

# Using Concept Maps to Navigate Complex Learning Environments

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## ABSTRACT

A concept map is a graphical representation of relationships among concepts. Willis and Miertschin suggested the use of technology-based concept mapping as an active learning strategy that can enhance learning and thinking skills, particularly among students native to a digital environment [16]. In addition, modern concept mapping software tools enable instructors and students to create visual navigation structures through complex knowledge domains. The authors find value in visual navigation structures for their relevance to organizing and simplifying learning environments and for their appeal to visual learners. This paper investigates different ways to develop digital interactive concept maps (CMaps) to help students navigate complex knowledge domains, such as the content of a course or a curriculum. CMaps can be used to present information in a nonsequential way or in several different ways, depending on the need. Interactivity enables students to easily locate digital information artifacts pertinent to a concept (media files, slide presentations, web pages, etc.) by clicking on links associated with a CMap node representing the course concept or category. A review of recent literature is provided, different software tools are compared, and the authors document their personal experience.

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## Categories and Subject Descriptors

K.3.1 [Computers and Education]: Computer Uses in Education – computer-managed instruction, distance learning.

**General Terms:** Management, Human Factors.

## Keywords

Concept Map, Resource-Based Learning, Mapping Knowledge Domains

## 1. COMPLEX LEARNING ENVIRONMENTS

Computer and communications technologies have advanced together so that anyone with a computer connected to the Internet is able to create and/or consume varied format information stored in digital files. As a result, resource-based learning, which is not

new, has come of age. 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” [5]. What is described here is an environment that increasing numbers of higher education faculty find they are challenged to create and manage. Typically, a faculty member is armed with their personal content knowledge and personal experiences with education and learning; traditional learning material such as a textbook; a learning management system (LMS); access to computer technologies for content creation together with, sometimes, support staff; and the wealth of information and tools that are freely and readily available via the Internet. With these, the faculty member is expected to create course structures that incorporate these elements, enabling students to enthusiastically consume as needed from the plethora of available information and make sense of it in a way that demonstrates they have met the course learning goals. This task is sometimes arduous for faculty members whose own educational experiences, especially at the undergraduate level, were primarily interactions with faculty in a teacher-centered learning environment where the instructor’s job was to dispense content and evaluate the student’s mastery of the content. Once a faculty member has course material in place in the LMS, her expectations are high with regard to how involved the students will be with the course and the materials offered.

Discussions with faculty members reveal a gap between student and faculty expectations with regard to engagement with the resources made available through a RBLE. Faculty members expect students to get input from the wide array of course resources, to process the input into knowledge through prescribed activities, and then, further, to use thinking processes to make predictions, to anticipate events, to remember things, to solve problems, etc. The environment promotes student-centered learning, where a student learns through interactions with the course learning resources (which include fellow students and the instructor) rather than from in-class lectures and discussion [12]. But are students prepared to be engaged in this way? As recent as ten years ago, course learning resources available to students were usually limited to an outline that organized the course knowledge domain into a hierarchical topics tree, a schedule for topic coverage, a textbook or two, a series of lectures, activities for processing input into knowledge such as assigned problem sets or research papers, and assessment activities such as exams. Compare that simple environment to one a student encounters today where she is offered interaction with a wide range of learning resources including books, teacher-created resources such as slide presentations and quizzes, and textual and multimedia resources available via both anonymous and authenticated access to the internet. Sometimes the instructor purposely provides more

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resources than every individual student can consume, with the expectation that each student will choose those resources best suited to their learning needs or preferences. A resource rich course format that requires some degree of student self-regulation of learning is a characteristic of resource-based learning. It is frequently encountered in distance or hybrid learning scenarios, but increasingly is encountered when students interact with instructors through an LMS [2].

Thus, we observe a learning environment where students must choose from a number of learning options and must navigate a complex array of information. Furthermore, the knowledge domains of courses are more complex and overlapping as we try to include more and more information into our curricula. This environment is often confusing for students who enter higher education lacking learning skills to cope. A challenge for the course designer/author is how to support students who lack skills necessary to competently navigate the instructional environment. The design of the information access is an important consideration [2].

Faculty members can facilitate by offering students instructional technologies that help them process new input into information by visualizing it in different ways and incorporating the new information into their personal knowledge schema. This paper describes concept mapping and computer technologies related to or based on concept mapping that might be used in higher education to enhance learning in RBLE.

## 2. Tools for Building Knowledge Schemas

Concept maps are graphical tools for representing knowledge. They emerged as tools as cognitive scientists developed understanding of the way humans learn. The process by which humans build knowledge is complex. Humans get input from the environment through their senses and store it in their brain for later retrieval. In addition, their brain processes input into information that can be used in different ways and contexts, a process some call understanding. Cognitive scientists believe that each person's brain organizes input as information in a way that is unique for that individual. Everything that Jane learns and everything she experiences is understood and appreciated by her in her own unique way. Each human's personal organization of input as information, or his knowledge, is his personal mental schema.

