REPORT DOCUMENTATION PAGE

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
30-06-2006	Final	Dec 2001 - Dec 2002

4. TITLE AND SUBTITLE

CRESST Human Performance Knowledge Mapping System

5a. CONTRACT NUMBER

5b. GRANT NUMBER

N00014-02-1-0179

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Gregory K. W. K. Chung, Joanne K. Michiuye, David G. Brill, Ravi Sinha, Farzad Saadat, Linda F. de Vries, Girlie C. Delacruz, William L. Bewley, and Eva L. Baker

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

UCLA CSE/CRESST
300 Charles E. Young Dr. North
300 GSE&IS/Mailbox 951522
Los Angeles, CA 90095-1522

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The UCLA National Center for Research on Evaluation, Standards, and Student Testing (CRESST) designed and developed a knowledge mapping tool intended to measure content understanding. This report presents a review of knowledge mapping scoring methods and current online mapping systems, and the overall design, functionality, scoring, usability testing, and authoring capabilities of the CRESST system. While several tools exist that are available to construct knowledge maps, CRESST's knowledge mapping tool is one of the only systems designed specifically for assessment purposes, the only system that can support multiple assessment formats, and the only system with an empirical research base. Limitations of the system and possible next steps are discussed.

15. SUBJECT TERMS

knowledge mapping, assessment, online mapping

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
Unclassified	Unclassified	Unclassified			19b. TELEPHONE NUMBER (Include area code)

**CRESST Human Performance
Knowledge Mapping System**

Deliverable – December 2002

Knowledge, Models, and Tools to Improve the
Effectiveness of Naval Distance Learning

Eva L. Baker
National Center for Research on Evaluation,
Standards, and Student Testing (CRESST)
University of California, Los Angeles

National Center for Research on Evaluation,
Standards, and Student Testing (CRESST)
Center for the Study of Evaluation (CSE)
Graduate School of Education & Information Studies
University of California, Los Angeles
301 GSE&IS, Box 951522
Los Angeles, CA 90095-1522
(310) 206-1532

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CRESST HUMAN PERFORMANCE KNOWLEDGE MAPPING SYSTEM

Gregory K. W. K. Chung, Joanne K. Michiuye, David G. Brill, Ravi Sinha,

Farzad Saadat, Linda F. de Vries, Girlie C. Delacruz, William L. Bewley,

and Eva L. Baker

CRESST/University of California, Los Angeles

Abstract

In this study we report on the design and development of a knowledge mapping tool intended to measure content understanding. We review knowledge mapping scoring methods and current online mapping systems. We then describe the overall design approach, functionality, scoring, usability testing, and authoring capabilities of our system. While there exist several tools available to construct knowledge maps, CRESST's knowledge mapping tool is one of the only systems designed specifically for assessment purposes, the only system that can support multiple assessment formats, and the only system with an empirical base. Limitations of the system and possible next steps are discussed.

Introduction

The Navy-wide distributed learning training vision is to deliver quality training—to the right people, at the right time, and at the right place—as part of a career-long training continuum supporting Navy operational readiness and personal excellence. Achieving this vision of delivering learner-centric training to individuals will require maximizing the overlap between instruction—its format, pacing, and complexity—and the individual's cognitive, affective, and learning predispositions and preferences, deficiencies, and strengths. Attaining this capability will help equip Sailors and Marines with effective mission-essential competencies when and where needed at an affordable cost.

A critical first step in developing learner-centric systems is gathering quality information about an individual's competency in a skill or knowledge domain. Such information includes, for example, an estimate of what trainees know prior to training, how much they have learned from training, how well they may perform in a future target situation, or whether to recommend remediation content to bolster a trainees' knowledge.

The focus of this report is on the development of a tool designed to assess a trainee's understanding of a content domain via graphical representation. The tool, referred to as the CRESST Human Performance Knowledge Mapping Tool (HPKMT), requires trainees to express their understanding of a content area by creating knowledge maps. Knowledge maps are network representations, where nodes represents concepts and links represent the relationship between two concepts. The questions that guided the development of the HPKMT were:

- What are the existing scoring methods for knowledge maps? While we had already had an approach for scoring knowledge maps, we were interested in incorporating any new developments in scoring approaches.

- What are the existing software packages that can be used for assessment purposes? At a minimum, we required the package to support the knowledge mapping format. In addition, we were interested in a tool that could support other, unforeseen formats. In a distributed learning context, it would be extremely useful to have a common user interface with a single metaphor to deliver different assessment formats. Thus, we reviewed existing software to determine whether there existed commercial, off-the-shelf (COTS) products that could be used.

- What are the key functional requirements for such an assessment tool? In a preview of our findings, we concluded from our evaluation of COTS products that there existed no product that would satisfy our requirements for an assessment tool.

There are three main sections of this report. In the first section, we situate the HPKMT within the general area of knowledge mapping for assessment purposes. We first review the different scoring approaches that have been used to evaluate the quality of knowledge maps. Our focus is on scoring because this aspect critically impacts the validity of the inferences drawn about trainee performance. We then discuss briefly current online mapping systems and our judgment of their ease of use and scoring capability. The second major section discusses the HPKMT functionality. Using the review of scoring, the review of online products, and our prior work with online knowledge mapping, we describe our design. We report on our experience with using the HPKMT in both a usability test and field test. The last major section is a description of the authoring prototype. We provide a functional description with screen shots for illustration purposes. We then discuss limitations of this work and identify next steps.

Overview of Scoring Methods for Knowledge Maps

A presumed critical capability of an assessment in a distributed learning setting is automated scoring. A critical validity issue of an assessment is the scoring, regardless of automated capability. In this section we briefly describe the different types of scoring and provide examples of their use. For in-depth reviews of assessment issues related to knowledge maps, see Ruiz-Primo and Shavelson (1996).

In general, scoring knowledge maps can be referent-based or referent-free. Referent-based methods compare a student's map against a referent map (e.g., an expert's map or other gold standard). Referent-free methods evaluate the student's map against a rubric or with other criteria (e.g., judging the quality of the propositions [node-link-node tuple], or counting the number of concepts in the map). In either case, different scoring approaches use to different degrees the configural and semantic properties of the network. Table 1 summarizes scoring methods.

Table 1
Simplified Summary of Knowledge Mapping Scoring Methods

	Configural	Semantic
Referent-free	Explicitly scores a map or elements of a map on its structural aspect (e.g., considering degree of hierarchical organization).	Explicitly scores a map or elements of a map on its semantic aspect (e.g., scoring quality of propositions).
		Example applications:
		Osmundson, Chung, Herl, and Klein (1999).
	Example application:	Shavelson (Ruiz-Primo, Schultz, Li, & Shavelson, 2001)
	Novak and Gowin (1984).	
Referent-based	Compares the network structure of a student's map and the referent map. Does not take into account the meaning of the relationships.	Compares the semantic structure of a student's map and the referent map (e.g., proposition-by-proposition comparison between a student's map and an expert's map). Ignores the configural aspects of the network.
	Example application:	Example applications:
	Herl, Baker, and Niemi (1996).	Herl et al. (1996).
		Osmundson et al. (1999).

Referent-Free Methods

The scoring procedure specified by Novak and Gowin (1984) is one of the earliest and most commonly used methods of scoring knowledge maps. Their method considers hierarchy as an important component of the scoring, as well as propositions, cross-links, and examples. In terms of hierarchy, credit is given for each hierarchical level showing subordinate concepts at a lower level as more specific than their parent concepts. Each valid and meaningful proposition is also credited, as are examples and cross-links. Cross-links are links between different hierarchical levels. Novak and Gowin's scoring scheme is weighted heavily towards the hierarchical structure of the map. The theoretical rationale for this scoring scheme is Ausabel's theory of learning, particularly the idea of subsumption (new ideas can be subsumed under more general concepts) and progressive differentiation (as learning occurs, there is more differentiation among the concepts, which is shown by the inclusion of more propositions and cross-links). Appendix A contains Novak and Gowin's scoring procedure.

Evidence from several studies suggests that Novak and Gowin's (1984) scoring scheme can differentiate between high- and low-knowledge students in biology (Markham, Mintzes, & Jones, 1994) and between first-year and advanced pediatric residents studying seizures (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). This scoring scheme also appears to be sensitive to learning, as student map scores increased over instruction (Pearsall, Skipper, & Mintzes, 1997; West et al., 2000).

A second scoring scheme that is commonly used considers only the propositions contained in the map and not the configural aspects. This method is to rate the quality of the propositions in the map. Each proposition is evaluated in terms of its accuracy. For example, Ruiz-Primo and colleagues used a proposition accuracy score as one measure of the quality of students' knowledge maps (Ruiz-Primo, Schultz, Li, & Shavelson, 1997a, 1997b; Ruiz-Primo et al., 2001). Each proposition in a students' map was scored on a 5-point scale, ranging from 0 (invalid/inaccurate) to 4 (complete and correct and showing a deep understanding of the relation between two concepts). Ruiz-Primo and colleagues found that students' proposition accuracy scores differentiated high-knowledge students from low-knowledge students (e.g., Ruiz-Primo et al., 1997a, 1997b) and students' map scores were moderately correlated (r between .40 to .50) with other measures of content knowledge formats (e.g., essays, multiple choice tests). Similar relationships have been found between knowledge map proposition accuracy scores and classroom end-of-unit tests and standardized tests of reading, math, and science (Rice, Ryan, & Samson, 1998), and between knowledge maps and physics problem solving (Austin & Shore, 1995).

Referent-Based Methods

Referent-based methods compare a student's map against a criterion map. Example referents include an expert's map, a composite map of experts, or the instructor's map. The essential measure is the number of propositions in the student map that are also in the referent map. Several studies have investigated the technical properties of this approach. For example, Ruiz-Primo et al. (2001), in addition to using proposition accuracy scores, also scored students' maps against an expert's map. The correlation between the proposition accuracy score and expert-based score was sufficiently high for Ruiz-Primo et al. to conclude that an expert-based method was the most efficient scoring method (i.e., in terms of scoring time and reliability of

scores). Similar results were found by Osmundson et al. (1999) and Chung, Harmon, and Baker (2001).

The findings of Ruiz-Primo et al. (2001) are consistent with earlier work by Herl (1995), Herl et al. (1996), and Osmundson et al. (1999). In general, scoring student knowledge maps using expert-based referents has been found to discriminate between experts and novices (Herl, 1995; Herl et al., 1996), discriminate between different levels of student performance (Herl, 1995; Herl et al., 1996), relate moderately to external measures (Aguirre-Muoz, 2000; Herl, 1995; Herl et al., 1996; Klein, Chung, Osmundson, Herl, & O'Neil, 2002; Lee, 2000; Osmundson et al., 1999), detect changes in learning (Chung et al., 2001; Osmundson et al., 1999; Schacter, Herl, Chung, Dennis, & O'Neil, 1999), and be sensitive to language proficiency (Aguirre-Munoz, 2000; Lee, 2000).

The final type of scoring is to simply compare the network topology of a student's map and the referent map. Herl et al. (1996) investigated the utility of this approach and found high correlations between scores based on a comparison of the network topology and scores based on the overlap of propositions between the student and expert map.

Summary

A variety of methods have been developed and researched for scoring knowledge maps. Using expert-based referent maps as scoring templates appears to be an efficient means of scoring and produces results comparable to proposition quality ratings. This finding has important implications for automated scoring purposes, as will be discussed in the next section.

Review of Existing Mapping Software

The purpose of this review was to identify COTS software that could be used for knowledge mapping for assessment purposes. Our guideline for inclusion was practical: If we were to adopt existing mapping software for our own assessment-focused applications, which software would we at least review for consideration? We reviewed 15 packages that were designed specifically for knowledge mapping or could be used to construct knowledge maps. Two raters judged the software on the following criteria: (a) intuitiveness of the interface, and (b) automated scoring capability. One rater conducted the usability study described in the next section, and

the second rater had no experience with knowledge mapping but had experience using graphical packages. Each criterion is briefly described.

Intuitiveness of the Interface

One of the critical lessons learned from our field experience using computer-based assessments is that the user interface needs to be as easy to use as possible. Typical field conditions include limited time in a group instructional setting in a non-computer lab room (e.g., classroom, library, or side room). The configuration of the setting has important training implications. Usually group instruction is required on how to use the software and users are not seated in front of a computer using the software during training. If the user interface is complex, then questions arise during the task. Under conditions where there is ample time, questions are usually not a problem; however, when there are time constraints (e.g., a class period) and the purpose is assessing student knowledge, then user-interface complexities may introduce undesirable effects that are unrelated to the task. In a distributed learning setting, we expect that the interface will play an even more important role as there will be no face-to-face support. Thus, ease of use is an important criterion for practical and validity reasons.

Scoring Capability

A second criterion is that if the intention is to use knowledge maps for assessment purposes in a distributed learning context, then as a practical matter there needs to be automated scoring capability. Further, it is not enough to be able to "score" a map. There should be validity evidence associated with the scoring algorithm, either by implementing one of the approaches discussed in the previous section, or by documenting the relationship between the scoring algorithm and other external measures, theory, or the extant literature.

