

**AC 2009-1768: USABILITY ANALYSIS OF A CONCEPT-MAP USER INTERFACE
FOR AN ON-LINE LEARNING ENVIRONMENT**

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Usability Analysis of a Concept Map User Interface for an Online Learning Environment

Abstract

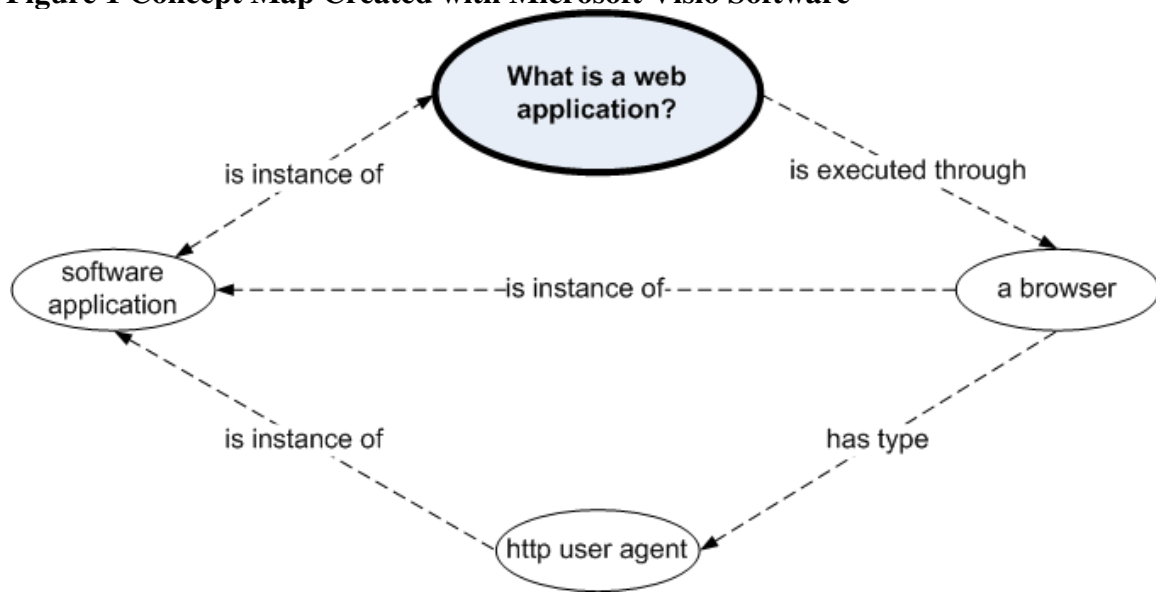
A concept map is a graphical representation of relationships among concepts. Construction of concept maps using modern concept mapping software has been suggested as an active learning strategy with potential for improved learner outcomes, particularly among students native to a digital environment. In addition, modern concept mapping software enables instructors and students to create visual navigation structures through complex multi-resourced knowledge domains, such as the content of a course. Value in visual navigation structures has been suggested for its relevance to organizing information and representing knowledge, especially for visual learners. This paper presents background information an examination of a concept map user interface in terms of usability.

Digital Concept Maps

Understanding that mental representations of knowledge and understanding are secreted away inside of human brains, concept maps are external semantic representations of such knowledge. Concept maps emerged from the work of cognitive psychologists who formulated theories and developed understanding of the way humans learn. The process by which humans build knowledge is complex, but there is agreement that as the brain processes inputs into information, each person organizes the inputs and information in a way that is unique for that individual, so that everything that a person learns and experiences is understood and appreciated by her in her own unique way. Each human's personal organization of input as information, or her knowledge, is her personal mental schema. The term schema used here means a generalized mental structure that is an abstract representation of events, objects, and relationships in the world. Concept maps are spatial semantic representations of a person's mental schema about a topic ¹.

A concept map (a.k.a. semantic network, mind map) is a graphical two-dimensional representation of concepts expressed semantically and their interrelationships. It represents the mental schema of the creator of the map – his unique way of understanding a concept in relation to others ². *Nodes* of a concept map are two-dimensional shapes that represent concepts, and labeled lines called *links* represent relationships between concepts. A pair of concepts linked with a named relationship is called a *knowledge element* or *proposition*. Each knowledge element formalizes an idea such as “optical network – is medium for – transporting data” or “variance theory – predicts – level of outcome variable.” A simple concept map created with Microsoft Visio software is shown in Figure 1.