The term schema used here means a generalized description, plan, or structure that is an abstract representation of events, objects, and relationships in the world. The term is also used widely in information technology to describe the definition of the structure of data. Both meanings of the term are relevant to this discussion.

In addition to personal mental schemas, there are collective knowledge schemas. Mapping knowledge domains is a term that describes a concept that has existed for eons, but yet is a new and evolving process when viewed through the lens of technology. The goal of the process is to organize, sort, chart, map, etc. the collective knowledge in a field so that it is readily navigable and accessible and can be mined for information. A critical objective identified by researchers in the field of knowledge domain mapping is the creation of end-user applications that allow the user to interact with knowledge elements from different perspectives and in varying visual ways. The value of these applications is seen in their effectiveness in enabling users "not only to visualize a few nearby trees in the forest of knowledge, but also to understand the entire landscape" [15]. Thus, as educators, we seek tools to help students not only develop highly connected

personal mental schemas, but also to view their personal schemas in the context of a larger domain of knowledge.

Tools used to engage learners in meaningful processing of input into their personal mental schemas are called cognitive tools [4]. Mindtools are computer-based cognitive tools that facilitate the creation of formal knowledge representations for analyzing the world, accessing information, interpreting and organizing personal knowledge, and representing personal knowledge to others [7]. Mindtools have 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 generalized 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. Mindtools have been shown to be effective in engaging students in critical thinking and inference-making [7].

Some mindtools are classified as semantic organization tools. Semantic organization tools help learners analyze and organize what they are learning with respect to what they already know. As a student integrates new concepts into her personal mental schema or knowledge structure, a semantic organization tool facilitates this process by engaging the student in a process of documenting and formalizing her schema. Once documented, her schema can be shared. Learning depends on the creation of a new schema or knowledge structure, or on existing structures being revised, extended, or reconstructed altogether.

A widely used semantic organization tool is a concept map (also known as semantic network or mind map). A concept map is a graphical spatial representation of concepts and their interrelationships that represents the structural knowledge (mental schema) that a learner has stored in long-term memory [10]. Nodes of a concept map represent concepts and labeled lines represent the links or relationships between concepts. A pair of concepts linked with a named relationship is a knowledge element or proposition. Each knowledge element formalizes ideas like "quadratic – is type of – polynomial", "stored procedure – implements – business logic", or "optical network – is medium for – transporting data." A knowledge element can also formalize an organizational concept like "exam 01 – will cover – chapters 1 and 2 plus assigned internet readings from modules 4 and 5". A simple concept map created with CMap Tools® software is shown in Figure 1.

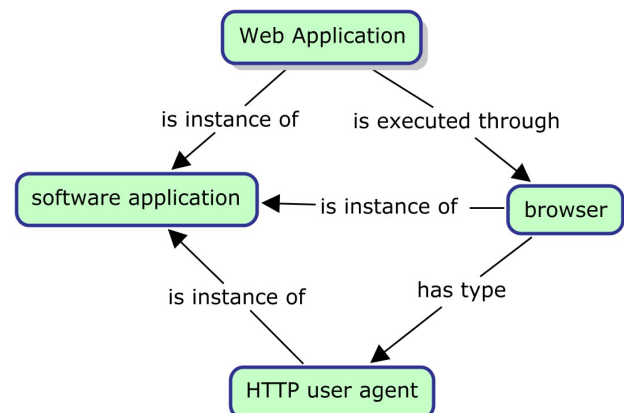


Figure 1 Concept map created with CMapTools software

Concept mapping is the process of constructing a concept map that represents a knowledge domain or the answer to a focus question. The process of concept mapping requires a learner to identify the important concepts of a domain, arrange those concepts spatially, identify the links or relationships between those concepts, and label the nature of the links between concepts to represent what she knows or is learning.

Because the process of building a concept map engages the learner with the content, it is an active learning strategy that can be used during class or for homework instead of traditional lectures or assignments. And while the only tools needed to construct a concept map are pencil and paper, the authors have found that today's digitally native students prefer developing interactive maps with computer-based concept mapping tools. Fortunately, a number of concept mapping software applications are readily available and some are free. Several are discussed in a later section of this paper.