Table 2
Summary of Product Evaluations

Product	Intuitiveness of the user interface		Automated scoring capability	Comments
	R1	R2		
IHMC Concept Map Software	L	L	No	Too hard to use without over-relying on Help function.
Inspiration	H	H	No	Easy to use, impressive range of choices.
Mind Matrix	H	H	Yes	Easy to use.
LifeMap	L	M	No	Hard to use. Icons are not clear.
Thinking Maps	M	H	No	Cannot add relation labels.
Concept Draw MindMap	M	M	No	Interface is intimidating. Difficult to link subcategories.
Semantica	Evaluation copy unavailable			
Visual Mind	M	H	No	Cannot add relation labels.
Smart Ideas	H	H	No	Easy to use. Linking in particular is very clear.
Mind Mapper	M	H	No	Difficult to find how to add relation labels. Icons are confusing.
Fuzzy Thought Amplifier	Evaluation copy unavailable			
Axon Idea Processor	M	M	No	Difficult to find how to add relation labels.
Knowledge Manager	Evaluation copy unavailable			
Visio	H	H	No	Easy to use and visually appealing.
Decision Explorer	L	L	No	Too hard to use.
Mind Manager	M	M	No	Not easy to use.
VisiMap	L	L	No	Too hard to use. Difficult to create new concepts.
SmartDraw	H	H	No	Easy to use but it has too many features that are not related to making concept maps.

Note. H = high, M = medium, L = low. An annotated list is given in Appendix B.

Summary

The majority of software that provide knowledge mapping capability appear to be focused primarily on instructional applications, including representing and organizing information, and planning. Aside from our original mapping software (Version 1.0, Chung & Baker, 1997), Mind Matrix is the only other product that has focused on assessment uses and the only other product that has automated scoring capability. However, the product appears to only support knowledge mapping representations. Our requirement was for a tool to support knowledge mapping at a minimum, with the capability to expand into other assessment formats as the need arose.

In general, products not specifically designed for knowledge mapping tend to be sophisticated drawing packages. For products that have been designed specifically for knowledge mapping, there is a range of support for different kinds of maps and media. With the exception of the CRESST system, there appears to be little empirical work directly associated with the use of these systems.

From the review of scoring algorithms and the review of COTS mapping packages, it was clear that there was no existing product that was sufficiently compelling to adopt out of the box for assessment purposes. Thus, we decided to design and develop our own system. We drew on our prior experience, the software review, and lessons learned from our Version 1.0 system to develop functional requirements.

HPKMT Functional Overview

The primary purpose of the Human Performance Knowledge Mapping Tool (HPKMT) is to support the assessment of an individual's content understanding of a particular domain in a distributed learning environment. There were four design goals: (a) develop a research-based, empirically supported measurement tool; (b) develop an easy-to-use application that can be used by users of different computer experience; (c) develop an architecture that can support the development of a networking tool as well as accommodate future, unforeseen assessment formats; and (d) develop an architecture that can accommodate automated scoring of student responses for all supported assessment formats.

The requirements for the HPKMT were generated from a variety of sources. First, we reviewed the knowledge mapping literature to get an overview of how

knowledge maps were used for assessment purposes. We also reviewed existing software from commercial and academic labs that purported to provide the capability to create knowledge maps. Finally, we incorporated lessons learned from the CRESST research experience with online knowledge mapping. Appendix C contains an outline of the functional requirements for the mapper.

The knowledge mapping system reported herein is a second-generation version of our online mapping system. Our original version, reported in Chung and Baker (1997), was used in numerous contexts, from elementary school science classrooms to adult learners, under a variety of conditions ranging from instructional use to tests of content knowledge. The current version incorporates lessons learned from this period. A summary of lessons learned from this period is presented in Table 3. Each issue is discussed further.

Table 3
Lessons Learned from CRESST Knowledge Mapping Studies (1997–2001)

Issue	Version 1.0 capability and lesson learned	Version 2.0 instantiation
User interface	Capability: Simple interface that is easy to use and easy to train. No special skills are needed.	Maintained simplicity and ease of use, and adopted a modern interface design for graphical drawing.
	Lessons learned: Need to retain simple interface.	Created an interface that is consistent with familiar applications (e.g., Word).
Task format	Capability: Single task format useful for original purpose but imposes limits on what can be assessed. Few options to respond to demands for more and varied formats.	Designed to accommodate multiple formats as needed. Provided the capability for user-defined icons to be uploaded and mapped. Provided background imaging capability for additional format choices.
	Lessons learned: Need to develop a general architecture that would accommodate the development of different assessment formats.	
Authoring capability	Capability: Minimal capability that required customized attention.	Developed capability to more easily stitch knowledge mapping tasks together.
	Lessons learned: Need to develop more user-friendly method of authoring knowledge maps.	
Network accessibility	Capability: Firewalls blocked applets; thus, the mapper could not be used in numerous environments.	Adopted Webstart as a way to launch the mapper on the client machine via the browser.
	Lessons learned: Need to develop method of invoking mapper that is not sensitive to typical network security constraints.	
Scoring	Capability: Scoring algorithm successful but operationally cumbersome.	Ported scoring algorithm and expanded the set of map attributes that can be scored. For example, comparisons are made between a student's map and the criterion map on the link line type, color, and weight, and the concept symbol type, line type, color, and weight.
	Lessons learned: Maintain capability and increase capability to incorporate multiple scoring approaches.	

User Interface

One of the clearest successes we have had with Version 1.0 is the usability of the software. Version 1.0 was simple, focused, and easily comprehendible by a wide range of users. There were clearly some user-interface problems, but these problems

could be handled via training. Once demonstrated, most users had little difficulty operating the software. We have repeatedly observed this result across different ages and contexts (e.g., Chung, Baker, & Cheak, 2002; Chung et al., 2001; Chung, O'Neil, & Herl, 1999; Herl, O'Neil, Chung, Bianchi et al., 1999; Herl, O'Neil, Chung, & Schacter, 1999; Klein et al., 2002; Osmundson et al., 1999; Schacter et al., 1999). Thus, our starting point for the design of Version 2.0 was to maintain the ease of use and simplicity of the user interface.

In Version 2.0, we adopted a modern interface for graphical drawing applications. As shown in Figure 1, the screen space was partitioned into two major areas: (a) symbol space, which housed icons; and (b) canvas space, which is where the drawing took place using the symbols from the symbol space. System functions common to applications were provided as well (e.g., buttons to open a file, save a file, zoom).

The main goal for the Version 2.0 user interface was for it to be simple and intuitive. Such an interface would translate into minimal training, explanation, and construct irrelevant variance—all important operational features when the tool is used for assessment purposes.

Basic Operation

The knowledge mapper was designed to be used with only the mouse. Concepts are added to the map by clicking and dragging the Concept icon onto the canvas. When a concept is added to the map, a pop-up menu of available concepts is provided for the user to choose from. Links between concepts are made by drawing a line from one concept to another. At the completion of the link operation, a pop-up menu of available links appears for the user to choose from. Concepts and links can be changed by either double-clicking or right-clicking on the concept or link to bring up the label menu.
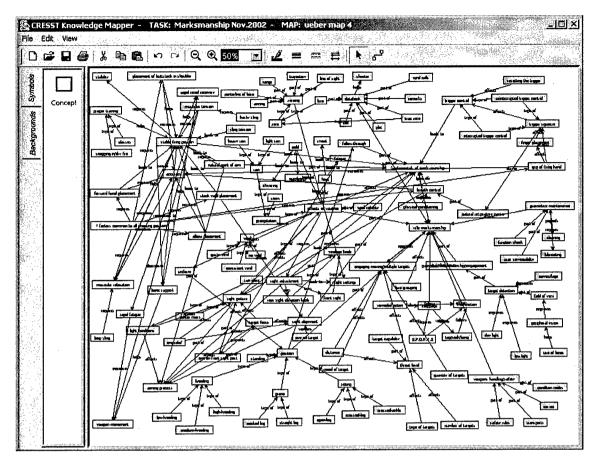
Figure 1. User interface of Version 2.0 of the CRESST knowledge mapper.

Task Format

Version 1.0 was designed specifically for mapping. One goal for Version 2.0 was to develop a more general system in terms of the types of knowledge the system can assess. Increasingly, we found a single-representation format limiting (e.g., see Herl, O'Neil, Chung, Bianchi et al., 1999). Thus, for Version 2.0 we began with the assumption that assessment needs will evolve over time and that a tool to support a variety of unforeseen formats would be desirable.

The approach we adopted was to provide the capability for end-users to use different icon sets. An icon set is a collection of icons that represents the elements of the domain being assessed. For example, the mapper shown in Figure 1 has an icon set with 1 icon—a rectangle. A procedural knowledge icon set might have 3 icons— rectangle for process, diamond for decision making, and circle for begin/end.

The utility of this approach is twofold: (a) The same codebase can be used to store, retrieve, and display the representation. Changes occur at the icon-set level

and not in the software. A library of icon sets can be developed to represent different assessments from the abstract (e.g., planning) to the concrete (as actual physical entities). (b) The assessment option is open-ended. If the domain can be represented using icons, the mapper shell can display it.

A second feature of Version 2.0 is to provide the capability to use different background sets. Like icon sets, the mapper can have images to display in the background. Different backgrounds can be used as insertable plates, depending on the purpose. For example, the way we typically use the mapper is with no background and the physical location of the nodes has no meaning. But another application may make use of the physical location. For example, this feature was used to assess Marines' knowledge of shot groups for a rifle marksmanship application. As shown in Figure 2, the same shell has been used to administer a "physical"-based representation. Physical placement of the icons relative to other icons and relative to the background image is used directly for scoring.
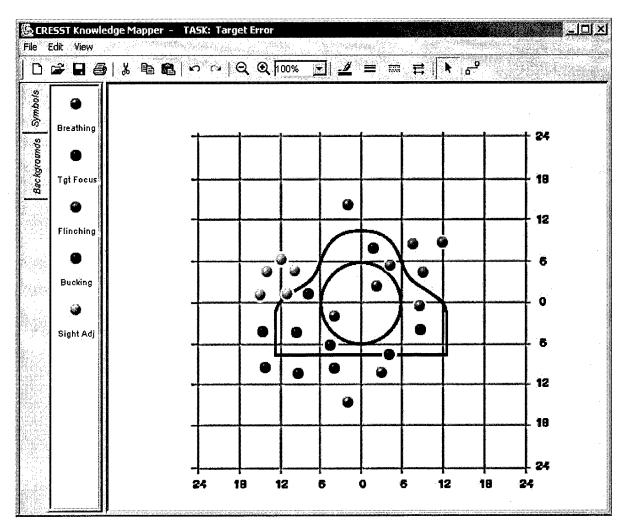
Figure 2. Use of background to depict physical-based layouts.

Network Accessibility

One restriction imposed by firewalls is the blocking or filtering of Java applets and other objects (e.g., Active X). Version 1.0 was applet-based, and our experience in large school districts and commercial sites suggested that firewalls were becoming commonplace and highly restrictive. Given the high probability of the use of firewalls by our likely end-users, we designed the mapper to be client-based. We used a technology called Webstart, which allowed the knowledge mapper to be launched as an application on the user's machine via the user's browser. This is a key feature because the mapper is implemented as an application, not an applet (thereby avoiding firewall restrictions). Code maintenance is handled automatically by Webstart, which automatically checks for updates to the mapper and downloads components that have changed.

Automated Scoring Capability

Scoring of knowledge maps. We designed the scoring engine to be loosely coupled to the system, thereby allowing for maximal flexibility in the scoring routines. That is, knowledge mapping data are stored in tables and databases that are independently accessed by the scoring engine. This separation reduces the complexity of the mapping code, increases maintainability, and allows for scoring algorithms to be developed independently of the mapper.

Currently, we have implemented the following scoring routines for the knowledge mapping representation: (a) exact proposition matching and (b) synonym-based proposition matching. The exact-proposition-matching algorithm is based on the algorithm developed by Herl et al. (1996). Exact proposition matching involves counting the number of propositions in the trainee map that also exist in the referent map (e.g., an expert's map).

Synonym scoring is a more lenient method that considers a match if there exists an intersection between the set of synonyms for each term in the trainee map and each corresponding term in the referent map. Currently, the synonyms are stored in a database table and manually specified depending on the context of the particular task. We are currently integrating WordNet into the synonym scoring algorithm, as the WordNet tables contain synonyms for over 100,000 words.

Scoring of shot groups. The second automated scoring application we have developed within the HPKMT shell is to score shot-group patterns. As shown in Figure 2, trainees are asked to depict the prototypical shot groups of five types of shooter errors. The scoring algorithm compares the trainee's response against an expert's response and was based on work by Johnson (2001). The particular variables compared differ by shot group, but in general include dispersion area, dispersion radius, vertical displacement, horizontal displacement, and target quadrant. A complete description of the scoring method is contained in Appendix D.

Summary. Our original design approach has already proved useful. The architecture of the system allowed us to deliver different assessment formats within the same delivery shell using the same codebase. Automated scoring has been implemented for each format. The use of the same shell to deliver assessments minimizes user-interface complexities.

We have developed a novel application that moves the complexity of software development to the scoring aspect. For each class of representation types, software needs to be developed to score that representation. But this is much easier to do than creating stand-alone software for each type of assessment. Thus, combinations of icons and backgrounds can be used to maximize the reuse and representational generalizability of the tool.

Usability Study

Because we anticipated a wide range of users of the mapper software, a usability study was conducted to (a) evaluate how intuitive the operation of the knowledge mapper was, (b) evaluate how learnable the knowledge mapper operations were, and (c) uncover error and atypical usage patterns.