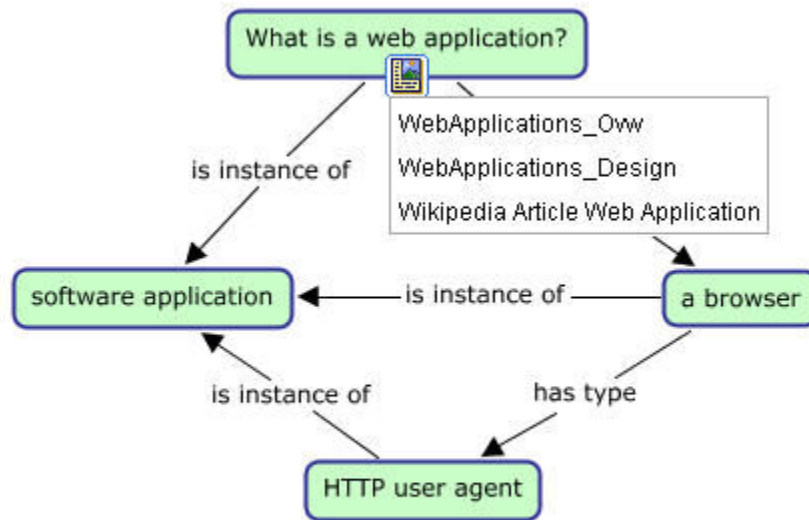
Figure 1 Concept Map Created with Microsoft Visio Software



Technically speaking, the only tools one needs to construct a concept map are pencil and paper. However, there is an abundance of software tools for creating digital maps. Milam, et. al. reviewed a number of computer-based mapping tools that were available before 2000, and there are even more tools available today³. Included in their review are Inspiration®, MindManager®, SMART Ideas™, IHMC Cmap Tools, and VisiMap (see Appendix A for URIs to information about each tool). All of these tools allow learners to create digital concept maps based on their personal knowledge structures and save them in standard file formats such as digital image formats. The digital maps can be revisited and revised, allowing newer versions to be compared to earlier versions to see what concept development has taken place.

In addition to the archive of a graphical representation of the map creator's knowledge structure, modern software tools can also embed links to information artifacts directly in the map. Usually the embedded link is associated with a node, the implication being that the link takes the map reader to an information artifact for the concept named in the node. Figure 2 shows a map created with Cmap Tools software that contains a node with links to several information artifacts. With this particular software, the artifact link presents a list of links to all available artifacts without distinguishing the artifacts by file type. For example, referring again to Figure 2, one of the links is to a web page which is implied by the semantic description of that particular artifact. There is no visual cue that informs the map user that the other two links are to presentation slides. Some software packages provide icons that distinguish the type of artifact referenced by the link.

Figure 2 Concept Map Containing Node with Links to Information Artifacts



Concept mapping software tools are evolving and increasing in functionality. A number of server-based tools that enable collaborative map creation are available, including a server version of Cmap Tools and BrainEKP®. There are web-based tools available and three-dimensional tools are emerging. Applications of these tools to different problem scenarios are numerous, including help desk tracking and organization, content management, intranet and portal development, database visualization, and people networks. Truly, concept mapping has come of age as an information technology application.

Value of Digital Concept Maps to Cognition

Concept maps are not new. They have been studied for their value to learning for many years. Before concept mapping software became available, concept maps were applied in classrooms in order to engage learners through activities that involve meaningful processing of inputs into personal knowledge schemas. In that respect, concept maps belong in the category of cognitive tools - “mental devices that support, guide, and extend the thinking processes of their users”⁴. Mindtools are computer-based cognitive tools with the following attributes: (1) can be applied across subject matter domains, (2) represent knowledge; (3) engage learners in critical thinking about the subject; (4) assist learners to acquire skills that are general and transferable to other contexts; (5) are simple but powerful in encouraging deeper thinking and processing of information; (6) facilitate active learning and (7) are relatively simple to learn to use. Thus, we see that computer-based concept mapping tools can be classified as mindtools. In particular, they belong to a subclass called semantic organization tools, which are tools that help learners analyze and organize what they are learning with respect to what they already know⁵.