### 3. Course Mapping

In addition to using concept mapping as an active learning strategy, the authors are investigating the usefulness of providing course maps to help students navigate the complexity of a RBLE. Figure 2 illustrates the complexity that a student may face. Shown is a screenshot of course resources for the sixth week of a course being delivered in a hybrid format (students meet with the instructor face-to-face once a week and use online resources the rest of the week). The instructor is using WebCT LMS and has created a "by week" organizational structure as opposed to a "by content" organizational structure. For the single week shown, students are provided eleven links to resources. Some resources provide content. Some set parameters for interactive learning activities. Some are prerequisites for others. Some link to multimedia resources on other servers. Students attempting to learn in this environment must navigate through the complicated array of resources shown for that week and be familiar enough with online course elements to place the information into the perspective of the rest of the course. Experience has shown that students have difficulty with these tasks.



Figure 2 Part of RBLE built in WebCT

A by week organizational structure is only one structure that is possible for a RBLE. Other LMS, such as the open source Moodle, provide course designers with more than one basic organizational structure around which to build the course. Moodle offers by week or by content organizational formats. If a student wants to see other views, such as a list of all the assignments for the semester, it may or may not be possible, depending on how the instructor implements assignments. It is possible for the student to access a particular view if the instructor provides that specific view. Often this is a labor-intensive task since the capability for multiple or changeable views through a 'tagging' system are not yet built in to most LMS.

Concept mapping software can enable an instructor to provide multiple views of a course. Figure 3 shows a concept map interface for the same sixth week of a course displayed in Figure 2. The map was created with CMapTools Knowledge Kit and can be exported as a web page with active links to content. The small icons at the base of node (a rounded rectangle) reveal active links to digital resource files of almost any type. In this map, all links except those to other maps are created as URIs to files on a web server, so all the resource icons look the same. If the files were located on the same shared directory with the map, and students were accessing the resource files through an active map (as opposed to an exported web page created with the software), then the icons could be differentiated according to the type of resource file to which the map provides access.

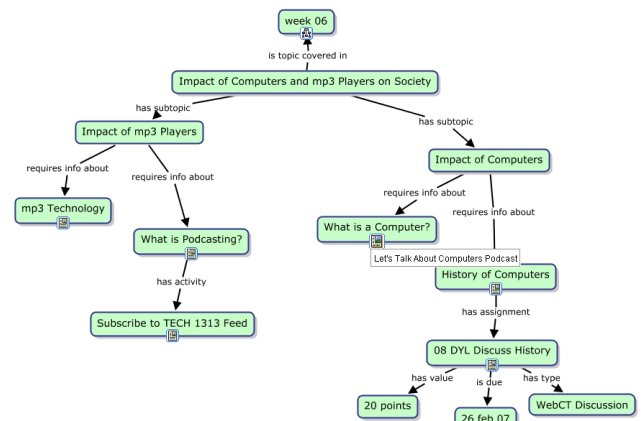
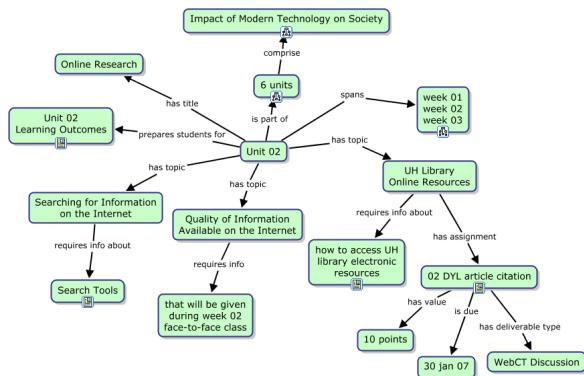


Figure 3 Concept map interface for RBLE week 6

Perhaps the map version of the sixth week activities appears as complex as the WebCT link version, but additional value achieved with mapping is the possibility for many other views of the same resources.

For example, for the same course there is a start page map of the RLBE that contains links to different views of the course. There is a by week view that leads to maps for the content for each week (such as the one already shown for week six). There is also a link to a by unit view that leads to maps for the content for each course unit. There is also an assignment view link that leads to a map of the course assignments with a link directly to each homework assignment for the course.

For comparison purposes, a course unit view is shown in Figure 4.



**Figure 4** Concept map interface for RBLE unit 2

An activity that would fully engage the students with the course structure would be to have them create their own views of course materials using concept mapping software, but the content value of such activity may be in question. However, having students create their own concept maps of course concepts and how they relate to learning outcomes for courses and programs is a worthwhile activity that lets them see how what they are learning

fits in to the knowledge domain of the field they are studying.

