CNT: Concept-Map Based Navigation and Discovery in a Repository of Learning Content

James H. McClellan[1], Lonnie D. Harvel[2], Rajbabu Velmurugan[3], Milind Borkar[4] and Chris Scheibe[5]

Abstract - **In this paper, we present a tool that automatically connects keywords in student generated concept maps to relevant learning components in our digital repository. Currently, there are over 6,000 heterogeneous components available in our systems, with more than 1,000 dedicated to the teaching of ECE 2025, an introductory course in Signal Processing. These components consist of captured lectures, support material, multi-media examples, worked problems and others. The CNT (Concept Navigation Tool) connects concept map nodes to course content based on keywords embedded in the concept nodes. CNT goes beyond just integrating search techniques with a map-authoring tool. The concept maps constructed by students become the navigation tool that allows them to explore the relevant content and improve or expand their concept maps as their understanding grows. This environment was designed to increase the depth of a student's conceptual understanding of course material. The paper includes details about the design and implementation of the CNT system and the supporting data systems.**

Index Terms - Concept maps, linking resources, repository of learning content, searching course content.

INTRODUCTION

In a concept map, information is presented in a structured graphical format that is easy for humans to interpret visually. Extensive research has been done in the area of understanding Concept Maps and their use as an educational tool; that work is not discussed here, but more details can be found in [8][10][12][13][14][15]. There are numerous applications for concept maps including teaching [1][4], assessing student understanding [3][5][13], improved creative thinking [4], brainstorming ideas in educational or business settings [10], or as a tool to support the design of instructional material [3]. They can also be used to simplify note taking, generating various graphics for presentations, lectures, textbooks, etc.

In this paper, we concentrate on three aspects of Concept Maps and their use as an educational tool. In one part, we describe a software tool [19] that was developed to create concept maps, and compare it with existing ones. Our work in this area was mainly motivated by work at IHMC, University of West Florida and their tool CmapTools [20] to develop Concept Maps and our attempt to extend it [18]. Similar freeware tools to generate computer-based Concept Maps developed at educational institutes include CM-ED [5] at University of the Basque Country, and Kmap [22][23] at University of Calgary. As well as these tools, there exists commercial software [25][26][27] to generate Concept Maps for use in different education and business settings. The difference between these tools and ours is its direct interface with a database, which acts a pool of resources. A similar approach has been reported under the National Science Digital Library (NSDL) initiative, as part of the GetSmart project [15][21]. In that project, there is a separate search tool that can search broad databases, even over the web, but it does not integrate automatically with the Concept Map.

In this paper, we will discuss the pedagogical aspects of creating concept maps and their use as an effective teaching tool. Our discussion here relates to a sophomore course on Signal Processing in the Electrical Engineering curriculum at Georgia Tech. Our group has been involved in improving and experimenting with new techniques in computer-based education for this DSP course. The work described in this paper is along similar lines, and was designed to bring together experiences and various multimedia resources used in teaching this course. Previous instances of using Concept Maps in engineering courses include using them as an assessment tool [3] in an Industrial Engineering course, teaching concepts [4] in an Aeronautics course and other fields including Biomedical [12][13][14] and Mechanical Engineering [17].

Our goal is to use Concept Maps to provide students with a high level view of materials in each chapter in the textbook *Signal Processing First* [11] that is directly connected to a growing repository of supporting content. We have achieved this by combining an existing database of resources for the book with the Concept Map tool. This database is an extensive collection of demos, tests, exercises, and homework problems used in the course over a period of 8 years, all linked through keywords. Along similar lines, it is interesting to note that the Aeronautics department at MIT plans to have a similar comprehensive database for their courses [4]. The authors are aware of a few earlier efforts that use Concept Maps as a part of textbooks, forthcoming textbooks [12] or CD-ROMs [13].