The value of using mindtools in a learning environment can be extrapolated from the value established for active learning strategies together with the recognition that using a mindtool, such as concept mapping, is an active learning strategy⁶. Active learning is an instructional technique that engages students in meaningful learning activities such as dialog, debate, writing, and problem solving, as well as higher-order thinking, e.g., analysis, synthesis, evaluation⁷. Utilization of active learning is a recognized best practice for undergraduate teaching⁸. Active learning and the use of computer-based mindtools are important strategies for reaching the youthful learners of today. These learners, dubbed “Digital Natives” by Marc Prensky are difficult to engage using activities that work well for more mature learners who are “Digital Immigrants”⁹. Thus, we can understand an expanded interest in computer-based concept mapping from its value for helping students access their underlying mental representations in an active way¹⁰.

e-Learning and Distributed Cognition

Distributed cognition involves tasks that require people to process information both internally in their mind and through an external environment or representation of an external environment (such as a computer interface)¹¹. In order to study the phenomenon of how distributed cognition works, one must first accept as real the construct of distributed cognition. The construct seems real based on personal experiences with learning and understanding. There are some tasks that are most adeptly handled using both internal conceptualizations and external representations. For example, arithmetic can be done very quickly using an abacus as a tool, but efficient use of the abacus is aided by the user first understanding place value concepts. A calculator (another external representation of arithmetic), on the other hand, does not require understanding place value concepts. Driving with a GPS device is another example. Personally, I feel comfortable relying on the GPS to help me find a specific location when I already have a “big picture” feel of direction and where things are in relations to others. When driving with a GPS in a completely foreign location, I find the GPS much less help in getting me where I want to go, generally speaking. A much-studied distributed cognition task and environment, and one that spawned research into the nature of distributed cognition, is the task of flying aircraft. This task, in modern airplanes, is much facilitated with the flight control panel interface as well as the air traffic control tower and related systems¹².

Once distributed cognition is accepted as an axiom, it makes sense to want to examine and understand the part of it that can be controlled – namely the external environment that takes part in the distributed cognitive tasks. Research contributions have been made that examine the importance of the external environment to aspects of task completion, and some has targeted human-computer interactions. For example, Wright, et. al. present a model of human-computer interaction with concepts rooted in distributed cognition¹³. Zhang and Norman present experiments that suggest that external representations (1) can provide memory aids, (2) can provide information that can be directly perceived and used without being interpreted and formulated explicitly, (3) can anchor and structure cognitive behavior, (4) change the nature of a task, and (5) are an indispensable part of the representational system of any distributed cognitive task.

It is a proposition of this proposal that e-Learning is a distributed cognitive task. Currently e-Learning environments are built by instructors using learning management systems. The learning management system provides the framework for the distributed cognition task of navigating the course and completing interaction tasks. This promotes the course interface as a vital part of the distributed task at hand, namely, developing concepts and integrating them into the learner's personal mental schema. If this is true, then it makes sense that concept map interfaces to course resources might improve learner outcomes by facilitating the distributed cognitive tasks involved in negotiating the course content online.

Value of Digital Concept Maps to e-Learning

Today, e-Learning opportunities often offer students very complex learning environments delivered via a learning management system such as the open source Moodle, Desire2Learn, or Blackboard/WebCT. Furthermore, information and communications technologies have advanced together enabling true resource-based learning. A resource-based learning environment (RBLE) is described as “an integrated set of strategies to promote student-centered learning in a mass education context, through a combination of specially designed learning resources and interactive media and technologies”¹⁴. In a complex RBLE, a student is offered interaction with books, teacher-created resources such as slide presentations and quizzes, and textual and multimedia resources available via the internet. Sometimes the instructor purposely provides more resources than an individual student can consume in the prescribed course time frame, with the expectation that each student will choose those resources best suited to her learning needs or preferences. A resource rich course format that requires some degree of student self-regulation of learning is frequently encountered in distance or hybrid e-learning scenarios¹⁵.

It has been suggested that concept map software tools might be useful in creating maps that help students navigate the complexity of a RBLE. It is also suggested that using them in this way may foster development of the identified personal knowledge management skills of knowledge identification, knowledge gap diagnosis, and resulting information search¹⁶. These personal knowledge management skills are critical for successfully assimilating the knowledge of a course or curriculum, and the skills are transferrable to lifelong learning. Thus, it is plausible that an improvement in learning outcomes after using a concept map interface to course resources is evidence that students are acquiring these life-long learning skills. It is also plausible that such an improvement would demonstrate the efficacy of using a concept map interface for negotiating online course content.

Analysis for Usability

If a course map is to serve as the interface for students to interact with course materials, then the interface should be examined with respect to its usability.

Task-Action Mapping: A competent interface will effectively map user tasks to user actions. One way to analyze and model user interfaces in consideration of this factor is with a GOMS (goals, operations, methods and selection) model which describes the methods needed to accomplish specified user goals.¹⁷ The author constructed a GOMS model after the design and implementation of the test interface based on concept mapping. A model was constructed for both the experimental interface and the usual course learning management system implied interface. The GOMS model helped the author to reflect on the completeness, consistency, and efficiency of the concept map design compared to the LMS design. The GOMS models for both interfaces are shown in Table 1.