In general, the usability study found that users of varying levels of computer experience learned how to use the knowledge mapper with minimal instruction. The most difficult function of the mapper to learn was linking concepts, with the most users requiring suggestions or explicit instruction on how to link. Since participants were asked to use and explore the mapper with no instruction outside of an introduction to knowledge mapping in general, the findings suggest that a short training illustrating the basic functions of the mapper would be sufficient for users with even limited computer experience. Once users learned how to use the mapper, there were few recurring usability issues. The usability study yielded recommendations for changes to the mapper, including modifications to the linking function, and renaming menu items and toolbar button labels for clarity. A full report is given in Appendix E. A preliminary user guide is provided in Appendix F.

Fielded use. We tested the knowledge mapper in an assessment context with 50 Marines at a training base in North Carolina. Most of the Marines were between 18 and 20 years old. Our informal observations, based on observing Marines using the software and Marines' questions and comments, suggested that the Marines had little trouble using the knowledge mapper. The only notable question was how to delete objects, as some users attempted to delete objects with the backspace key instead of the delete key.

Prototype Authoring Functionality

To support the creation and maintenance of knowledge mapping tasks, a prototype authoring system was created. The design of the system was based on the work of Chung et al. (2002). The near-term goal of the authoring functionality was to support research activities. A long-term goal was to develop an interface that is suitable for use by a wide audience (e.g., trainers, trainees, researchers, course managers).

The authoring process is illustrated in Figure 2. The metaphor adopted was that of a course. A course consists of activities or tasks that students engage in. There can be one or more tasks belonging to a course. An activity is a knowledge mapping task. Each mapping task has properties associated with it, such as the set of concepts and links, the set of icons used, and the mode of operation (e.g., select-only, type-in, or both). Tasks can be created by using existing concepts and links or by creating new ones or augmenting an existing set. Trainees' names must be registered in the system before mapping can be accessed. Trainees are assigned courses (and indirectly tasks). In the following sections, each major functional area is discussed with accompanying screen shots.
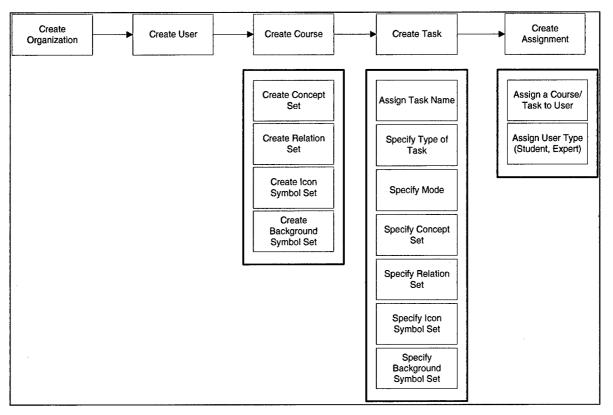
Figure 3. Top-level flow for creating a new knowledge mapping task.

Top-Level Screen

Users can access all top-level functions from the main screen shown in Figure 4. The design of the Web favored breadth over depth, which allows users to reach their destination within 4 clicks (Chung et al., 2002).
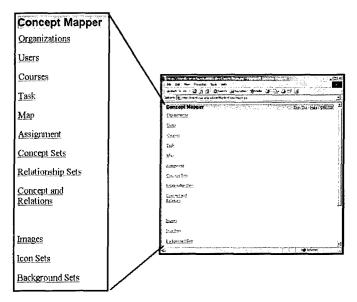
Figure 4. Top-level screen for the authoring prototype.

Course Creation

A critical step in the authoring process is setting up a "course." A course bundles one or more tasks and can be assigned to trainees. All tasks that are part of a course are made accessible to the trainee. An example of the course listing screen is shown in Figure 5. A summary listing is shown in the left figure and a detailed screen is shown in the right figure.

Figure 5. Assigning tasks to courses.

Task Creation

To create a task, users click on the "add task" link shown in Figure 5. The task creation screen appears as shown in Figure 6. The task screen allows users to label a task; select the type of knowledge representation; and specify whether the student will be able to select terms and links, type terms and links, or both. This screen also allows the specification of the set of concepts and relations to be used, as well as the set of icons to be used for mapping and the background.
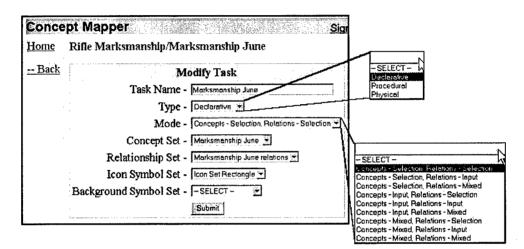

Figure 6. Specifying task attributes.

Specifying Concept and Link Sets

Specifying the set of concepts and relations is done via a simple form, as shown in Figure 7. This allows the creation of sets of concepts and relations that can be reused in other tasks. For example, one use of this feature is to define a generic set of links and add domain-specific links. In this way, link sets can be quickly created with a known set of links, and tailored to specific content areas.

Figure 7. Specifying task attributes.

Specifying Image Sets

Analogous to specifying concept and link sets, users can also specify image sets for the mapping symbol set and the background symbol sets. Examples of these features are shown in Figure 8, where the figures on the left show the interface for specifying mapping icon sets, and the figures to the right show the user interface for the background images.
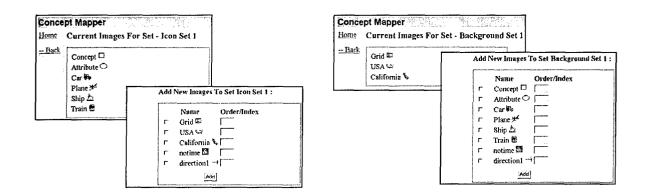

Figure 8. Adding images.

Summary

The authoring prototype has been developed to facilitate the research use of the knowledge mapper. The prototype contains the minimal functionality required to allow users to create mapping tasks and assign tasks to students and other trainees.

Discussion

We have developed a software application that can administer and score knowledge maps and other formats. Our usability testing and our field test suggest that we have developed an easy-to-use application. Our architecture was designed to allow different assessment formats by allowing end-users to upload icons and background images. In our review of existing mapping software, we found only one other application focused on assessment, and we found no other application that has multiple assessment capability. Our use of knowledge mapping as an assessment tool with automated scoring, and our general capability to support unforeseen assessment formats are unique. CRESST research appears to be the only empirically supported online mapping tool in existence.

Limitations of This Work and Next Steps

There are two major limitations of this work. First, the authoring component needs to be recast to make it more user-friendly and intuitive. Currently, specialized knowledge and training are needed before tasks can be created. There is no capability to specify tasks in real-time (e.g., using the mapper itself as the authoring tool). The second limitation is the lack of reporting. We currently have no unified method of reporting student performance. Scores can be reported on a single-user basis, but there is no capability for group-level reporting.

Our efforts at designing a usable knowledge mapping tool appear to be a successful first step. The software is reasonably stable and we have tested the architecture by implementing two different assessment formats with scoring capability. Clear next steps include retooling the authoring prototype interface. A second line of activity is to deploy the mapper in distributed learning contexts in different content areas to expand the suite of assessments.

References

Aguirre-Munoz, Z. (2000). *The impact of language proficiency on complex performance assessments: Examining linguistic accommodation strategies for English language learners.* Unpublished doctoral dissertation. University of California, Los Angeles.

Austin, L. B., & Shore B. M. (1995). Using concept mapping for assessment in physics. *Physics Education, 30,* 41-45.

Chung, G. K. W. K., & Baker, E. L. (1997). *Year 1 technology studies: Implications for technology in assessment* (CSE Tech. Rep. No. 459). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Chung, G. K. W. K., Baker, E. L., & Cheak, A. M. (2002). *Knowledge Mapper authoring system prototype* (CSE Tech. Rep. No. 575). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Chung, G. K. W. K., Harmon, T. C., & Baker, E. L. (2001). The impact of a simulation-based learning design project on student learning. *IEEE Transactions on Education, 44,* 390–398.

Chung, G. K. W. K., O'Neil, H. F., Jr., & Herl, H. E. (1999). The use of computer-based collaborative knowledge mapping to measure team processes and team outcomes. *Computers in Human Behavior, 15,* 463–494.

Herl, H. E. (1995). *Construct validation of an approach to modeling cognitive structure of experts' and novices' U.S. history knowledge.* Unpublished doctoral dissertation, University of California, Los Angeles.

Herl, H. E., Baker, E. L., & Niemi, D. (1996). Construct validation of an approach to modeling cognitive structure of U.S. history knowledge. *Journal of Educational Research, 89,* 206-218.

Herl, H. E., O'Neil, H. F ., Jr., Chung, G. K. W. K., Bianchi, C., Wang, S-L., Mayer, R.E., Lee, C-Y., Choi, A., Suen, T., & Tu, A. (1999). *Final report for validation of problem-solving measures* (CSE Tech. Rep. No. 501).Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Herl, H. E., O'Neil, H. F., Jr., Chung, G. K. W. K., & Schacter, J. (1999). Reliability and validity of a computer-based knowledge mapping system to measure content understanding. *Computers in Human Behavior, 15,* 315–334.

Johnson, R.F. (2001). *Statistical measures of marksmanship* (ARI Tech. Note TN-01/2). Alexandria, VA: U.S. Army Research Institute.

Klein, D. C. D., Chung, G. K. W. K., Osmundson, E., Herl, H. E., & O'Neil, H. F., Jr. (2002). *The validity of knowledge mapping as a measure of elementary students' scientific understanding* (CSE Tech. Rep. No. 557). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Lee, J. J. (2000). *The impact of Korean language accommodations on concept mapping tasks for Korean American English language learners.* Unpublished doctoral dissertation. University of California, Los Angeles.

Markham, K., Mintzes, J., & Jones, M. G. (1994). The concept map as a research and evaluation tool: Further evidence of validity. *Journal of Research in Science Teaching, 31,* 91-101.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* New York: Cambridge University Press.

Osmundson, E., Chung, G. K. W. K., Herl, H. E., & Klein, D. C. D. (1999). *Concept mapping in the classroom: A tool for examining the development of students' conceptual understandings* (CSE Tech. Rep. No. 507). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Pearsall, N. R., Skipper, J., & Mintzes, J. (1997). Knowledge restructuring in the life sciences: A longitudinal study of conceptual change in biology. *Science Education, 81,* 193-215.

Rice, D., Ryan, J., & Samson, S. (1998). Using concept maps to assess student learning in the science classroom: Must different methods compete? *Journal of Research in Science Teaching, 35,* 1103-1127.

Ruiz-Primo, M. A., Schultz, S., Li, M., & Shavelson, R. J. (1997a). *Concept map-based assessment in science: Two exploratory studies* (CSE Tech. Rep. No. 436). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Ruiz-Primo, M. A., Schultz, S., Li, M., & Shavelson, R. J. (1997b). *On the validity of concept-map based interpretations: An experiment testing the assumption of*

hierarchical concept maps in science (CSE Tech. Rep. No. 455). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Ruiz-Primo, M. A., Schultz, S. E., Li, M., & Shavelson, R. J. (2001). Comparison of the reliability and validity scores from two concept-mapping techniques. *Journal of Research in Science Teaching, 38,* 260-278.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33,* 569-600.

Schacter, J., Herl, H. E., Chung, G. K. W. K., Dennis, R. A., & O'Neil, H. F., Jr. (1999). Computer-based performance assessments: A solution to the narrow measurement and reporting of problem-solving. *Computers in Human Behavior, 15,* 403–418.

West, C. D., Pomeroy, J. R., Park, J. K., Gerstenberger, E. A., & Sandoval, J. (2000). Critical thinking in graduate medical education: A role for concept mapping assessment. *Journal of the American Medical Association, 284,* 1105-1110.

Appendix A
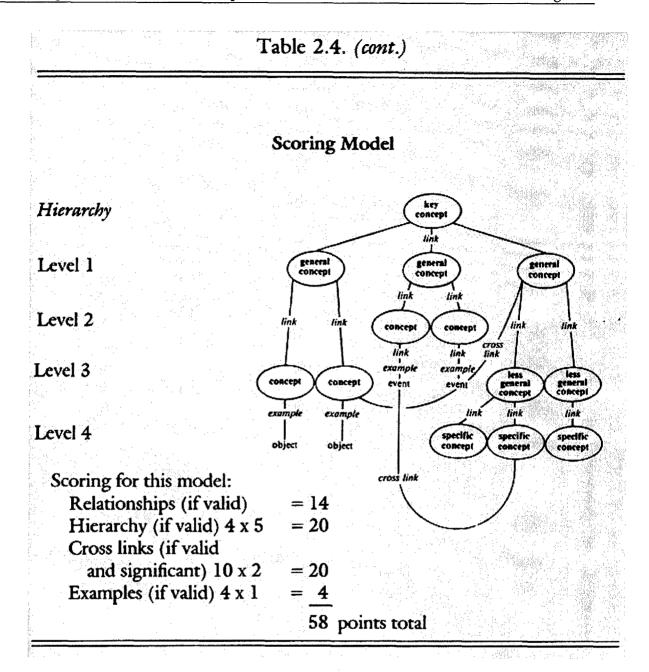
Novak and Gowin's Scoring Guide

Reprinted from page 107 of Novak and Gowin (1984).