[1] James H. McClellan, School of ECE, Georgia Institute of Technology, jim.mcclellan@ece.gatech.edu
[2] Lonnie D. Harvel, Digital Media Lab, Georgia Institute of Technology, ldh@ece.gatech.edu
[3] Rajbabu Velmurugan, School of ECE, Georgia Institute of Technology, rajbabu@ece.gatech.edu
[4] Milind Borkar, School of ECE, Georgia Institute of Technology, milindb1@earthlink.net
[5] Chris Scheibe, Digital Media Lab, Georgia Institute of Technology, scheibe@ece.gatech.edu

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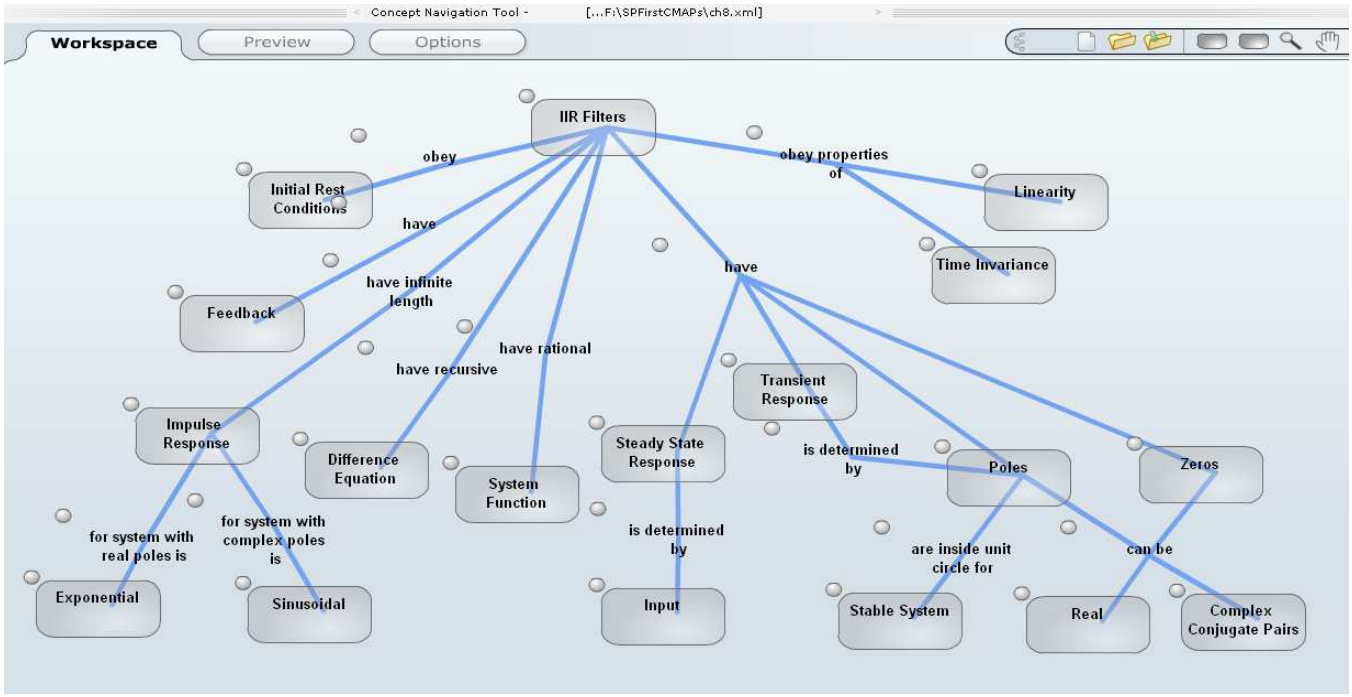

FIGURE 1
SCREENSHOT OF THE *CONCEPT NAVIGATION TOOL,* SHOWING A CONCEPT MAP FOR CHAPTER 8 IN *SIGNAL PROCESSING FIRST.*

These projects, however, do not provide a connection between the course text and a dynamic repository in an automated fashion. Some earlier work has also reported that students have been asked to create Concept Maps for specific chapters from books as part of student evaluation [14][15].

CONCEPT NAVIGATION TOOL – CONCEPT MAP SOFTWARE WITH RESOURCE DISCOVERY

There are several software tools available for creating Concept Maps. Early in our project, we used the CmapTools from IHMC for developing Concept Maps for the course *Introduction to Signal Processing*. However, we were also interested in linking resources developed for the course to concepts in Concept Maps, and to automate this process. Our initial attempt was to develop a set of Perl scripts [18], but this was a time consuming solution that lacked flexibility. This motivated us to develop a tool of our own, called the *Concept Navigation Tool* (***CNT***) [19], which has the ability to automatically link resources to the concepts by accessing a database. The tool was developed as a general application so that other groups with their own content repositories could also use it.