#### 4. Content-to-Outcomes Mapping

Concept maps have been suggested for faculty use in course and curriculum mapping. They have also been used as organizing tools for tracking results of continuous quality assurance practices. Student course artifacts can be linked to learning outcomes established by accrediting agencies and/or stakeholders using a map. In the same context, concept mapping tools can manage course syllabi, handouts, presentations, assessments, student projects, and other learning artifacts geared to show adequate coverage of a knowledge domain. If faculty members find this organization method useful, then imagine how useful students might also find it to help them understand the complex knowledge domain of the discipline.

To demonstrate the complexity of academic disciplines and curricula, consider three different computing programs that have accreditation standards through CAC of ABET -- software engineering, information technology, and information systems. All three programs include lists of similar concepts under different knowledge domains in the area of networking. Table 1 is the result of work by content experts representing the three program areas who took on the task of combining common elements into a single representation, a task they acknowledged was daunting.

**Table 1** Networking Knowledge Domain

Network Management	Communication and Networking	
<ul style="list-style-type: none"> <li>Performance Management</li> <li>Fault Management</li> <li>Configuration Management                             <ul style="list-style-type: none"> <li>Domain names</li> <li>Name services</li> </ul> </li> <li>Accounting Management</li> <li>Link to Security Management in Security                             <ul style="list-style-type: none"> <li>Examples of Protocols                                     <ul style="list-style-type: none"> <li>SNMP (Simple Network Monitoring Protocol)</li> <li>RMON (Remote Monitoring)</li> </ul> </li> <li>Network Management Software</li> <li>Quality of Service Approaches                                     <ul style="list-style-type: none"> <li>Differentiated Services</li> <li>Integrated Services   <ul style="list-style-type: none"> <li>Example Protocol</li> <li>RSVP (Reservation)</li> </ul> </li> </ul> </li> <li>Congestion Management</li> <li>Queue Management</li> <li>Link Efficiency</li> <li>Traffic Shaping and Policing</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Network standards                             <ul style="list-style-type: none"> <li>Standardization bodies</li> <li>ISO 7-layer reference model</li> <li>TCP/IP reference model</li> <li>IEEE 802.x</li> </ul> </li> <li>Switching modes                             <ul style="list-style-type: none"> <li>Circuit switching                                     <ul style="list-style-type: none"> <li>Examples</li> <li>PBX</li> <li>POTS</li> <li>ISDN</li> </ul> </li> <li>Packet switching                                     <ul style="list-style-type: none"> <li>Data Grouping</li> <li>Streams</li> <li>Datagrams</li> </ul> </li> </ul> </li> <li>Physical Media                             <ul style="list-style-type: none"> <li>Wired</li> <li>Wireless</li> </ul> </li> <li>Network device types</li> </ul>	<ul style="list-style-type: none"> <li>Physical Layer (Layer 1)                             <ul style="list-style-type: none"> <li>Encoding and Modulating</li> <li>Signaling techniques</li> <li>Transmission impairments</li> <li>Protocol Examples</li> <li>Cellular technologies</li> <li>Bandwidth</li> </ul> </li> <li>Data Link Layer (Layer 2)</li> <li>Network Layer (Layer 3)</li> <li>Transport layer (Layer 4)                             <ul style="list-style-type: none"> <li>Connection management</li> <li>Reliability</li> <li>Flow control</li> <li>End to end transmission</li> <li>Segmentation</li> </ul> </li> <li>Protocol examples                             <ul style="list-style-type: none"> <li>TCP</li> <li>UDP</li> </ul> </li> <li>Application layer                             <ul style="list-style-type: none"> <li>Protocol examples                                     <ul style="list-style-type: none"> <li>HTTP</li> <li>FTP</li> <li>Telnet</li> <li>SMTP</li> <li>DNS</li> </ul> </li> <li>Gateway</li> <li>Middleware                                     <ul style="list-style-type: none"> <li>Remote Procedure Call (RPC)</li> <li>Transaction Processing Monitors (TPM)</li> <li>Message-Oriented Middleware (MOM)</li> <li>Object Request Broker</li> </ul> </li> </ul> </li> </ul>

(ORB)

If academic content experts have difficulty organizing and seeing relationships among topics taught across related curricula, think how difficult it must be for students to grasp connections among concepts within a domain and how they are connected to other knowledge domains covered in their degree programs. What tools are students provided to help them make sense of the cohesive body of knowledge represented by the sum of all their college course work?

The legacy method for mapping the content of a curriculum is to provide a list of required courses and electives, and then, in each course, provide students a course topic outline. A slightly more modern spin on a course topic outline is presenting the students with a written list of modules organized into units. When web-based learning became feasible, faculty were encouraged to convert their outlines and module lists to a web format. Today, software applications enable faculty members to create web-based learning environments for their students without having to learn the architecture and technology behind web applications. These systems enable faculty to upload or link to outlines, content modules, and any number of other content artifacts. The faculty member then creates a system of links whereby students can access content.