(1) Score all relationships that are valid (form valid propositions). You may wish to subtract wrong or ambiguous concept linkages, but this may complicate scoring unnecessarily. Valid cross-link relationships might be scored also, or simply weighted into rule 3 below.

(2) Count valid levels of hierarchy and score each level X times as much as each relationship. The value for X is arbitrary, but because maps have many more relationships than hierarchies, and because valid hierarchies signal progressive differentiation and integrative reconciliation of concept meanings, it seems reasonable and valid to score each level of the hierarchy 3 to 10 times as much as each relationship. Scoring levels of hierarchy when maps are not symmetrical is a problem, but we suggest that the number of valid hierarchies in the most branched segment of the map be counted. Words that have simply been strung together without clear subordinate conceptual relationships, however, should not count as levels of hierarchies (see Figure 5.5).

(3) Cross links that show valid relationships between two distinct segments of the concept hierarchy signal possibly important integrative reconciliations, and may therefore be better indicators of meaningful learning than are hierarchical levels. We suggest that each valid cross link receive 2 or 3 times the points assigned to each hierarchical level. Since it is possible to construct some kind of cross link between almost any two concepts on a map, you must use judgment to decide if a given cross link represents substantial integrative reconciliation of two sets of concepts. As with essay exams, students may want to defend their answers, and you can expect some negotiation with them on this aspect of scoring. If you view concept mapping primarily as a learning tool, these negotiations might be as valuable to the student as the map construction.

(4) It may be desirable to ask for specific examples in some cases to be sure that the students know what kind of event or object is designated by the concept label. You may want to score valid examples the same as relationships, or perhaps give them half as many points because they are usually easy to supply and less indicative of meaningful learning. It is possible for students to rote learn that a cat is an example of the concept mammal (or that ice is an example of a solid) without knowing the regularity the concept designates. Of course, because concept links can be learned by rote as well, not all relationships will signal meaningful learning.

Table 2.4. *Scoring criteria for concept maps*

1. *Propositions.* Is the meaning relationship between two concepts indicated by the connecting line and linking word(s)? Is the relationship valid? For each meaningful, valid proposition shown, score 1 point. (See scoring model below.)

2. *Hierarchy.* Does the map show hierarchy? Is each subordinate concept more specific and less general than the concept drawn above it (in the context of the material being mapped)? Score 5 points for each valid level of the hierarchy.

3. *Cross links.* Does the map show meaningful connections between one segment of the concept hierarchy and another segment? Is the relationship shown significant and valid? Score 10 points for each cross link that is both valid and significant and 2 points for each cross link that is valid but does not illustrate a synthesis between sets of related concepts or propositions. Cross links can indicate creative ability and special care should be given to identifying and rewarding its expression. Unique or creative cross links might receive special recognition, or extra points.

4. *Examples:* Specific events or objects that are valid instances of those designated by the concept label can be scored 1 point each. (These are not circled because they are not concepts.)

5. In addition, a criterion concept map may be constructed, and scored, for the material to be mapped, and the student scores divided by the criterion map score to give a percentage for comparison. (Some students may do better than the criterion and receive more than 100% on this basis).

Table 2.4. *(cont.)*

Scoring Model

Hierarchy

Level 1

Level 2

Level 3

Level 4

Scoring for this model:
Relationships (if valid)   = 14
Hierarchy (if valid) 4 x 5   = 20
Cross links (if valid
    and significant) 10 x 2   = 20
Examples (if valid) 4 x 1   = 4
                             ───────
                             58 points total

Appendix B

Annotated List of Existing Mapping Software

IHMC Concept Map Software
PC/Mac/Solaris/Linux
http://cmap.coginst.uwf.edu/
This software is for academic purposes, including collaborative learning, curriculum planning, and knowledge organizing. Users can share propositions in maps and form discussion groups about maps. Other advanced features of the software include the ability to add images, movies, and hyperlinks to concepts. Unfortunately, the increased functionality of the software hinders its usability; creating a new map is not intuitive enough to be done without following the step-by-step instructions provided in the Help window that opens upon start-up. This software has no automated scoring capability; it appears to be mainly an instructional, not assessment, tool, best used for organizing thoughts or sharing ideas within a group.

Inspiration
PC/Mac
http://www.inspiration.com/productinfo/index.cfm
This software is for academic purposes and helps teachers implement visual learning techniques. Students can use maps to process and organize information. Automated scoring is not available, although the website acknowledges, "Misdirected links or wrong connections alert educators to what students do not understand, providing an accurate, objective way to evaluate areas in which students do not yet grasp concepts fully."

Mind Matrix
PC/Mac
http://www.mind-matrix.org/index?
Targeted to the academic community, this software offers the ability for instructors or experts to create tasks and then administer them to students. Registered Mind Matrix users can share and view tasks and maps created by others. Reporting capabilities include statistical reports, proposition reports, and individualized student reports. Feedback can be provided to students based on whether their propositions match propositions in the expert map.

LifeMap
PC on the Web/Mac
http://www2.ucsc.edu/mlrg/mlrgtools.html
This software appears to be intended for an academic audience. Features include exporting maps to JPEG format, generating Proposition Databases that can be used to generate maps based on all the propositions in the database, supporting QuickTime movies in maps, and editing by multiple users at different locations on the same map. Building a map is not as straightforward as most other mapping

programs that have the look and feel of graphics programs, because LifeMap relies heavily on dialog boxes. There does not appear to be automated scoring available.

Thinking Maps
PC/Mac
http://www.thinkingmaps.com/httmsoftware.php3
This software is for educational purposes. Thinking Maps are asserted to promote continuous development and integrated thinking. A training workshop on how to create and use maps is required, as there is a specific method for teaching and assessing Thinking Maps. Because of the required training, however, teachers can use Thinking Maps for assessments because both teachers and students will understand the common visual language in the maps, and therefore students from year to year as well as within a class can be compared to each other. It is not clear if assessment includes the ability to automatically score maps.

Concept Draw MindMap
PC/Mac
http://www.conceptdraw.com/en/products/mindmap/main.php
The software isn't geared to any one community, but instead offers different uses for various populations. It is recommended for teachers for "preparing lesson plans" and for students for "thinking over essays and projects." It appears to be mainly a project planning or brainstorming tool. It features export capabilities to present maps in Powerpoint or put them on the Web, formatting functions for text as well as graphics, and a library of objects as well as the ability to create your own.

Semantica
Mac
http://www.semanticresearch.com/index.html
This software was unavailable for evaluation. The software is not geared to any particular community. The software is intended to be used to represent a knowledge base that can be shared with others. The website says, "Semantica software is intended to facilitate the transfer and sharing of knowledge. This can be from expert to learner or student, or among peers, experts and decision makers. In an eLearning environment, Semantica can be the basis of stand-alone courses, an adjunct to a blended learning episode, or a reference for existing texts and in-class assignments." While Semantica can be used for instruction, for assessment it does not appear to be any better than most other mapping programs that lack an automated scoring component.

Visual Mind
PC
http://www.visual-mind.com/

The software appears to be mainly an organizing or planning tool. Academic uses include note-taking, studying, and outlining, such as a course syllabus. While not targeted at one specific group, it appears to have greater functionality for business applications, as opposed to instruction or assessment. The ability to label relations between concepts was not found. No automated assessment capability appears to be available.

Smart Ideas
PC

http://www.smarttech.com/products/smartideas/
The software says students can use concept maps to organize ideas. Hyperlinks can be added to concepts to link to files or Web sites. Maps can have multiple levels (for example, you can have multiple propositions embedded within a concept). This software has high usability and the interface is not cluttered with too many features. No automated scoring capability appears to be included.

Mind Mapper
PC

www.mindmapper.com
Instructional uses for Mind Mapper include organizing notes (such as for a lecture by a teacher or from a lecture by a student), brainstorming, organizing complex thoughts and ideas, outlining papers, or testing comprehension (although no automated scoring component appears to be provided). Functions include the ability to recognize outlines in text files and import them as maps, and the ability to link Powerpoint and Excel files to maps. Intuitiveness of the interface was low; the ability to label links was not found.

Fuzzy Thought Amplifier
PC

http://www.fuzzysys.com/ftaprod.html
No evaluation version of this software was available, so usability cannot be gauged. This software does not appear to be for any particular group. Explicit uses for the program include documenting, manipulating, and communicating ideas, as well as for spreadsheets, bar charts, and history plots. Applications include college plans, legal strategy, and traffic control design. Features include mathematical functions like arctan and sine. The functionality of this program is a little different than most because of the spreadsheet capabilities, but for instruction purposes, it does not appear to offer more than a standard mapping program.

Axon Idea Processor
PC

http://web.singnet.com.sg/~axon2000/

This software is explicitly designed for "planners, writers, managers, and students." It is mainly for organizing ideas. Features include 3-dimensionality; export capability to HTML, XML, EFM, and RTF; drawing and graphics capabilities; and support of Hypertext and Richtext. While students can use this program, it is not explicitly for instruction and does not feature automated assessment capabilities. Usability is at a medium level.

Knowledge Manager
PC
www.knowledgemanager.us
This program is not directed at any particular group of users, although for teachers, the website states, sharing knowledge bases over the Internet "multiplies his presence and didactic capacities with minimum effort, even in distance learning." Other uses include decision support and brainstorming. No evaluation version of this software was available, but the website says the software is easy to use. With this software you can share with a group, annotate concepts, organize maps into levels (submaps), export to text or image files, search semantically, open a map form the Web, export to HTML, make relations across maps, associate external documents or applications to concepts. No automated scoring capability was found.

Visio
PC
http://www.microsoft.com/office/visio/default.asp
This program is for visualizing and sharing ideas. Visio is a straightforward mapping program that is easy to use and does not have an overabundance of features to weigh down the software. Creating a map is easy to accomplish from start-up. It does not feature an automated scoring capability.

Decision Explorer
PC
http://www.banxia.com/demain.html
Geared towards business applications although many academic institutions (mainly universities, colleges, and graduate schools) are listed as users, the website for this software lists as uses, "providing help with structuring messy or complex data for problem solving, assisting the interview process by increasing understanding and generating agendas, and managing large amounts of qualitative data from documents." Features of the software include multiple views of a map, functions to hide or show certain parts of the map (e.g., groups of closely linked concepts, concepts that most influence outcomes), and the ability to reduce maps to provide an overview map or a map with no links "to focus on an issue." Usability of this program was low, and it seemed overburdened with features.

Mind Manager

PC

http://www.mindjet.com/index.shtml

This software clearly markets corporations; case studies listed on the web sites boast of "an amazing business advantage" and are worded in terms of cost savings, employee productivity, and customer satisfaction. The software allows for real-time sharing of maps. Some additional features include ability to create Web sites or site maps, project tracking, and integration with Microsoft Word, Project, PowerPoint, and Outlook. Usability was at a medium level, but too many features seem irrelevant for instructional or assessment purposes. It does not appear to have an automated scoring function.

VisiMap

PC

http://www.coco.co.uk/

This software is designed for brainstorming, problem solving, outlining, planning, and meeting facilitation. Functionality includes spellcheck, import/export ability from picture files (e.g., JPEG, TIFF), and a separate viewer application that allows others who do not have the software to view maps. This software was difficult to use and seemed to have too many features than would be used in a classroom.

SmartDraw

PC

http://www.smartdraw.com/specials/diagram.asp?id=2387

This software offers the capability to create professional-looking graphics with an emphasis on diagrams and flow charts, including but not limited to organizational charts, floor plans, and engineering schematics. The program offers a library of drag-and-drop graphics, such as all 50 U.S. states. While the software is easy to use, it seems better applied to creating professional-looking pictures than knowledge maps.