Table 1 Comparison of Tasks to Goal for Two Interfaces

GOMS Task Description for Accomplishing the Same Goal with Two Different System Interfaces	
<p>TECH 1313 via WebCT</p> <p>Method for accomplishing goal of: Complete</p> <p>Activities for TECH 1313 for the Week</p> <p>Step 1 Log on to WebCT and select TECH1313 course from My WebCT list.</p> <p>Step 2 Select Course Info By Week link from n X 4 array of m links + p toolbar links on the home page. Each link represents course activity categories (assessments, assignments, discussions, mail, general course info, calendar etc.).</p> <p>Step 3 Select link for the week wanted based on visible start date of week.</p> <p>Step 4 IF user wants an overview of week activities THEN accomplish goal of Get an Overview.</p> <p>Step 5 IF user wants to complete a reading assignment THEN accomplish goal of Complete a Reading Assignment.</p> <p>Step 6 IF user wants to complete an interaction assignment THEN accomplish goal of Complete an Interaction Assignment.</p> <p>Step 7 IF user wants to complete an evaluation THEN accomplish goal of Complete an Evaluation.</p> <p>Method for accomplishing goal of: Get Overview of</p> <p>Class Activities for TECH 1313 for the Week</p> <p>Step 1 Select List of Planned Activities link (always the first link in the upper left corner of the n X 4 array of links) to retrieve pdf format artifact that is a sequential list of activities in spreadsheet format.</p> <p>Step 2 Review the list to determine all scheduled events for the week.</p>	<p>TECH 1313 via Course Map</p> <p>Method for accomplishing goal of: Complete</p> <p>Activities for TECH 1313 for the Week</p> <p>Step 1 Use a browser to open the course map from its url.</p> <p>Step 2 Select weeks map from link on Weeks node (weeks node is approximately in the upper left corner of all map pages). There is a radial array of n nodes from which to choose.</p> <p>Step 3 Select link for the week wanted based on visible start date of week.</p> <p>Step 4 Review the week map to identify the topic for the week.</p> <p>Step 5 Follow a map path from the central concept to a node to download or open each document artifact associated with the scheduled event, reading assignment, interaction assignment, or evaluation assignment.</p> <p>Step 6 IF user wants hardcopy of artifact THEN accomplish goal of Print Item (browser specific, but basically press the Print button).</p> <p>Step 7 Read directly from artifact or from resources specified in artifact.</p> <p>Step 8 IF artifact is a reading assignment THEN return to Step 5 until all nodes are examined.</p> <p>Step 9 IF artifact describes an interaction assignment THEN follow the instructions provided in the interaction artifact to prepare appropriate interaction content to submit for the interaction assignment.</p> <p>Step 10 IF artifact describes an interaction assignment THEN locate and open the appropriate interaction submission tool (e.g., email, discussion board, drop box, survey, quiz) in WebCT.</p>

Step 3	Review the list to identify the topic for the week.	Step 11	Use WebCT tool interface to submit interaction assignment and return to Step 5 until all nodes are examined.
Step 6	Review the list to determine the number and nature of content artifacts for the week (e.g., one slide show in pdf format named Impact of Biotechnology; three urls to web content about agricultural, human, and industrial applications of biotechnology).	Step 12	IF artifact describes an evaluation THEN Follow the instructions provided in the evaluation artifact to prepare appropriate interaction content to submit for the interaction assignment.
Step 6	Review the list to determine the number and nature of interaction assignments for the week (e.g., an assignment with a discussion board deliverable, a project assignment with a due date several weeks away).	Step 13	Locate and open the appropriate evaluation submission tool (e.g., email, discussion board, drop box, survey, quiz) in WebCT.
Step 7	Review the list to determine the number and nature of interaction evaluation activities for the week (e.g., an online quiz).	Step 14	Use WebCT tool interface to submit evaluation assignment content and return to Step 5 until all nodes are examined.
Step 8	Make a mental note of the number and nature of artifacts and interactions for the week (e.g., "I see 1 slide show, 3 web sites, a discussion board activity of indeterminate complexity, a large project to get started on, and an online quiz that need to be completed for the week").	Step 15	Return with goal accomplished.
Step 8	IF user wants hardcopy of List of Planned Activities THEN accomplish goal of Print Item (browser specific, but basically press the Print button).		
Step 9	Return with goal accomplished.		
<p>Method for accomplishing goal of: Complete Reading Assignment for TECH 1313 for the Week</p>			
Step 1	From n X 4 array of links, select link to content artifact that pertains to content delivery with cues provided through the Get an Overview goal or through text annotations below each link.		
Step 2	IF user wants hardcopy of content artifact THEN accomplish goal of Print Item (browser specific, but basically press the Print button).		
Step 3	Read directly from artifact or from resources specified in artifact.		
Step 4	Return with goal accomplished.		
<p>Method for accomplishing goal of: Complete Interaction Assignment for TECH 1313 for the Week</p>			
Step 1	From n X 4 array of links, select link to interaction assignment artifact with cues provided through the Get an Overview goal or through text annotations below each link.		
Step 2	IF user wants hardcopy of interaction assignment		