For example, Michael Ruffini, an assistant professor at Bloomsburg University (PA), uses course concept maps as online course outlines. He creates a concept map of course content and materials using software and then exports it to a web format so that his students can see all the course content elements and the relationships among those elements. He believes that mind mapping a course saves time from a longitudinal perspective, and he believes it makes courses better because faculty and students can then see, at a glance, how all the course content elements relate to each other.

The advent of Learning Object Repositories and LMS based on Web 2.0 technologies will finally allow repurposing of content and assessment artifacts so that multiple views of student data can provide information relevant to students, faculty, and administrators without as much angst as before. Web-based LMS such as Angel Learning Systems or TaskStream have the capability of providing distance learning services, national standards assessment, and e-portfolio services.

## 5. Software Applications

In the authors' experience, concept maps are rarely created with paper and pencil voluntarily by students. Perhaps one reason is that once scanned for electronic storage, they are difficult to modify [1]. Today's digitally native students want course content and assignment interactions in digital formats. Much like the advantages of using a word processing program to write research papers, a computer-based concept mapping tool makes it easy to construct and then revise, customize, and revise concept maps again. This refinement process is not as easy with paper and pencil versions. Other practical advantages include exporting maps to different digital formats, digital storage of maps together with other course artifacts, ease of collaboration with others, and dynamic linking [11].

Computer-based mapping tools that are available and have been investigated by the authors include Inspiration®, MindManager™, Semantica®, CMapTools Knowledge Modeling Kit, and BrainEKP®. All of these tools allow students and faculty to create digital knowledge structure representations. The user creates nodes labeled with concepts or ideas, he links concept

nodes together with directed lines, and then he labels the directed lines to name the relationships between ideas. Color and graphics can be added to enhance, elaborate, and emphasize points. These tools also enable course mapping of content to digital resources as they allow the mapper to add hyperlinks to content artifacts such as presentation slides, a web page, text annotations, image files, podcasts, vodcasts, etc.

Because of the obvious knowledge visualization capabilities of diagramming tools such as Microsoft Visio 2003, they can be adapted rather easily for concept mapping activities. Their advantage derives from the perceived resume power of diagramming tools to the students and the crafty embedding of the knowledge representation tasks within course activities that lead to completion of course and program learner outcomes. As an introduction to an on-going homework assignment in one course, students learned about the importance of knowledge and information visualization techniques for effective client and team communications. The importance of an effective knowledge management system to an organization's memory was also emphasized. After a brief introduction or review of the features of Microsoft Visio, students were asked to list five concepts they remembered from the prerequisite course, and then with a partner were tasked to come up with a unique list of 10 concepts, and finally with another pair of students were to come up with a list of 20 distinct concepts. As time allowed, the teams of 4 students used Visio shapes to pair related concepts and to draw connecting lines between. Each subsequent week students had either handouts or textbook chapters to read and to deconstruct into related concepts, to link assignment documents to appropriate concepts or pages, and to relate new concepts to previously learned concepts. Finally, the students added a Visio page for the User Interface to their database application project with a statement reflecting on the concepts underlying its features and in which courses these concepts might be used again. Figure 5 (next page) illustrates a student's interpretation of the Information System Knowledge Domain concepts discussed in a chapter of a text. Also shown are the names of the five other Visio pages required in the semester-long project.

Of the other tools investigated, CMapTools Knowledge Modeling Kit had the advantage of being free as it was developed by the Institute for Human Machine Cognition (IHMC), a not-for-profit research institute of the Florida University System affiliated with several Florida universities. A recent email announced the commercialization of CmapTools as Ceryph Insight, a program that will be offered to commercial and not-for-profit companies and individuals who use the program for business purposes. Ceryph, Inc. will offer commercial grade customer support and training that is not part of the mission of IHMC. Further however, CmapTools will continue to be free for educational institutions, federal employees working for the US Government, and individuals not using it for business purposes. Each software application examined had a different 'feel' and it is likely that different users will prefer one over the other just from the standpoint of individual preference. Semantica® was developed by Semantic Research, Inc. as "a platform for knowledge capture, management and transfer" [13]. They provide a version of the software for education, Semantica® SE; the authors experimented with this version.

Figure 6 shows the start page view of a partial course map created with Semantica® SE software. With this particular software, the term "start" page becomes somewhat relative when you begin mapping concepts and content.