Appendix C

Outline of the Human Performance Knowledge Mapper Functional Requirements

1. Icon Set
   1.1. Drag to canvas
   1.2. Icon labeled to denote meaning of symbol
2. Background set
   2.1. Drag to canvas
   2.2. Background labeled to denote meaning of background
3. Icon operations
   3.1. 1=click selects object
      3.1.1. Apply weight
      3.1.2. 5-levels
      3.1.3. Line width proportional to weight
      3.1.4. Colors
   3.2. Double-click = right click
      3.2.1. Popup menu of concepts
         3.2.1.1. Grayed = used
         3.2.1.2. Not grayed = available
      3.2.2. Text-box fill-in
      3.2.3. Use increases size of box for oversized text
   3.3. Drag from icon panel and plop on canvas
4. Link operations
   4.1. 1=click selects object
      4.1.1. Apply weight
      4.1.2. 5-levels
      4.1.3. Line width proportional to weight
      4.1.4. Colors
   4.2. Link label operation
      4.2.1. Weight
      4.2.2. Label selection after connection in dialog box
         4.2.2.1. Cancel = no link
      4.2.3. Double-click = right click
         4.2.3.1. Popup menu of links
         4.2.3.2. Text-box fill-in
      4.2.4. Direction of arrows (reverse)

5. Network operations

   5.1. Delete node

      5.1.1. Delete attached links

   5.2. Explicit click on link mode button

   5.3. Explicit click on arrow-button for move and delete operations

   5.4. Operations applied to selected objects

   5.5. Zoom

      5.5.1. Scale/% and default

   5.6. Cut, copy, paste

   5.7. Ctrl-drag

   5.8. Group selected object operations

      5.8.1. Link – apply selected or typed in term to all links

      5.8.2. General properties – apply property to all selected operations

6. Icon/Background Panel

   6.1. Tab-option

      6.1.1. 1st choice: vertical tabs

      6.1.2. 2 tabs – one for "Icon" one for "Background"

      6.1.3. Populate icon panel w/set of icons relevant to task

      6.1.4. Populate background panel w/set of icons relevant to task

7. Canvas

   7.1. Multiple canvases

   7.2. Tabs on bottom

   7.3. Size of infinite w/scroll capability

8. File Operations

   8.1. Saving

      8.1.1. Dirty-bit

      8.1.2. Options

         8.1.2.1.Assessment/formal – save when exit, no prompt

         8.1.2.2.Informal – check dirty-bit, prompt to save

      8.1.3. Save

   8.2. Opening

      8.2.1. Task

      8.2.2. Map (concept, procedural, physical)

8.2.3. Options

8.2.3.1.Panel for tasks

8.2.3.2.Panel for maps, content dependent on task items

9. Printing Operations

9.1. Print map

Appendix D

Shot Group Analyses Scoring Methodology
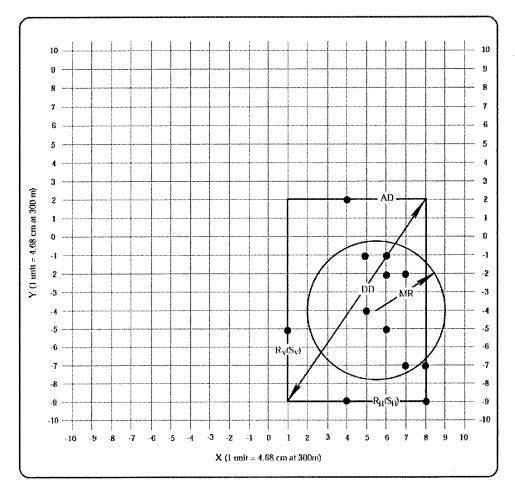
Figure 9. Shot group measures.

Measures

Center of the shot group (CSG)

$$CSG = (\bar{x}, \bar{y}) = \left(\frac{\sum x_i}{n}, \frac{\sum y_i}{n} \right)$$

CSG is the center of mass (CM) of the shot group. CSG must be calculated for both the expert and the student.

Constant Error

This is the distance between the two centers of mass (student and expert). It is better known as the "Constant Error."

$$DCM_{SG} = \sqrt{(\overline{x_s} - \overline{x_e})^2 + (\overline{y_s} - \overline{y_e})^2}$$

For the purpose of this report, a shot group may be considered functionally accurate if the constant error, DCM_{SG} is less than or equal to 6.

Shooting Error

The average of the separate straight lines between each student's shot and the CM of the expert shots.

$$DCM_S = \frac{\sum \sqrt{(x_i - x_{CM\,expert})^2 + (y_i - y_{CM\,expert})^2}}{n}$$

DCM_S is a useful measure of marksmanship accuracy because it gives information on whether each shot actually comes close to the center of the target.

Precision, The mean Radius: (Fig. 1)

$$MR = \frac{\sum \sqrt{(x_i - \overline{x})^2 + (y_i - \overline{y})^2}}{n}$$

Refers to the average of the distances between the CSG and each shot. MR gives the shooter important information about the overall shot group tightness. Shot group tightness is a popular term for marksmanship precision and is the magnitude of dispersion of a group of shots.

In scoring, we have to compare:

$$MR_{Student} \quad \Leftrightarrow \quad MR_{expert}$$

the max permissible value for $| MR_{Student} - MR_{expert} | \leq 6$.

Area of Dispersion (AD) and Diagonal of Dispersion (DD) (see Figure 9)

$$AD = (x_{Max} - x_{Min})(y_{Max} - y_{Min})$$

$$DD = \sqrt{(x_{Max} - x_{Min})^2 + (y_{Max} - y_{Min})^2}$$

For each expert and student these parameters are calculated and compared.

$$AD_{student} \quad \Leftrightarrow \quad AD_{expert}$$

$$DD_{student} \quad \Leftrightarrow \quad DD_{expert}$$

Standard deviation:

a) Horizontal Component, S_H

$$S_H = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

b) Vertical Component, S_V

$$S_V = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$$

c) Radial Component, S_R

$$S_R = \sqrt{(S_H)^2 + (S_V)^2}$$

Standard deviation is a very efficient measure of variable error.

Scoring Criteria for Shot-Group Task

Breathing problem (does not fire during the natural respiratory pause).

The following conditions must be satisfied:

1- Shots should be vertically lined up around the center line x = 0 with (±1 unit) away.

2- $AD_{student}$ vs AD_{expert} should be comparable ($1 - \dfrac{AD_{student}}{AD_{expert}} \leq 25$)

3- Highs AND lows of the student and expert shots should not be more than 1 unit.

Bucking the rifle:

    1- All shots must be located at the third quarter.

    2- Shots must be close together so that $AD_{student}$ vs AD_{expert} should be comparable ($1- \dfrac{AD_{student}}{AD_{expert}} \leq 25$)

Flinching:

1- All shots must be located at the first quarter.

Not focusing on front sight tip:

1- All shots must be well distributed around the center of the target (0,0)

2- $MR_{Student}$ vs MR_{expert} must be comparable.

3- Shots must be close together so that $AD_{student}$ vs AD_{expert} should be comparable ($1- \dfrac{AD_{student}}{AD_{expert}} \leq 25$)

Sight adjustment:

1- With the wind blowing from the right, all the shots must appear in the far left from the center, around the line y = 0.

2- The shots must be as close as possible so the $AD_{student}$ vs AD_{expert} should be comparable ($1- \dfrac{AD_{student}}{AD_{expert}} \leq 25$).

Data File Format:

Column	Description
B	Xs=Xmax Xmax of the shooter shots
C	Xe=Xmax Xmax of the expert shots
D	ratio of column B / column C
E	Xs=Xmin Xmin of the shooter shots
F	Xe=Xmax Xmin of the expert shots
G	ratio of column E / column F
H-M repeats the same for the Y	
N	RHs refers to the Horizontal range for the shooter
O	RHe refers to the Horizontal range for the expert
P	ratio of Column N/Column O
Q-S repeats the same for the vertical ranges	
T	ADs is the area covered by the shooter shots
U	ADe is the area covered by the expert shots
V	ratio of Column T/Column U
W	Xbar-s is the X coordinate of the center of mass for the shooter shots
X	Xbar-e is the X coordinate of the center of mass for the expert shots
Y	ratio of Column W/Column X
Z-AB repeats the same for the Y coordinates	
AC	MRs is the mean Radius of the shooter shots
AD	MRe is the mean Radius of the expert shots
AE	ratio of Column AC/Column AD
AF	dsFromCenter refers to the distance from the center of mass to point(0,0) of the shooter shots
AG	deFromCenter refers to the distance from the center of mass to point(0,0) of the expert shots
AH	ratio of column AF / column AG
AI	alphaS is the angle between horizontal line (where y=0 and x>0) and the line from the center of mass and (0,0) for the shooter.
AJ	alphaE is the angle between horizontal line (where y=0 and x>0) and the line

	from the center of mass and (0,0) for the expert.
AK	ratio of Column AI/Column AJ
AL	StandardDev_Horizontal
AM	StandardDev_Vertical
AN	StandardDev_Radial
AO	Scores
AP	Details

Note.

1. *s* means the shooter or the student, and *e* means the expert.

2. With the pair (dsFromCenter, alphaS) you can find the exact orientation of the center of mass with respect to where the quarter is located. This information is particularly important for scoring Sight Adjustment and Flinching.

Appendix E

Knowledge Mapper Usability Study

The Knowledge Mapper created by the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) is a software application to create knowledge maps. A usability study was conducted to measure the intuitiveness of the program, as well as its usability after basic functions were learned.

The Mapper can be operated solely with the mouse, although some keyboard commands are functional. Concepts are added to the map by clicking the Concept icon in the window on the left side of the screen and dragging it to the canvas (see Figure E1). When a concept is added to the map, a pop-up menu of available concepts is provided for the user to label the concept. Links between concepts are made by clicking the Connect icon (the button at the far right of the toolbar) and then drawing a line from one concept to another. Similar to labeling concepts, links are labeled from a pop-up menu of available links that is provided as soon as a link is made. Concepts and links can be changed by either double-clicking or right-clicking on the concept or link to bring up the label menu.

Figure E1. Knowledge Mapper interface.

Concepts and links can be deleted by clicking on Delete Symbol in the Edit menu or hitting the delete key on the keyboard. Other functions in the Mapper include line-formatting capabilities, such as changing line color and line width, and the option to view windows that show concepts and links available for the task.

Procedure

Usability testing for the Knowledge Mapper was conducted from Oct. 3 to Oct. 22, 2002, with 14 participants. Users were separated into three categories based on results of the computer experience measure (Appendix E1): *High* users had extensive experience with graphics programs and computers in general (4 total), *medium* users had minimal exposure to graphics programs and some or extensive general computer experience (6 total), and *low* users had no graphics program experience and minimal computer experience, limited mainly to word processing, data entry, and Internet access (4 total).

Participants were grouped based on what they indicated they use a computer for, as well as the icon identification portion of the survey on the last two pages. Icons in the survey represent (a) general system functions that appear in a wide variety of software applications (e.g., undo, copy), (b) drawing or formatting functions that appear across applications (e.g., line weight, line color), and (c) higher level graphics functions from a few applications or sophisticated functions from graphics programs (e.g., group, blur). In general, participants who correctly identified more than half of the graphics functions were classified as high users, those who correctly identified some of the functions from each category were classified as medium users, and those who did not identify any of the graphics and any or almost any of the drawing functions were classified as low users. Because functions in the Mapper are similar to those in drawing and graphics applications, the assumption was that users with graphics program experience would learn how to use the Mapper more easily than those users who had no exposure to such software.

The icon identification items also served to provide additional feedback on the recognizability of the Knowledge Mapper icons, as all of the toolbar icons featured in the Mapper appeared in the survey.

Participants first read a brief introduction to knowledge maps, administered on the computer with PowerPoint (see Appendix E2 for knowledge map introduction). Then users were administered two tasks on the Knowledge Mapper.

For Task 1, users were given no instruction on the Mapper and were asked to create a knowledge map on the human body (see Appendix E3 for concepts and links). The program was started for them and a new map was created at the outset. They were given a maximum of 20 minutes for this task, or until they felt they could add no more to their map. Suggestions or instructions were provided when users either exhibited or expressed confusion.

For Task 2, users were given step-by-step instructions to build a knowledge map. Instructions were presented in a separate window on the screen. The subject was the human eye. Instructions were intended to cover most of the functions of the Mapper since it was unlikely users would discover all of them on their own in the first task. Instructions were phrased as actions such as *"Change arrow direction of 'controls' so the relationship reads 'brain controls eye'"*—users were not explicitly told to find the arrow direction function and flip the arrowhead. Because of the wording of the instructions, however, users often found workaround solutions to some actions; for example, with the above instruction, some users deleted the "controls" link and created a new one in the opposite direction—the instruction was followed, although the Arrow Direction function was not sought or discovered. This means that some functions, while targeted in the instructions, were not discovered or used by all users. For this task, users were given 20 minutes or until they completed the last step (17 steps in all; see Appendix E4 for task steps).

While participants completed the two tasks, an observer recorded occurrences when the user expressed confusion about a function or appeared to have difficulty with a function. After completing the two tasks, participants were asked questions about the functions that were observed as difficult to use or understand. After the interview, participants completed an exit survey (Appendix E5) that asked more general questions about the Mapper and gave an additional opportunity for open-ended feedback.

The exit survey also features questions about the eye-tracking camera that was piloted with this study. The eye tracker captured the participant's gaze and superimposed it on a videotape that recorded the participant's computer screen. The data from the eye tracker, however, were not usable because (a) the eye tracker

could not be used for all participants, and (b) those participants whose gaze was captured frequently moved out of range of the camera when they were observed to be engaged in the task.

Results

Table E1 presents a summary of errors made by users in order of severity. Severity is determined by the number of users who made the error and the number of times the error occurred.

