - I had a window up for the info & built the concept map about
B	- copy and paste - color and appearance changes - automating redrawing of relations
C	It's easier and more convenient to make corrections
D	- the network content/multimedia file types - quite editable - can change files without too much hassle.
E	- editing for update moving nodes with attached links
G	- greater variety of media available - easily modifiable - important - colors, shapes aid in visualization
H	- Resulting concept map is much prettier - making modifications to an existing map is easy - multimedia!
I	- Easy to move objects around, change them, annotate...etc
K	Incremental modification and creation: since I evolved the map over time, wholesale changes could be made without redrawing by hand. The redrawing affected further creation. Important were link and node movement and group attribute settings.
L	- easier editing - access to web pages directly

C.2.12 What disadvantages does the computer aided concept maps have over paper and pencil model?:

Remarks	
Subject	Comments
A	More constraints on shapes of nodes, exactly where links go (i.e. "shape" of links) but this doesn't really change the meaning of the maps - just being picky
B	learning curve
C	People have to understand the functions of the toolbar. Many mistakes can be made before I get used to the buttons
D	- speed - flexibility of different link types not conceived by software
E	- slow, a lot of blinking due to repaint
G	not quite as fast - if all you want is a rough sketch to get the general idea, then pencil and paper is the way to go
H	- Takes longer to produce - There may be memory advantages to physically writing a map
I	slower to construct objects initially
K	Original sketching is much faster on paper for me, I could draw a rough sketch much faster if I knew what I were drawing. I would use multiple pieces of paper and compare previous drawings. I could use the floor to spread out the map.
L	- lack of flexibility - have to keep moving/resizing windows - all of the disadv. that dwg. pgms have over quick pencil sketch

C.3 Concept Map Issues

C.3.1 A constructivist believes that students build knowledge by constructing concepts to old knowledge and building relationships between them to create a greater understanding. A behaviorist believes that knowledge occurs when information is transferred from an instructor to a student. Do you agree with :

behaviorist 1 2 3 4 5 constructivist

Responses			
Rank	Value	Subject	# Responses
Behaviorist	1		0
:	2		0
:	3	k	1
:	4	eghl	4
Constructivist	5	abcdi	5

C.3.2 How important do you think the Internet will be as a resource of information for education in the future?

not important 1 2 3 4 5 important

Responses			
Rank	Value	Subject	# Responses
Not Important	1		0
:	2		0
:	3	a	1
:	4	dehi	4
Important	5	bcgkl	5

If you were in an educational setting as either a teacher or student how useful would you find

C.3.3 adding text comments to nodes and links?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2		0
:	3		0
:	4	bdk	3
Very Useful	5	aceghil	7

C.3.4 the ability to connect URL's to nodes?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2		0
:	3		0
:	4	dehi	4
Very Useful	5	abcgkl	6

C.3.5 the ability to add sound files to nodes?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2	eil	3
:	3	dk	2
:	4	abcgh	5
Very Useful	5		0

C.3.6 the ability to add image files to nodes?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2	eil	3
:	3	dk	2
:	4	abcgh	5
Very Useful	5		0

C.3.7 the ability to represent nodes as images?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2		0
:	3	il	2
:	4	acdk	4
Very Useful	5	begh	4

C.3.8 the ability to embed concept maps within nodes?

not useful 1 2 3 4 5 very useful

Responses			
Rank	Value	Subject	# Responses
Not Useful	1		0
:	2		0
:	3	di	2
:	4	h	1
Very Useful	5	abcegkl	7

How effective would concept maps be in the following scenarios:

C.3.9 getting instructors to create concept maps as learning modules to students

Not effective 1 2 3 4 5 Very effective

Responses			
Rank	Value	Subject	# Responses
Not Effective	1		0
:	2	i	1
:	3	hl	2
:	4	bdeg	4
Very Effective	5	ack	3

C.3.10 helping students to construct their own knowledge

Not effective 1 2 3 4 5 Very effective

Responses			
Rank	Value	Subject	# Responses
Not Effective	1		0
:	2		0
:	3		0
:	4	bdeh	4
Very Effective	5	acgikl	6

C.3.11 organizing and grouping useful information together

Not effective 1 2 3 4 5 Very effective

Responses			
Rank	Value	Subject	# Responses
Not Effective	1		0
:	2		0
:	3	ak	2
:	4	ei	2
Very Effective	5	bcdghl	6

C.3.12 method of navigating through a personalized web space

Not effective 1 2 3 4 5 Very effective

Responses			
Rank	Value	Subject	# Responses
Not Effective	1		0
:	2		0
:	3	acdgi	5
:	4	be	2
Very Effective	5	hk	2

* One respondent proposed a combination of Concept Mapping with another tool to provide good navigation through the World Wide Web.

C.3.13 Which types of educational training do you feel this is most effective for (be as specific or unspecific as you like)?