I. Overview of CNT

This software was developed by the Digital Media Labs at the Georgia Institute of Technology using Macromedia Flash. Using this software, concept maps can be created and a variety of resources (demos, labs, homework problems, animated tutorials, other concept maps, etc.) can be lined to each concept node. The advantage of using Flash in its design is that it is visually oriented and is easily deployable over the web; thereby, making it platform and web browser independent. This also relieves the user from the burden of downloading and installing a separate tool or software package. Figure 1 shows a sample Concept Map created using ***CNT***.

CNT works by generating XML code which depicts the structure of the Concept Map in its current state. Thus, saving a map involves saving the XML code generated by ***CNT***. This XML code can be opened again in ***CNT*** for the purpose of editing or viewing the map. Another advantage of using XML is that the output is a text file that can be read by other programs, e.g., doing a statistical analysis over a set of graphs generated by many students.

As mentioned earlier, a major purpose for developing this tool is to automate the process of linking resources to concepts in Concept Maps. This is a two-step process. First, a map has to be created. If the Concept Maps correspond to chapters in a book, then the designer (or learner) must have a fairly good understanding of the subject in order to structure all the information efficiently. No map is ever perfect, so a student learning the subject would add new concepts as they are acquired. In an ideal learning situation, a concept map might go through several revisions to update and continually improve the map.

The second step is the addition of relevant resources to the map. This step is often very tedious. The maps created for this paper are based on concepts in *Signal Processing First*, the required text for the Georgia Tech ECE course *Introduction to Signal Processing*. Concept Maps for chapters in the book would require resources that appear in many locations throughout the book. It would be extremely difficult and tedious to process the whole book (by hand) to add

relevant resources to each and every concept; and the resulting linkage of resources to concepts would be static.

The ***CNT*** concept map software solves this problem of adding resources. Each concept node in a map has two fields associated with it, as shown in Figure 2. The first field holds the concept name that is displayed on the map in the viewer. The second field contains a list of keywords. This field is not visible when the map is displayed in the viewer. Once a concept node is created, the software uses the keywords to search through a database of resources and those resources that have matching keywords are automatically added to the concept. This eliminates the tedious process of manually adding resources. All that the map designer has to do is design the map with relevant keywords and resources are automatically added. Moreover, the creator of the map need not have prior knowledge of the resources, which might include recorded lectures, demos, labs, homework problems, animated tutorials, other concept maps, etc. Once this is done, the resources can be accessed from the Concept Maps by clicking on the Nodes while viewing the Concept Map using the viewer.

FIGURE 2
FIELDS IN A CONCEPT NODE: NAME AND KEYWORDS

The Concept Maps can be stored either locally or over the network on a common server. This facilitates sharing, improving and evaluating Concept Maps by members of a class or project group.

To summarize, the main features of ***CNT*** are:

- Visually appealing layout
- Ease of use
- Operates across various platforms and can be used in common browsers
- Generates XML code representing the node-link structure of the concept map
- Keyword list associated with each concept automates the resource discovery process

II. Architecture and Software Components of the Concept Navigation Tool

We designed ***CNT*** to interact with a dynamic repository of resources. The software components and architecture of the tool can be thought of as having three different layers as shown in Figure 3. The first layer (Level-1 in Figure 3) is the user interface where the actual Concept Map, represented in HTML/Flash, is created and viewed.