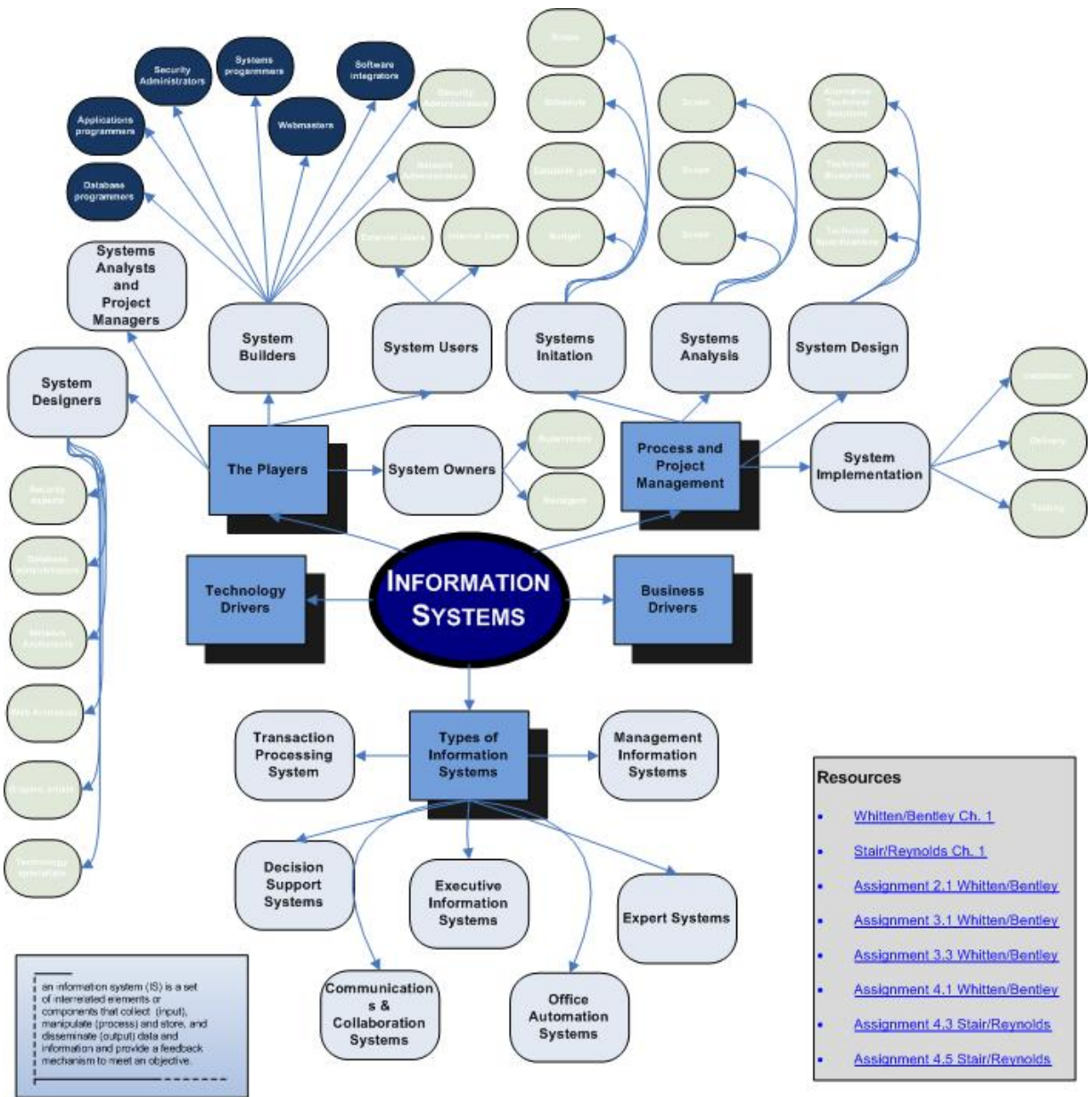


Figure 5 Concept map created with MS Visio

When the user double clicks on a concept node the software changes the view, making the selected concept the central concept of the current view. That gives this particular software a distinctively interactive feel that is extremely engaging. Each view can be exported as an image, but not as a web page. Also the entire map cannot be seen. Only one central concept and a single level of related concepts is available in any one view.

MindManger™ concept mapping software is pen-enabled for the tablet pc (TPC). Users have the choice of operating in pen-mode where inked text is either kept as ink (see Figure 7) or converted into ASCII text by the handwriting recognition engine that is part of the TPC operating system.

MindManager mindmaps have several attractive features. The central concept is located in a rectangle at the center of the map. Branches (as opposed to shapes) represent topics related to the central concept. These are easily added simply by pressing the Enter key when the focus is on the parent concept. Similarly, a subtopic is easily added to a main topic by pressing the Insert key. Clipart, map markers, notes, task memos, and prioritizations can be inserted into the map as well. The map can be viewed in outline format or presentation mode. In presentation mode, each topic of the map is featured while presenting details of the topic. Map topics can be linked to databases, other documents, web pages, bookmarks within the map, and to other maps.