Table E1

Knowledge Mapper Usability Study Error Log

	No. of users (no. of occurrences)			
	High ($n = 4$)	Medium ($n = 6$)	Low ($n = 4$)	Total ($N = 14$)
Began creating link or tried to end link close to the edge of a concept but without completing the link	1 (1)	5 (17)	4 (14)	10 (32)
Tried to link after clicking out of link mode	2 (7)	3 (19)	4 (17)	9 (43)
Clicked on concept icon to add concept (more than one attempt)	1 (2)	4 (7)	4 (5)	9 (14)
Linked from side ports of a concept but link was not completed	2 (5)	2 (21)	4 (5)	8 (31)
Resized concepts instead of moving or linking them	1 (3)	2 (12)	4 (6)	7 (21)
Disconnected link from concept and did not reconnect it to another concept	1 (1)	3 (6)	3 (6)	7 (13)
Created a link without labeling it	2 (7)	2 (13)	2 (2)	6 (22)
Clicked on link direction button to link	1 (6)	3 (15)	1 (1)	5 (22)
Linked concept to itself	1 (1)	1 (3)	2 (4)	4 (8)
Clicked on items in concepts/links list to add a concept or link to the map	1 (2)	1 (1)	2 (2)	4 (5)
Dragged concepts under left pane to expunge from map	0 (0)	1 (2)	2 (7)	3 (9)
Went to File-Delete to delete a concept/link	0 (0)	1 (1)	2 (3)	3 (4)
Resized concept to thin line instead of moving it	0 (0)	1 (1)	2 (2)	3 (3)
Zoomed out at start of task so when concepts were dragged onto the canvas, they were too small to read	0 (0)	1 (1)	2 (2)	3 (3)
Made a link with the arrow in the wrong direction	0 (0)	0 (0)	2 (3)	2 (3)
Clicked on Background tab and didn't click back to Symbol	0 (0)	1 (1)	1 (1)	2 (2)
Clicked on Select button to link	0 (0)	1 (3)	0 (0)	1 (3)
Moved populated concept on top of a blank concept and made links to the blank concept	0 (0)	1 (3)	0 (0)	1 (3)
Selected wrong direction to switch arrow direction	0 (0)	0 (0)	1 (3)	1 (3)
Made links bend at pivot points and then spent time straightening the lines	0 (0)	1 (2)	0 (0)	1 (2)
Attempted to make a link with only one concept on the map	0 (0)	1 (1)	0 (0)	1 (1)
Dragged link labels so it appeared a link label had changed	0 (0)	0 (0)	1 (1)	1 (1)
Widened left pane instead of moving a concept	0 (0)	1 (1)	0 (0)	1 (1)

In short, the usability study found that users of varying levels of computer experience learned how to use the Mapper with minimal instruction. The most difficult function of the Mapper to learn was linking concepts, with the most users requiring suggestions or explicit instruction on how to link. Recommendations for changes to the Mapper based on study findings include modifications to the linking function to head off some of the problems encountered in the study, in addition to other areas of the software, such as suggestions for renaming menu items and toolbar button labels for clarity.

Since participants were asked to use and explore the Mapper with no instruction outside of an introduction to knowledge mapping in general, the findings suggest that a short training illustrating the basic functions of the Mapper would be sufficient for users with even limited computer experience. Once users learned how to use the Mapper, there were few recurring usability issues.

The following presents in more detail highlights of observations of testing sessions, comments from participants, and recommendations for changes to the Mapper as well as suggestions for training on using the Mapper and creating knowledge maps.

<div align="center">

Concepts

</div>

Adding Concepts

Adding concepts to the map was observed to be learned after trial and error. All participants clicked once on the Concept icon, without dragging, to add the concept to the map. Some participants tried double-clicking on the icon to add it to the map. Users from all three groups (1 high, 4 medium, 4 low) made repeated attempts to single- or double-click on the concept icon to add it to the map before abandoning that method. Users from all three groups were given suggestions (1 high, 1 medium, 3 low) or explicit instructions (1 medium, 1 low) on how to add concepts to the map. More experienced users more quickly abandoned unsuccessful efforts to add concepts and dragged the icon to the canvas without instruction.

Users across all three groups (1 high, 1 medium, 2 low) went to View => Concepts and tried clicking on the concept names to add them to the map.

Two users (1 medium, 1 low) clicked on the Background tab, which hid the Concept icon, and did not click back to the Symbol tab on their own.

Users from all three groups (1 high, 2 medium, 1 low) suggested the instruction to click and drag the concept icon should be made explicit through training or through a Help feature.

Once users learned how to add concepts, no further instructions or reminders were needed as all users completed the second task with no instruction on adding concepts.

Recommendations. Add tooltip "click and drag to map" for Concept icon. Disable ability to click on Background tab if there are no background options provided.

Labeling Concepts

All users successfully labeled concepts with no instruction, both when initially labeling concepts after adding them to the map and also when renaming concepts.

Moving Concepts

Progress on creating maps was hampered when users clicked on corner points of concepts and resized them instead of moving them (1 high, 2 medium, 4 low). Time was spent restoring concepts to their original size before continuing with the task. Three users (1 medium, two low) resized concepts to thin lines and did not expand them, blocking their ability to use that concept in their map. One user (low) dragged a resized concept, now a thin vertical line, to connect two other concepts until he learned how to use the Link function.

One user resized concepts for the Human Body map to create a representation of the body on the canvas (i.e., "body" was expanded to fill most of the screen and organ concepts were placed within the borders of "body"). While this approach to creating a knowledge map was creative, the Mapper's automated scoring function would not recognize the extra effort expended on the pictorial representation, and therefore time and thought that could have been spent refining and building the knowledge map were wasted.

One user (medium) moved an unlabeled concept on top of a labeled concept twice. Later in the same session, she moved a labeled concept on top of the

unlabeled concept. The unlabeled concept was longer than the labeled concept, so it was still visible from underneath. The presence of unpopulated concepts was not only a distraction, but would have posed a scoring problem when the user, instead of linking to the labeled concept on top, created links that adhered to the blank concept underneath.

One user (high) said in the interview that it should not be possible to have unlabeled concepts.

Recommendations. Limit the range a concept can be resized. If a concept is not labeled after it is dragged to the map, it should disappear.

Links

Adding Links

Adding links to the map was observed to be more challenging than adding concepts, and was the function that required the most aid. Users from all three groups (1 high, 5 medium, 3 low) were given suggestions or explicitly taught to link (1 high, 2 medium, and 2 low were given repeated instruction on linking). One user (low) who successfully linked concepts in the first task without instruction was taught how to link in the second task (he said, "I didn't know what I was doing). Another user (medium) who had been instructed on linking during the first task needed a reminder for the second task.

In the post-task interview, 4 users (1 high, 3 medium) cited the link icon as being unfamiliar and therefore linking wasn't very intuitive for them. Only one user (medium) said the icon is appropriate because that was how linking should be represented, and that since the button's tooltip said "connect," it was obvious that was the button to use for linking. This user, however, also needed a suggestion to use the Link button before he began linking in the first task.

Four users (1 high, 3 medium, 1 low) tried to use the Arrow Direction button to create links. One of the medium users made repeated efforts across tasks to use the Arrow Direction button and was the same user as above who was given a reminder on linking in the second task.

One user (medium) repeatedly tried to link using the Select button, which features an arrow on it.

Users across all three groups tried to link concepts after they had clicked out of the link mode (2 high, 3 medium, 4 low), most of them repeatedly either within the first task (2 high, 2 medium, 3 low) or across both tasks (1 medium, 4 low). One user (high) said the link mode should be locked so the user does not need to click on the button for each link.

Most users were observed to link concepts from edges, as opposed to the center of the concept. While linking was for the most part successful, two issues that hampered progress and frustrated users arose.

The first issue involved concepts with many links made to side ports. Users across all groups (2 high, 2 medium, 4 low) failed to complete links made to concepts with many links (more than 4 or 5 at one side), even though they initiated and terminated the link on the borders of the concepts and had successfully linked earlier using this method. If linking from the center port was not discovered on their own, when instructed to connect from the center of one concept to the center of another, users linked successfully, but most first repeated linking to side ports, as that was the learned method of linking. Impact was limited to those users with more complex maps that had concepts with multiple links, but because of the number of unsuccessful attempts made by users to complete links (high users made 4 and 1 attempts each, medium users made 11 and 10 attempts each, 1 low user made 2 attempts, and 3 low users made 1 attempt each), this impeded progress.

The second issue is more likely to be fixed by training and instruction. As most users used side ports to link, some users (1 high, 5 medium, 4 low) began or ended links very near to concept borders but without connecting to side ports, possibly not noticing the spark that appears on the concept border when a link connection has been made. Six users experienced this multiple times (4 medium, 2 low). Instruction to link from the centers of concepts would likely solve this problem as a software fix is unfeasible.

Four users (1 high, 1 medium, 2 low) linked a concept to itself. Because one user (low) labeled the link, the relationship appears in the detail of the map (waste => carries => waste). The user had at first related two concepts with the link, but then dragged the origin point of the link to the destination concept, linking it to itself. Then he moved the link label so it was in between the concepts he had originally linked, giving the appearance of two linked concepts.

<u>Recommendations.</u> The tooltip for the Link button should be changed to "link" to aid users unfamiliar with the icon and to keep language consistent. If there is a limit to the number of links that can be made to side ports, increase the limit. Training should emphasize linking from the centers of concepts. Concepts should be restricted from being linked to themselves.

Labeling Links

Almost all users labeled links successfully on their own (4 high, 5 medium, 4 low). Nevertheless, 6 users (2 high, 2 medium, 2 low) at some point while creating their map had at least one unlabeled link.

One user (medium) created links and repeatedly clicked out of the pop-up menu without making a selection. She was reminded that all links in a knowledge map need to be labeled.

One user (high) said in the interview that it should not be possible to have unlabeled links.

<u>Recommendation.</u> If a link is not labeled after it is drawn, it should disappear from the map.

Changing Link Labels

Two steps in Task 2 asked the participant to change a link label. Four users (1 high, 3 medium) deleted the existing link and created a new one. One user (low) dragged the text label from a nearby link to another so it appeared on the screen that the link had changed, when in reality only the position of the link label had been moved.

<u>Recommendation.</u> Limit the range a link label can be moved.

Moving Links

Some users moved links by grabbing end points and dragging them to other concepts, reconnecting them successfully most of the time. However, 7 users (1 high, 3 medium, 3 low) disconnected links from concepts and then dragged concepts near or on top of the end point of the link to simulate a complete relationship.

<u>Recommendation.</u> If a link is disconnected from a concept and not reconnected to a concept, it should disappear from the map.

Changing Link Direction

One step in Task 2 asked the participant to change the arrow direction of an existing relationship. Two participants (1 medium, 1 low) skipped this step. Four participants (1 high, 3 medium) deleted the existing link and added a new one in the opposite direction. One participant (medium) dragged the end points of the link from one concept to the other to reverse the arrow direction. Six participants (3 high, 1 medium, 2 low) successfully changed the arrow direction on their own, and only one user (low) needed instruction on how to use the Arrow Direction button.

One user (medium) had some difficulty using the Arrow Direction button to reverse the arrow direction in Task 2. He had accidentally reversed the arrow direction of the wrong relationship, so he spent some time trying to change it back. The relationship he wanted to change had the arrow running from right to left. He selected the link, clicked on the Arrow Direction button, and selected the first arrow in the pop-up menu, as it runs from left to right (the new direction he wanted for the link). This failed to change the direction of the arrow. He repeated the actions multiple times without success. Moving from that problem, he successfully changed the direction of the arrow in the task instructions as that arrow ran vertically and the first option he chose changed the direction.

In the post-task interviews, two users (1 medium, 1 low) said changing the arrow direction was difficult.

Recommendation. Since users with graphics experience had no trouble with this function, it seems unwise to radically change the function of the button from the standard. Only one user (medium) in Task 1 (the non-directed task) used the Link Direction button. Most users likely will never need to use this function or will be able to work around it (deleting and replacing links).

Link Pivot Points

One user (medium) made pivot points in her links and spent time straightening the lines.

Concept and Link Menus

Access to Concept and Link Menus

Four users (2 medium, 2 low) accessed the concept and link menus, but they closed them after attempting to add concepts using them. It appeared most users added new concepts or links or clicked on existing concepts or links to see the options available for building maps.

One user (medium) said viewing relations, but not necessarily concepts, should be made easier, because the list of concepts was finite and after they were all added to the map, you would not need to see a list of concepts. Because relations could be reused, however, she said a more convenient way of seeing a list of links should be provided, since creating new links to see the list was cumbersome. When informed the View menu contained the lists of concepts and links, she said that was not where she expected to find them, and that she thought if a list of links was built into the Mapper, it would have been in the same window with the Concept icon.

One user (high) said she expected that clicking once on the Concept icon would bring up a list of available concepts and she would have preferred that option rather than having to drag a concept to the map and commit to adding a new concept.

Recommendation. Perhaps buttons to view concepts and view relations should be added to the toolbar.

Edit Menu Functions

Cut/Copy/Paste

The cut, copy, and paste functions were not functional on the version of the Mapper in the usability study. Two users (one high, one low) commented that the Mapper needs these functions.

Delete

The Delete function was the second most difficult function on the Mapper for users to perform, with more than half of the users needing suggestions on how to delete (2 high, 2 medium, 4 low). Users were directed to the Edit menu if they were having trouble deleting; most found the "Delete Symbol" option then. One user

(high) was directed to the Edit menu, but he said the Delete function was not there; he was later taught how to delete.

Three users (1 medium, 2 low) were observed to drag concepts under the left pane to expunge them from the map instead of deleting them.

Three users (1 medium, 2 low) went to File => Delete to delete a concept or link. This is covered in detail in File Menu Functions: Delete Map.

One user (medium) commented that the Delete function should be made more obvious.

Recommendations. Training should include instructing users that they can use the Delete button on the keyboard. Also, on Mac keyboards, the Delete button is in the same spot as the Backspace key on a PC keyboard, so if possible, both the Backspace and Delete keys should delete concepts and links. The Delete Symbol menu option could be changed to "Delete Concept/Link" so it stands out more to anyone skimming the menu, or possibly simply "Delete."

Undo/Redo

Most users (2 high, 5 medium, 2 low) used the Undo/Redo functions in the Mapper, with most using the button in the toolbar, but some going to the Edit menu to undo actions. Three users (2 medium, 1 low) were given suggestions on the Undo function.

The step in the directed task targeting the Undo function asked users to restore a link deleted in the previous step. Five users (2 high, 1 medium, 2 low) simply recreated the link instead of using Undo.