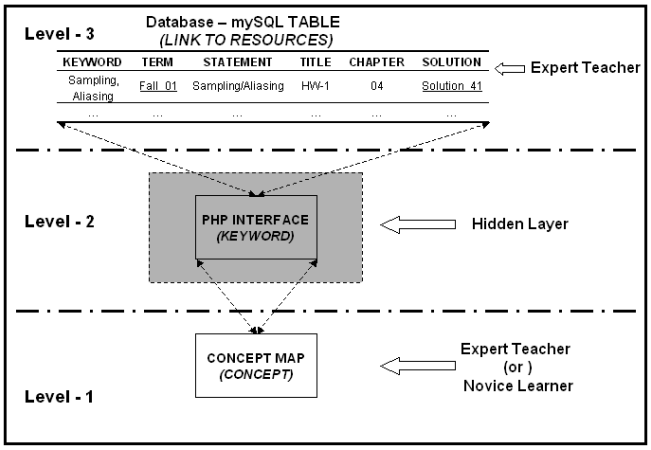

FIGURE 3
ARCHITECTURE SHOWING HOW ***CNT*** ACCESSES THE MYSQL DATABASE USING A PHP LAYER.

The background layer (Level-3 in Figure 3) is a mySQL database, which contains tables whose elements are the different types of resources. Over time, instructors teaching this course have developed a rich set of demos, labs, tutorials, lectures, homework problems and exercises to bring out important concepts underlying signal processing. All of this material, collected over many years, has been archived and indexed in order to create this repository. Each table within the database is a collection of one type of resource. Each entry in a table contains a set of keywords, a description of the resource, the location of the resource (e.g., from the CD that forms part of the textbook), and details that uniquely represent the resource. In most cases, these indexing keywords in the database might also be concept names in the Concept Map. Thus, by linking a concept or a keyword to the archive of resources, the tool acts as a "Resource Discoverer" for the Concept Map.

The intermediate layer (Level-2 in Figure 3) is a PHP interface between the Concept Map and the mySQL database. The PHP layer helps in providing a seamless interface between the Concept Map and the database for automatically adding resources. Once a user enters the keywords (in the Concept Map dialog box), a PHP script searches through the database to retrieve relevant resources for the specific keyword. In this way, the learner gains access to all the resources (homework problems, exercises, demos, labs or tutorials) related to the specific concept.

Another significance of the link between a Concept Map and the database is that the resources linked to a Concept Map

are always up to date, i.e., whenever the database is updated with new resources, the creator of the Concept Map need not update the Concept Map for these resources. An instructor or an expert user can update the databases using shareware tools that provide a graphical interface to the contents of the mySQL database.

Previous work [6] has described a mechanism that uses the Web to suggest concepts and relevant resources. As mentioned earlier in the Introduction, an even more extensive and ambitious project is being developed under the National Science Digital Library initiative, called GetSmart [15][21]. Their key notion is the integration of search tools and curriculum support with Concept Mapping. They envision a system to enhance exchange across a much wider range of users at multiple universities. Even in such a broad search space, it seems likely that with the restricted domain of a textbook, lectures and related course content, the search results will have less clutter. This implies that we need virtually no restrictions on our search to remove clutter. However, given the viewable area of a computer screen, some restrictions on the number of resources need to be placed and the ***CNT*** provides a mechanism to do this.

Our use of a database of resources is in someway similar to the proposed work in [4] in which a database for MIT Aeronautics courses will be developed. With our work, we have partly accomplished this based on a specific book. A natural extension to this would be to the case where a book is made available online. If this can be done, we would be able to link or refer to more resources available both on the Web and in the book. This would be similar to the approach in [15], though the intent there is different.

CONCEPT MAPS AS A TOOL IN TEACHING

The work described in this section is an attempt to give a brief description of using Concept Maps based on experience with the Signal Processing course at Georgia Tech. One method for incorporating Concept Maps into course work would be to have a domain expert create Concept Maps relevant to the course material. Each Concept Map would be populated with resources from the content repository because these resources would be linked to specific concepts. When these expert-created concept maps are made available, students could use them as aids to solving problems. This would require that they have an understanding of which concepts are being covered in a particular homework problem. Then they would browse through the linked resources (such as demos, sample problems and solutions) under those particular concepts as well as related concepts and gain a better understanding of how they could solve the problem at hand. The ***CNT*** also gives an option to choose resources like external Web sites, copies of hand-written notes, etc., that might not be present in the database. Thus, from a basic understanding of which concepts were being tested, the student would be rewarded with a small set of relevant resources that needs to be explored rather than having to search through an entire database.