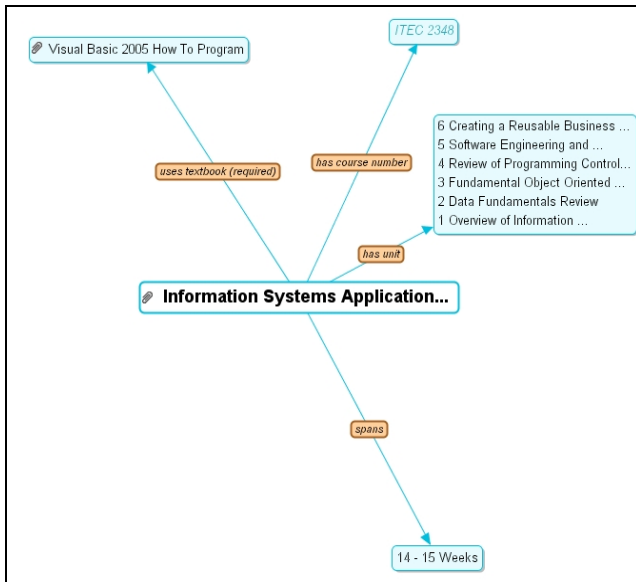


Figure 6 Course map "start" page created with Semantica

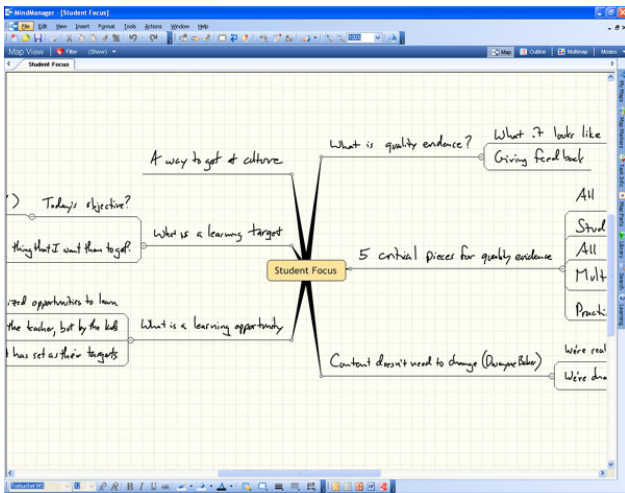


Figure 7 MindManager mindmap created in ink mode

Maps can remain dynamic by saving them in native MindManager format, or completed maps can be saved as images or web pages. An attractive MindManager feature is its integration with Microsoft Office. Maps can be exported to PowerPoint and Word. Tasks assigned through a map can be exported to Project. If the user has an account on an Exchange server, map contents can be synchronized with an Outlook calendar or email [9].

An enterprise level software product that is web-based and that has been examined by the authors for its potential application to course mapping is the BrainEKP (where EKP stands for Enterprise Knowledge Platform) by TheBrain®. It is described as an enterprise knowledge management system as well as visual search and categorization software. It depicts information relationships in an interactive map. The tool supports multiple sources of information that can be connected through rules-based links to documents, web pages, podcasts, etc. In addition, the tool supports unique map views for each user; that is, all users share the same content artifacts through either an instructor generated map of the content or through an individual map each user creates

himself. Thus, users can adjust their interface and make the system grow according to their thinking process as information is created and used. Small groups of students could collaboratively produce maps as well. The system also implements drag-and-drop capabilities that allow users with appropriate permission settings to expand the knowledgebase by adding content artifacts as well as nodes and links. Figure 8 shows a portion of a "brain" for a Database Management course with the Content dialog open, illustrating the variety of files that can be attached to any node. While The Brain does allow the user to attach names to the relationship lines, they are visible through a mouse over event.