Recommendation. Most users found and utilized the Undo/Redo functions in the Mapper. However, the computer experience survey shows that only 3 users correctly identified the Redo icon and 4 users correctly identified the Undo icon. Possibly these two icons could be redesigned for greater recognizability.

Zoom

Zoom in/Zoom Out

Most users (4 high, 5 medium, 3 low) successfully zoomed into and out of the map without help. Three users (1 medium, 2 low) were given a suggestion to use the magnifying glass icon to zoom in.

Three users (1 medium, 2 low) zoomed out of the map at the start of the first task, so when they started to add concepts to the map, the concepts were too small to read. The users were guided to zoom in to 100%.

One user (high) said the zoom function was not convenient because if you select an area and then hit the zoom button, it should focus on that area.

Formatting

Line Weight

Most users (4 high, 6 medium, 2 low) successfully changed the line weight per Task 2's instructions ("Make the border of the concept 'Brain' thicker"). Only one user (low) needed a suggestion before changing the line width.

One user (low) skipped the step entirely.

Another user (low) passed the mouse over the icon and "Line weight" popped up as a tooltip, but he did not click on the button. Instead he interpreted the instruction as making the concept larger and resized the concept. In the post-task interview, when asked if he would have clicked on the button if the label said "line width," he said that would have made more sense to him.

Recommendation. Since most of the users from all groups had no trouble with this function, it may be unwise to deviate from the standard and change the tooltip label.

Line Color

Most users (4 high, 5 medium, 3 low) successfully changed the line color of a link. Only 2 users needed either a suggestion (1 low) or to be taught how to use the function (1 medium).

The icon for line color was the only icon on the computer experience survey that no one got correct. Most users did not attempt to label the icon at all; the two who did try chose the wrong answer. Conversely, the Microsoft Word Line Color icon had 13 of 14 participants label it correctly.

Recommendation. Change the Line Color icon so it is more recognizable.

Line Style

Most users (4 high, 6 medium, 3 low) successfully changed the line style of a link. Only one user (low) skipped this step.

Other Formatting Issues

In the exit survey and post-task interviews, users brought up other issues regarding formatting. One (low) asked for the ability to change fonts and arrowhead appearance. Another (high) asked for the option to change the fill color of the concepts.

File Menu Functions

Save Map

All users saved the map successfully on their own.

Delete Map

Two users (low) went to File => Delete to delete a concept or link. One user chose the function and cancelled out of the dialog window. He then found in the Edit menu the option to delete a concept or link. Later in the same session, however, the user went to File => Delete and clicked OK without paying attention to the warning message in red, and he deleted a map.

The second user went to File => Delete but was instructed before he clicked anything to cancel out of the window to prevent any other maps from being deleted.

Recommendations. The menu option for deleting a map should read "Delete Map." Also, there should not be a default map highlighted for deletion—if a user wants to delete a map, the map should be specifically chosen.

Miscellaneous Comments

User Interface: Background Grid

Two users in the post-task interview had negative comments about the preset background grid on the canvas. One (medium) said the grid was harsh on the eye. Another (high) said the grid was unnecessary.

User Interface: Symbols/Background Pane

One user (medium) widened the left pane of the Mapper window instead of grabbing a concept. In addition, users (1 medium, 2 low) dragged concepts, some labeled, under the left pane instead of deleting them.

Recommendations. The left pane should be a fixed width and impervious to modification by the user. In addition, it should demarcate the left border of the map, as opposed to lying on top of the map, so users cannot leave concepts underneath the pane.

General User Interface Issues

Two users (1 medium, 1 low) said having graphic icons for the concepts (e.g., a brain icon and a heart icon) instead of boxes would make it more visually interesting for users.

Increased Functionality—Right-Click

Two users (1 high, 1 low) said right-clicking on a concept or a link should provide a more extensive menu with more options, including cut, copy, paste, delete, as well as the concept or link labels. The low user said a hint or help function that could be accessed by the right-click would also be helpful.

Miscellaneous User Recommendations

Users offered general recommendations in their exit surveys and post-task interviews. One (medium) suggested making the Mapper more like a game would make it more engaging.

One user (low) said the software needs a Help feature.

Observed Bugs

1. An unlabeled concept was deleted, but the outline remained on the canvas. Later, the user was able to rename the concept and integrate it into the map, but it was the only transparent concept on the map (one occurrence).

2. No matter where you clicked the mouse, the link would begin in the upper left corner of the canvas in the same spot, until the Mapper was restarted (two occurrences).

3. Clicked on paste and "<DOCT" popped up on canvas (one occurrence).

Positive Feedback

Many users expressed positive feedback about the Mapper, calling it easy to use (1 high, 2 medium, 1 low), self-explanatory (2 medium, 1 low), and interesting (1 low). One user explicitly said she liked it. Two (low) said the Mapper could potentially be useful. Another user (medium) was impressed that the Mapper was sophisticated enough that keyboard commands, such as control-Z, worked.

Negative Feedback

Some users said the Mapper was confusing at first (2 low) and boring (1 medium).

Knowledge Mapping Training

Three users (1 high, 1 medium, 1 low) left unlabeled links in their maps upon completion of the task. At least one user (low) had an arrow pointing in the wrong direction. One user (medium) tried to make a link when there was only one concept on the map. Several users needed to be reminded that the second part of making a knowledge map is creating links between concepts, as they had dragged concepts to the map and only worked on arranging them on the map either in groups or hierarchically, before asking what they were to do next.

Some changes to the Knowledge Mapper will mean some of the above will no longer apply (i.e., unlabeled links). Nevertheless, an introduction to knowledge mapping must emphasize the creation of links between concepts as well as the importance of arrow direction.

Appendix E1

Computer Experience Survey

UCLA CRESST Knowledge Mapper
KMT Usability Study
Computer Experience Survey

Your responses will be kept completely confidential. The results of this survey will be reported only for this study as a whole. Your particular responses will not be identifiable in any way.

GENERAL INFORMATION

1. How many hours per week do you use a computer? _____ hours

2. How long have you known how to use a computer? _____ years

3. Do you use a computer at work?   ❏ Yes   ❏ No

4. Do you use a computer at home?   ❏ Yes   ❏ No

5. What do you use a computer for? (Check all that apply.)

   ❏ Word processing   ❏ E-mail   ❏ Working with photos or graphics
   ❏ Playing games   ❏ Editing movies   ❏ Working with databases
   ❏ Desktop publishing   ❏ Programming   ❏ Visiting Internet chat rooms
   ❏ Visiting Web sites   ❏ Data entry   ❏ Creating Web site(s)
   ❏ Creating music CDs   ❏ Data analysis   ❏ Working with charts or tables
   ❏ Other _____

6. Do you use: ❏ Mac   ❏ PC

7. Which of the following have you used? (Check all that apply.)

   <u>Apple</u>   <u>PC</u>   <u>Other</u>
   ❏ OS 9 or lower   ❏ DOS   ❏ Unix/Linux
   ❏ OS X   ❏ Windows (any version) ❏ Other _____
   ❏ Other _____   ❏ Other _____

   ❏ Don't know

Below are icons for buttons that are used in a variety of software applications. <u>First,</u> indicate how confident you are that you know what the icon does by circling either "Don't know" or one of the numbers. <u>Second,</u> indicate the function of the icon by using the numbered list given to you and writing the number corresponding to the function of the icon in the last column. **If you do not recognize the icon, circle "Don't know" and leave the last column blank.**

	How confident are you that you know what this icon does?					Number corresponding to icon's function
	Don't know this icon	Not very confident	Somewhat confident	Confident	Very confident	
≡	Don't know	1	2	3	4	
⬆	Don't know	1	2	3	4	
↷ ▾	Don't know	1	2	3	4	
⟳	Don't know	1	2	3	4	
⌸	Don't know	1	2	3	4	
⬧ ▾	Don't know	1	2	3	4	
▤	Don't know	1	2	3	4	
⌗	Don't know	1	2	3	4	
⎙	Don't know	1	2	3	4	
⬚	Don't know	1	2	3	4	
⊹	Don't know	1	2	3	4	
⊜	Don't know	1	2	3	4	
💾	Don't know	1	2	3	4	
◣	Don't know	1	2	3	4	
✎ ▾	Don't know	1	2	3	4	
⬙	Don't know	1	2	3	4	
▥	Don't know	1	2	3	4	
◱	Don't know	1	2	3	4	
⚲	Don't know	1	2	3	4	
⛶	Don't know	1	2	3	4	
⟳	Don't know	1	2	3	4	
⇄	Don't know	1	2	3	4	

	How confident are you that you know what this icon does?					Number corresponding to icon's function
	Don't know this icon	Not very confident	Somewhat confident	Confident	Very confident	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	
	Don't know	1	2	3	4	

Appendix E2

Knowledge Map Introduction

Usability Study

- We are asking you to help us determine the usability of the Knowledge Mapper because it is new software.

- We want to know how we can fix it to make it easy to learn and easy to use.

What Is a Knowledge Map?

- A knowledge map measures what a person knows about a subject.

- In a knowledge map, the person relates concepts to each other.

Creating a Knowledge Map

- A set of concepts and relations is given to a person to construct a knowledge map.

- For example, for a recycling knowledge map, some concepts are environment, pollution, and recycling. The list of relations includes helps and hurts.

Linking Concepts and Relations

- The person then has to use the relations to link the concepts together.

- Here the person has linked pollution and environment together with hurts, and recycling and environment with helps.

Tip: Arrow Direction for Relations

- Arrows on the relations show the direction of the relationship.

- In the previous example, the arrow is pointing from pollution towards environment because that is the direction the thought is read.

- To have the arrow point the opposite way would have the relationship read environment -> hurts -> pollution, which is incorrect.

Tip: Relating Concepts

- Only one relation can be used to link two concepts going in one direction.

- However, two concepts can be linked twice, if the relations go in opposite directions.

Tip: Grammar Does Not Matter

- Focus on the meaning of a relationship without thinking about grammar.

- For example, oceans -> is a part of -> environment will be scored as correct.

What We Are Measuring

- Usability of the software to create knowledge maps

What We Aren't Measuring

- This study is not concerned with measuring how much you know about the subject—the maps you create will not be evaluated.

- However, we are still asking you to create the best map you can, as we would like to simulate actual test-taking conditions.

Questions?

- If you have any questions at this time, please ask the researcher now.

Appendix E3

Human Body Concepts and Links

Concepts for Task 1	Links for Task 1
Body	Carries
Brain	Controls
Stomach	Digests (breaks down)
Intestines	Goes to
Food	Is made of
Waste	Maintains
Nutrients	Is part of
Energy	Pumps
Blood	Removes
Heart	
Tissues	
Cells	

Appendix E4

Task 2 Step-by-Step Instructions

Step 1. Create the relationship "Optic nerve —> Hits —> Brain"

Step 2.. Create the relationship "Eye —> Controls —> Brain"

Step 3. Create the relationship "Light —> Focuses —> Retina"

Step 4. Create the relationship "Retina —> Is connected to —> Optic Nerve"

Step 5. Create the relationship "Brain —> Creates —> Image"

Step 6. Change the arrow direction of "Eye —> Controls —> Brain" so it reads "Brain —> Controls —> Eye"

Step 7. Change "Light —> Focuses —> Retina" to "Light —> Hits —> Retina"

Step 8. Make the line around the concept "Brain" thicker

Step 9. Delete the relation "Hits" in "Optic nerve —> Hits —> Brain"

Step 10. Restore the relation "hits" in "Optic nerve —> Hits —> Brain"

Step 11. Change "Hits" to "Sends messages to" in "Optic nerve —> Hits —> Brain"

Step 12. Change the color of the relation "Controls" to blue

Step 13. Change the relation "Controls" to a dotted line

Step 14. Zoom in to "Light —> Hits —> Retina"

Step 15. Delete the concept "Light"

Step 16. Zoom out to see the whole map on the screen

Step 17. Save the map as "Eye Map"

Appendix E5

Exit Survey

UCLA CRESST Knowledge Mapper Usability Study
Exit Survey

Your responses will be kept completely confidential. The results of this survey will be reported only for this study as a whole. Your particular responses will not be identifiable in any way.

1. **Age:** _____ years

2. **Gender:** ❑ Male   ❑ Female

3. **Ethnicity:**

   ❑ Biracial/multiethnic   ❑ Native American

   ❑ African American   ❑ White, non-Hispanic

   ❑ Asian American   ❑ Other _____

   ❑ Latino/Hispanic

4. **What are your overall impressions of the Knowledge Mapper?**
   Please check one item in each row.

Not pleasing	❑	❑	❑	❑	❑	❑	❑	Pleasing
Complicated	❑	❑	❑	❑	❑	❑	❑	Simple
Difficult to use	❑	❑	❑	❑	❑	❑	❑	Easy to use
Incomplete	❑	❑	❑	❑	❑	❑	❑	Complete

5. **How <u>familiar</u> were you with the computer task topics?**
   Please circle one number in each row.

	Not familiar	Somewhat unfamiliar	Somewhat familiar	Familiar	Very familiar
Human body	1	2	3	4	5
The eye	1	2	3	4	5

6. **How <u>easy or difficult</u> did you find the computer task topics?**
   Please circle one number in each row.

	Very difficult	Somewhat difficult	Somewhat easy	Easy	Very easy
Human body	1	2	3	4	5
The eye	1	2	3	4	5

7. How <u>easy or difficult</u> was it to keep your head still for the eye tracking system and understand the material at the same time?