	artifact THEN accomplish goal of Print Item (browser specific, but basically press the Print button).	
Step 3	Follow the instructions provided in the interaction artifact to prepare appropriate interaction content to submit for the interaction assignment.	
Step 4	Locate and open the appropriate interaction submission tool (e.g., email, discussion board, drop box, survey, quiz).	
Step	Use tool interface to submit interaction assignment content.	
Step 4	Return with goal accomplished.	
Method for accomplishing goal of: Complete		
Evaluation for TECH 1313 for the Week		
Step 1	From n X 4 array of links, select link to evaluation artifact with cues provided through the Get an Overview goal or through text annotations below each link.	
Step 2	IF user wants hardcopy of evaluation assignment artifact AND IF hardcopy printing is available THEN accomplish goal of Print Item (browser specific, but basically press the Print button).	
Step 3	Follow the instructions provided in the evaluation artifact to prepare appropriate interaction content to submit for the interaction assignment.	
Step 4	Locate and open the appropriate evaluation submission tool (e.g., email, discussion board, drop box, survey, quiz).	
Step	Use tool interface to submit evaluation assignment content.	
Step 4	Return with goal accomplished.	

The GOMS models reveal a more integrated task view through the concept map interface when compared to the LMS interface. The author believe the highly integrated view more closely resembles cognitive processing that is distributed across both the human student user and the course interface, a view that is more closely aligned with a modern view of distributed cognition.

Cognitive Walkthrough: During summer of 2008, three users were videotaped using the concept map interface for a course. Each user was provided a list of target tasks related to navigating through an online course. This method for evaluating a user interface is called a cognitive walkthrough.¹⁸ Each user was able to easily navigate the interface and complete the assigned tasks. It appeared that the tasks were easy to complete using the interface and no user expressed frustration at not being able to complete the information

seeking tasks. However, upon completion of the task list, each test user expressed the opinion that the map “seemed confusing”, especially at first. After completing the exercise, which took about 30 minutes for each user, each user expressed the opinion that the map would be an acceptable alternative to usual course layouts, but there was no enthusiasm expressed indicating that the map was better than a more traditional course interface.

Student Acceptance: During Fall 2007 semester, the author offered a concept map navigation system to students enrolled in a freshman level course that was taught in a hybrid format. The course used no textbook and relied exclusively on Internet and electronic library resources and student interactions for developing concepts, thus it presented a classic example of resource based learning. In prior semesters, anecdotal evidence indicated that students had difficulty navigating the complexity of the resources and activities, making this course an ideal test ground for whether a concept map navigation system could be a good alternative to a folder structure. Data was gathered from a brief end-of-course survey to which 13 students responded. The results are summarized in Table 2. All responders answered all the questions, so the responses not accounted for in the tabulated percentages indicated a neutral opinion.

Table 2 Concept Map Navigation Opinion Survey Results

Opinion/Perception	% Responses	Opinion/Perception	% Responses
No or little prior use of concept map interface	100%	Some or much prior use of concept map interface	0%
Knew where the link to the map was at the course web site	85%	Didn't know where the link to the map was at the course web site	15%
Found it easy to use	69%	Did not find it easy to use	23%
Thought it was a good tool navigation of course resources	54%	Did not think it was a good tool for navigation of course resources	31%
Would like to see concept map navigation systems used in other courses	62%	Would not like to see concept map navigation systems used in other courses	8%

The author believes the results justify further development of and experimentation with concept map navigation systems for complex learning environments. A usability study grounded in theoretical principles of human-computer interaction and interface design is recommended for future work.

Conclusions

Technology continues to transform all aspects of society, but especially areas related to information organization, integration, and delivery. While most educators have had some experience with learning management systems, many have not yet experienced the breadth of changes represented by innovations related to knowledge management. This paper presents some basic ideas and technology related to the idea of mapping knowledge in a domain and how this technique may be useful for making complex learning environments more navigable. The author believes advances in technology are poised to make huge differences in the way we teach and the way students learn. Future work will include implementation of such tools in courses taught and comparative assessment of student learning outcomes.

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Appendix A

URIs to Software Websites

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