Remarks	
Subject	Comments
A	representing info as concepts and relations between concepts
B	Sex education: students could find out info about stuff they may be too embarrassed to ask
C	Analyzing the technical experiment e.g. Understanding the procedure of starting the car engine
D	I really am not sure where this fits into any educational context. I suppose I would use it to clarify my relationship to a particular subject topic, flush out links in the topic that I might have overlooked. Then, I would use this knowledge to produce something like a term paper. It's like a preparation step along the way to something else.
E	*No response*
G	Useful for students (especially younger ones who are still developing thinking patterns) to help organize their thoughts and visualize a problem. Not limited to "hard" sciences, either. Social sciences could benefit (eg. history)
H	- education - logic / AI - biology
I	Understanding physical sciences; wonder if it's useful for arts courses (history, polisci, English lit, etc.)
K	Probably scholarly review such as literature review (eg. Philosophy texts which rehash and invent many abstract concepts). Also, non-hierarchical areas such as interface design, graphic arts, and human psychology could benefit. A concept map could organize the first unit of a course (ie the "review of previous concepts" section).
L	In general, getting an overview, and as a nav. aid. It needs to be much more "transparent"

C.3.14 Which types of educational training do you feel this is least effective for (be as specific or unspecific as you like)?

Remarks	
Subject	Comments
A	Knowledge with structure other than concepts and relations between concepts or for the actual exploration of the relations – so I might use a frame to explore all possible relationships between sets of concepts
B	religions training
C	Spoken Languages training
D	Not really sure
E	*No response*
G	Anything which is based mainly on a transfer of facts from teacher to students (I have taken many psych courses like this)
H	mathematics (aside from geometry)
I	Not sure how useful this would be for abstract domains - math, theoretical stuff. Would be nice if it could be used for it though!
K	Practical applications typically learned by apprenticeship. For example pottery making, stock price prediction and mechanics. Although knowledge models might help, some learning is done best by doing and experiencing under guidance.
L	*No response*

C.3.15 What added functions would you like to see made to the concept mapping tool?

Remarks	
Subject	Comments
A	- undo last edit - bidirectional arrows for links
B	drag 'n' drop url's, links, pics, audio from the browser
C	- Undo button - Change Background color - when the link is selected by using the icon, it's good to show the ends of the link, then user can click on it and move(drag) to another box (event). It can save the time from deleting the link and create another one.
D	Meta nodes : if I have 3 nodes and they are all related and constitute a larger concept, I would like the ability to show this. ie: just as I, II and III are all related so too is a,b, and c. Equally, this map could be part of yet another concept.
E	*No response*
G	Simply using an alternate mouse button to edit nodes would be good, instead of going back to the edit panel.
H	make the sounds/image more accessible from the node display somehow?
I	Not sure how useful representing a concept map within a node. I found that things didn't neatly order themselves into disjoint hierarchies. eg. A key interacts with the components of a lock but if I put the lock components of a lock but if I put the lock components into groups of concept maps, I want the key to be related to both the upper level (the lock) and the lower levels (groups of components, the components themselves).
K	Link-to-link relations(?). UNDO!, group motion (was it there), alternative views, and some type of automated layout of selected multiple components.
L	Somehow we need to combine CZ Web and Concept Mapping to get best of both

C.3.16 Comments and Suggestions:

Remarks	
Subject	Comments
A	3D concept map for meta-constructs
B	- resize box should have guiding band - combine set and select - This is excellent work! As the technology of books becomes obsolete (sp), techniques such as this will certainly become the standard for learning. Shakespeare would have been impressed. But he's dead. (I hope you're happy).
C	- when a specific link is created, it takes pretty long time to "refresh" the link. - It's really helpful to analyze a system by creating a concept map step by step
D	- more link styles - thicker lines - different labels for direction * the interface for the toolbar needs to be cleared up a bit. - I'd juggle the images around and also try to find new widgets. (a cursor change when a new tool is selected would be cool, too.)
E	- display colors in the interface - change image size within palette - combine move and select so that click and drag and select - Node Set $\rightarrow$ don't change name or URL when grouping nodes, potentially switch from ellipse to square. - move label - show icon or something to represent nodes or links with sound, images, etc. inside the concept - remove concept maps - need an "undo" - possibility to change thickness of a link - need a "group" and "ungroup" - The cursor is not visible when editing field and moving cursor with arrows

Remarks	
Subject	Comments
G	Was alot of fun. I really think using something like this could encourage learning, especially in younger students (such as under 12)
H	- just work on the palette interactions - maybe use double-click on a node for some function.
I	Maybe it depends on how the source information is presented, but I kind of wanted an easy way to group stuff together. I found that I built the concept map from the bottom up- I started with all the little details and as things got cluttered, I wanted to group stuff to clean things up (but see my prev. comment on hierarchies). I wonder if something like Apple's HotSauce would be useful? I didn't make much use of the Internet links of multimedia options. In a sense, I thought of the concept map as a great way to take point form notes - I'm not sure how often I would refer back to the concept map after I constructed it, so it didn't occur to me to add lots of images and sound. BTW- I really like the idea of concept maps and I'll probably try using them myself. Last thing - Java was way too slow on the machine I was using, so this made things a bit tedious.
K	- Adding a node, I think I almost always want to set properties immediately so it might be a good idea to have this screen pop-up immediately. - some visual indication of "thinking" would be useful for operations which take some time (eg paste)
L	The UI is critical. I found the basic concepts (no pun intended) useful, but the actual UI really awkward. Large windows kept getting in my way and mode changes made for more mouse-motion than I like.