Very difficult	Somewhat difficult	Somewhat easy	Easy	Very easy
1	2	3	4	5

8. What effects, if any, did the eye tracking system have on you during the computer task? Please list below or check "no effects" if there were no effects.

❏ No effects

_____

_____

_____

_____

9. What would you <u>change</u> on the Knowledge Mapper?

_____

_____

_____

_____

_____

_____

_____

Appendix F

Preliminary Quick Start User Guide

Knowledge Mapper Quick Start

UCLA CSE/CRESST

July 2002

Technical Contact: Dave Brill, <u>brill@cse.ucla.edu</u>

This is a short guide to the basic features of the CRESST KnowledgeMapper. It shows you how to create, modify, and save a graphical representation of the concepts and relations in a knowledge domain. This document uses screen captures and color-coded annotations, so it is best to read it from a monitor or print it on a color printer. A more detailed User's Guide will be available in the near future.
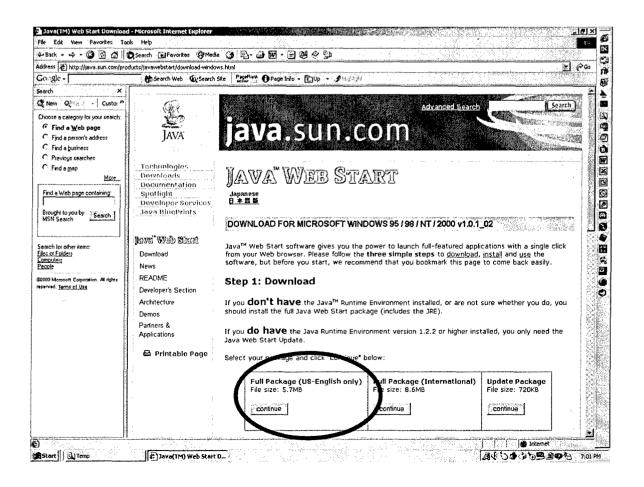
Use your regular browser and enter this URL in the address bar.

When the Concept Mapper page appears in the browser, enter your login information. In this case, the login address is mary@england and the password is mary1.

Enter your Email and password to sign in

Email Address : mary@england

Password : ●●●●●●●

Sign In

If this is the first time that you are using the KnowledgeMapper, you will need to install Java Web Start. Clicking on the Install Web Start link takes you to the Sun site from which you can download this software. This only needs to be done once.
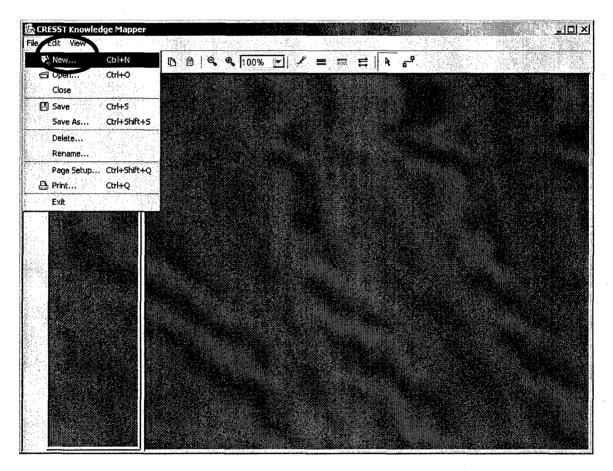
Java Web Start is a new technology that lets you run applications in your browser and automatically gets updates whenever they are available. Select the English Full Package option and then follow the download instructions. If you don't have the current version of Java on your machine, this could take several minutes.
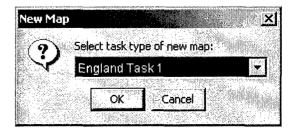
Now click the Launch link to start the KnowledgeMapper. Whenever you use the Mapper after the first time, you can go immediately to this step.

You can create a new map by selecting the New item in the File menu. Or you can press the New button, which is the first button on the toolbar.
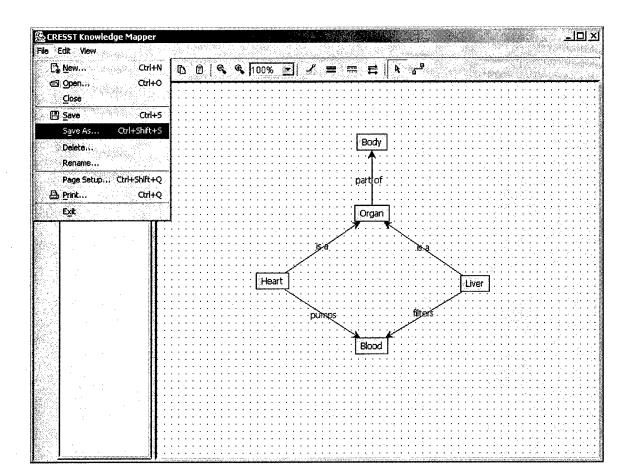
Every map belongs to a content area called a *Task*. Tasks are assigned when your account is set up. Select which task you want the new map to be placed in.

Maps are created by dragging icons from the palette (on the left side of the Mapper) to the canvas. When the mouse button is released, a text box appears in the new node, and you can enter the name of the concept that the node represents. In some tasks, these names are selected from a list rather than entered free-form. Also, some tasks have several different icons on the palette.

CRESST Knowledge Mapper

File Edit View

New...	Ctrl+N
Open...	Ctrl+O
Close	
Save	Ctrl+S
Save As...	Ctrl+Shift+S
Delete...	
Rename...	
Page Setup...	Ctrl+Shift+Q
Print...	Ctrl+Q
Exit	

Body

part of

Organ

is a   is a

Heart   Liver

pumps   filters

Blood

Save Map As

Enter name for map:

Physiology

OK   Cancel

Maps are saved by selecting the Save As menu item (or Save if you are changing an old map). Enter a name for the new map. Then choose Exit if you are finished.

CRESST Knowledge Mapper

File Edit View

New...	Ctrl+N
Open...	Ctrl+O
Close	
Save	Ctrl+S
Save As...	Ctrl+Shift+S
Delete...	
Rename...	
Page Setup...	Ctrl+Shift+Q
Print...	Ctrl+Q
Exit	

Body

part of

Organ

Saved maps are stored in a database on a CRESST server. You can retrieve an old map by selecting the Open item on the File menu, or by pressing the second button on the toolbar. When the Open dialog appears, first choose a task from the upper box, and then choose one of the maps belonging to that task. When the map is displayed, you can alter or extend it, and then save it again. To save a map under its original name, select the Save item or press the third button on the toolbar.
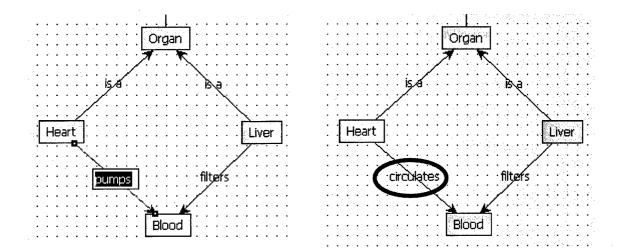
To give a saved map a new name, select the Rename option in the File menu. In the Rename dialog, select the task and map that you want to rename, and then type in the new name.

CRESST Knowledge Mapper

File   Edit   View

New...	Ctrl+N	
Open...	Ctrl+O	
Close		
Save	Ctrl+S	
Save As...	Ctrl+Shift+S	
Delete...		
Rename...		
Page Setup...	Ctrl+Shift+Q	
Print...	Ctrl+Q	
Exit		

▶

Rename Map

Select task:

England Task 1

Select map to rename:

England Map 1
Physiology

Enter new name for map:

Human Body

Rename   Cancel

CRESST Knowledge Mapper

File   Edit   View

New...	Ctrl+N	
Open...	Ctrl+O	
Close		
Save	Ctrl+S	
Save As...	Ctrl+Shift+S	
Delete...		
Rename...		
Page Setup...	Ctrl+Shift+Q	
Print...	Ctrl+Q	
Exit		

▶

Delete Map

Select task:

England Task 1

Select map to delete:

England Map 1
Human Body

Warning: This operation cannot be undone.

Delete   Cancel
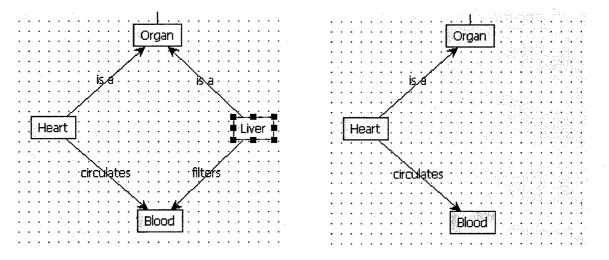
You can delete a saved map by selecting the Delete option in the File menu. When the dialog appears, choose a task and then select the map that you want to delete. Once a map is deleted, it cannot be restored.

In a knowledge map, nodes are labeled with concept names and links are labeled with relation names. To change a concept name, either right-click or double-click the node, and when a text box appears, enter the new name. (For some tasks, a list may appear rather than a text box.) Similarly, in order to change a relation name, right-click or double-click a link and enter the new name. In the following example, a link label is changed from *pumps* to *circulates*.

To delete a node or a link, select it by left-clicking and then press your keyboard's delete button. (You can also use the Delete Symbol item in the Edit menu.) When you delete a node, you also remove all links that are connected to it. When you delete a link, the connected nodes are not removed, but they may be left isolated. Unless these nodes are reconnected to the map, they won't be considered when the map is scored.

Nodes can be moved by simply dragging them across the canvas. When a node is moved, all attached links follow it to the new location. A link, however, cannot be moved independently of the nodes that it connects.
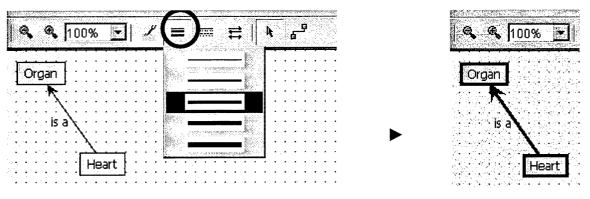
Groups of nodes (and attached links) can be moved as a single unit. First draw a marquee around the nodes you want to move. Do this by holding the left mouse button down while you drag the mouse diagonally across the canvas. Then select any node within the marquee and drag it to its new location. The other nodes will follow. This same technique can be used to delete groups of nodes and arcs in a single operation.

Link labels are usually drawn over the links. If these labels are hard to read, they can be moved a small distance by dragging them with the mouse.
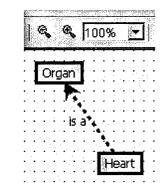
Use the width menu to change the width of an object. First select a node or link, or drag a marquee around a group of nodes and links. Then choose the desired line width from the dropdown width menu.
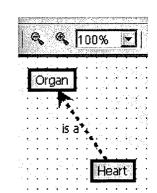

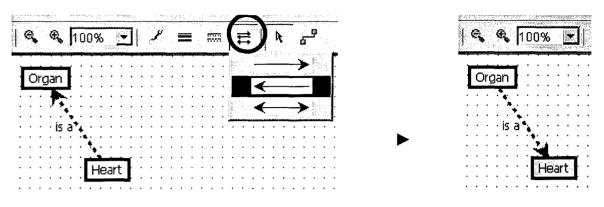Select a line pattern from the pattern menu. This is only for links, not node borders.

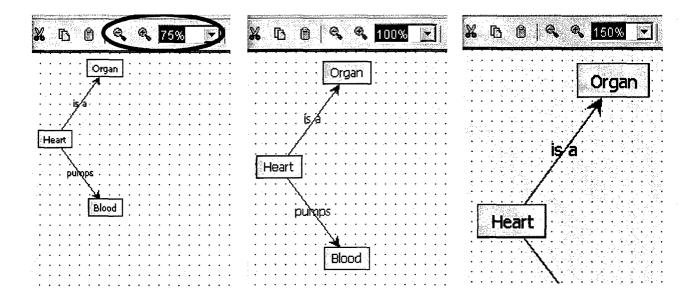

Select a line color from the color menu.
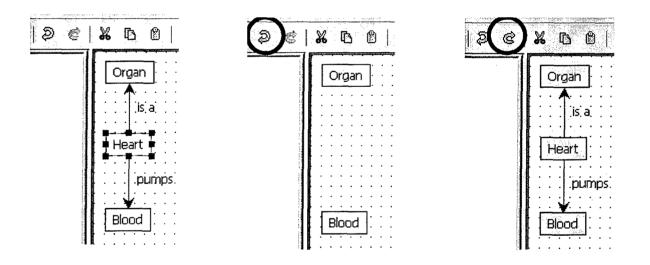
Reverse link direction by choosing the back-arrow on the direction menu.

If you change your mind about a modification you've made to a map, click the Undo button and the previous state of the map will be restored. By clicking Undo repeatedly, you can go back as many steps as you want. If you go too far, click Redo one or more times to reinstate changes that you made.

The zoom controls allow you to change the size of the nodes and links in the map. The Plus and Minus magnify buttons increase or decrease the current scale by a factor of two each time they are pressed. The Zoom dropdown allows you to select one of several fixed magnification levels, or to type in any scale that you want.

We hope you find that the CRESST KnowledgeMapper is a useful addition to your evaluation tools. Please contact us with any questions or suggestions.