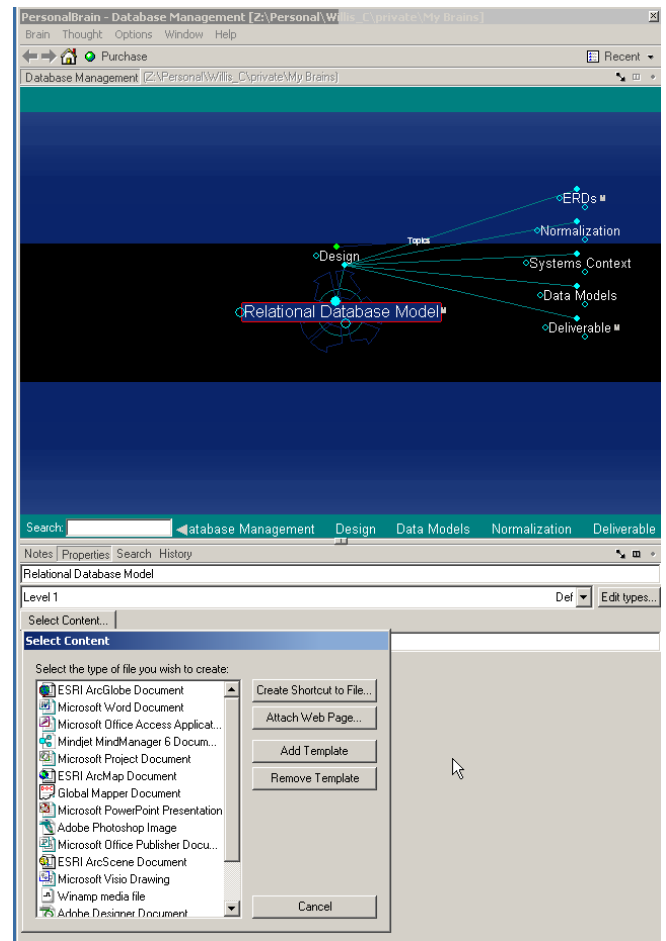


Figure 8 Content map in The Brain with links to resources

Two of the software applications investigated can be integrated with server technology that enables collaborative development of server hosted concept maps. One of those is IHMC CmapTools already mentioned and the other is BrainEKP. Both of these products warrant further investigation with respect to collaboration and the value that can be derived from it. Implementation of server functionality requires supporting infrastructure that the investigators' institution currently does not have.

The research conducted to date reveals many more mapping software products that educators are experimenting with. The ones mentioned here are the ones the authors have examined to date. The selection of one of these applications as the desired tool for a RBLE cannot be done by faculty in isolation from information technology support staff. Infrastructure and competent technical

staff to install, support and maintain the tool is mandatory if it is to be used in a classroom laboratory environment. If the selected tool requires a new set of hardware and operating system (OS), the cost could become prohibitive. It is even more difficult if a different OS is used by different units within an educational system and the goal is to have all units use the selected tool. Table 2 shows the system requirements for the tools discussed here, plus one other that the authors have not yet experimented with extensively. As can be seen, each tool has different requirements and supports two or more OSs. The tool vendors must be contacted for any additional requirements and any support that they offer during the installation and post installation.

**Table 2 Comparison of software applications**

Tool	Version	OS Supported	Web Site
Inspiration	8	1. <b>Windows</b> 95, 98, 2000, NT 4.0, ME or XP (including Tablet PC Edition) 2. <b>Macintosh</b> ® System 8, 6, 9.x or OS X (10.1.5 or higher)	<a href="http://www.inspiration.com">http://www.inspiration.com</a>
Semantica	SE 3.0.1	1. <b>Windows</b> 2000 or Windows XP 2. <b>Mac OS X</b> 10.2.6 or later	<a href="http://www.semanticresearch.com">http://www.semanticresearch.com</a>
CmapTools Knowledge Kit	4.07	1. <b>Windows</b> 95/98/Me/NT/2000/XP (56.6 MB) 2. <b>Mac OS X</b> (30.2 MB) 3. <b>Linux</b> (Intel) (80.7 MB) 4. <b>Solaris</b> (Sparc) (80.1 MB)	<a href="http://cmap.ihmc.us/">http://cmap.ihmc.us/</a>
MindManager	6	1. <b>Windows</b> 2. <b>Mac OS X</b> 10.4.x Tiger or later	<a href="http://www.mindjet.com/us/">http://www.mindjet.com/us/</a>
Personal Brain	3.03	1. <b>Windows</b> 2. <b>Mac OS X</b>	<a href="http://www.thebrain.com">http://www.thebrain.com</a>

## 6. Extension

According to Shen, Richardson, and Fox (2005), concept maps, because of their knowledge visualization capabilities, have great potential as a digital library tool [14]. Information science researchers see a need to transform the view of the library from one of an information provider to one of a knowledge repository with services that enable users to effectively categorize, analyze, and organize the library's contents into their own unique and sometimes new knowledge structures. Developed by the AI Laboratory at the University of Arizona, GetSmart is a set of digital library services that include a concept map creation component in addition to digital library tools and curriculum tools. In a study of GetSmart conducted at Virginia Tech, concept maps created by students were used to summarize the concepts in chapters of their textbooks, and at the same time, added to their personalized structure of the knowledge domain represented by the course [8]. Students were also able to store related resources with their concept maps and to collaborate on shared group maps with other students.

## 7. 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. The authors believe these 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 by each author and comparative assessment of student learning outcomes.

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