BIBLIOGRAPHY

1. Colin Ware and Glenn Franck "Viewing a Graph in a Virtual Reality Display is Three Times as Good as a 2D Diagram", *1994 IEEE Conference on Visual Languages*, Conference Proceedings 1994

2. Ashish Pimplapure, "Virtual Groups: A Web Based Electronic Conferencing System for Online Education", Master's Thesis, Simon Fraser University, 1996

3. Glenn Franck and Colin Ware, "Representing Nodes and Arcs in 3D Networks", *1994 IEEE Conference on Visual Languages*, Conference Proceedings, 1994

4. Mimi M. Recker, Ashwin Ram, Terry Shikano, George Li and John Stasko. "Cognitive Media Types for Multimedia Information Access". *Journal of Education Multimedia and Hypermedia*, June 1995.

5. Doris H.U. Kochanek and Richard H. Bartels "Interpolating Splines with Local Tension, Continuity and Bias Control", Computer Graphics, Vol. 18, Num 3

6. Marlene Scardamalia and Carl Bereiter, "Technologies For Knowledge Building Discourse", *Communications of the ACM*, May 1993, Vol 36, No. 5

7. Rosalind Driver, Hilary Asoko, John Leach, Eduardo Mortimer and Philip Scott, *Educational Researcher*, October 1994

8. Seymour Papert, "Literacy and Letteracy in Media Ages", *Wired Online*

9. Margaret Recker, Ashwin Ram, George T. Li, Terry Shikano and John Stasko, "Multimedia Information Access in Support of Knowledge Construction"

10. Virtual U Project
http://virtual-u.cs.sfu.ca

11. Calculus, Concepts, Computers and Cooperative Learning (C4L)
http://cuhwww.upr.clu.edu/mate/C4L

12. Alfred W. Hubler and Andrew M. Assad, "CyberProf: An Intelligent HCI interface for Asynchronous Training and Teaching",
http://www.ccsr.uiuc.edu/cyberprof-docs/general, 1994

13. Joseph D. Novak and D. Bob Gowin *Learning How To Learn*, Cambridge University Press, 1984

14. M. Sheelagh T. Carpendale, David J. Cowperthwaite, F. David Fracchia, "3-Dimensional Pliable Surfaces: For the Effective Presentation of Visual Information", Simon Fraser University, 1995

15. Kim Fairchild, Steven Poltrock, George Furnas, "Semnet:Three-Dimensional Graphic Representations of Large Knowledge Bases",

16. David H. Jonassen, Katherine Beissner, Michael Yacci, "Structural Knowledge: techniques for representing, conveying and acquiring structural knowledge", Hillsdale, N.J., 1993

17. The Exploratorium
http://www.exploratorium.edu

18. New Jersey Networking Infrastructure in Education
http://www.njnie.dl.stevens-tech.edu/curriculum/currichome.html

19. David H. Jonassen, "Mental Models: Knowledge in the Head and Knowledge in the World"

20. Erik F. Strommen, "Children's Television Workshop",
http://www.ilt.columbia.edu/k12/livetext/docs/construct.html

21. R. Axelrod, "Structure of Decision". Princeton, New Jersey, Princeton University Press, 1976

22. C. Eden, S. Jones and D. Sims "Thinking in Organizations", London, Macmillan (1979)

23. S. Buckingham Shum, A. MacLean, V. Bellotti and N. Hammond. "Graphical Augmentation and Design Cognition", Technical Report KMI-TR-25, Knowledge Media Institute, The Open University, U.K., 1996

24. Richard Catrambone, "Aiding Subgoal Learning: Effects on Transfer", *Journal of Educational Psychology*, 1995, Vol 87, No. 1

25. Wayne State University CSC 811 class
http://www.cs.wayne.edu/ lmn/CSC811/concepts/map_arc.html

26. Brian R. Gaines and Mildred LG Shaw, "Collaboration Through Concept Maps", *CSCL '95 Proceedings*

27. G. Collaud, J. Dill and P. Tan. "The Continuously Zoomed Web- a Graphical Navigation Aid for WWW". Proc. Visualization '96, Late Breaking Hot Topics, pp.1-3

28. Nancy Howard, "Questmap EPSS Review",
http://tiger.coe.missouri.edu/ perfsppt/questmap.htm

29. Roger Hurwitz and John C. Mallery, "The Open Meeting: A Web Based System for Conferencing and Collaboration", Artificial Intelligence Lab, M.I.T.,
http://www.ai.mit.edu/projects/iiip/doc/open-meeting/paper.html

30. J.F. Sowa. "Conceptual Structures: Information Processing in Mind and Machine". Addison Wesley, 1984

31. "PEIRCE Group Home Page",
http://www.cs.adelaide.edu/users/peirce

32. Eileen C.Way, "Conceptual Graphs- Past, Present and Future",
Conceptual Structures: Current Practises, pg. 11-30 Springer-Verlag, 1994

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