A more useful method of using concept maps as learning tools would be to have students create their own concept maps. Creating a good concept map requires, as well as promotes, a good understanding of the material. The first step would be to train students in the basics of developing good maps. Basic concept map theory is given in [1]. Initially, an expert should demonstrate to students the step-by-step creation of a concept map. This serves to familiarize students with the software and basic concept map construction theory. Students are then shown good maps as well as bad maps and the distinguishing features between them are clearly pointed out. They need to understand the importance of the various aspects of a concept map, such as depth, breadth and interconnectivity. However, this knowledge is best gained through practice.

In order to encourage students to create their own concept maps, incentives such as extra credit might be awarded. This will make students comfortable with the software as well as make them familiar with concept map construction theory. This should be started early in the course when minimal material is covered so that students can concentrate on learning how to build good maps before the course load gets heavy. During the course, students should be encouraged to add newly learned concepts to existing maps and to interconnect these new concepts with existing concepts. They should be encouraged to create comprehensive concept maps that cover all the concepts taught in the entire course as well as "specialized maps" that cover specific chapters or specific theory taught in the course [14]. As an initial step in this direction, we have developed lab exercises in which the students had to either create or modify Concept Maps involving specific topics in the course. Instructors could then assess these concept maps, using one of the several techniques discussed in [3]. Once we have acquired a significant number of student-generated concept maps we plan to conduct a formal evaluation on the effectiveness of using these tools.

CONCEPT MAPS FOR INSTRUCTIONAL MATERIAL IN A BOOK

Concept Maps can also be used to structure information and instructional material for courses. ECE-2025, a sophomore level course in Signal Processing offered at the Georgia Institute of Technology provides an example of a course in which students benefit from visually structured information. In this course, students learn fundamental concepts in electrical and computer engineering along with signal processing theory. They learn to solve simple problems that deal with individual concepts; however, they sometimes have difficulty solving problems that involve multiple concepts. This seems to happen because they do not have a firm grasp on how different concepts are interrelated. By using Concept Maps, a variety of concepts are linked to each other and the relationships among concepts are represented in an easy to understand display. This should help students to gain a better understanding of the material in the course. This is also supported by [8] "concept mapping fits in a more fundamental research line in which efficiency of traditional linear text based upon natural language is questioned."

It has been demonstrated that we often learn by associating new information with information already existing

in memory. Our Concept Maps give a visual description of an entire chapter on a single page. For example, Figure 1 shows a sample concept map for Chapter 8 from *Signal Processing First*. Once a student studies a chapter in the book, they may look at the Concept Map for the corresponding chapter to understand how the concepts are interrelated. Learning in this way fortifies connectivity between different concepts and promotes improved retention. A combination of learning the theory behind concepts by reading the book, and then using Concept Maps to express how new concepts are interrelated and also exploiting the relevant resources, will give students an improved understanding of the material.

The *Signal Processing First* book currently comes with a CD-ROM that supplies many of the resources used in this project. It is organized in a traditional manner to provide an overview and table of contents to navigate the book and its chapters. The result is an outline view that is presented to a HTML page based browser as shown in Figure 4. We have developed an alternative and more effective overview of the book and chapters using the Concept Map based browser (interface), similar to Figure 1. Moreover, the mySQL database mentioned earlier, was used as the basis for a HTML based search tool for the textbook *Signal Processing First*. This helps the user/student in making an "intelligent search" for resources within the textbook. A similar but more effective substitute is the option of using the concepts and resources in the Concept Map, to navigate to the area of interest.

The advantage of using Concept Maps over outline-structured web pages for information searching has been demonstrated in [7]. The results suggest that Concept Maps can be a more effective navigational tool for hypermedia environments for rote learners as well as meaningful learners. The work in [7] was restricted to a specific domain (psychology) but suggested that similar tests can be performed in other domains. We have not yet performed controlled experiments to validate this for our situation, but anecdotal feedback from students suggests that, by linking to the textbook and providing an opportunity to browse concepts in a chapter, Concept Maps can provide effective support for learning.

CONCLUSIONS AND FUTURE WORK

In this paper, we have discussed how Concept Maps may be used as an effective instructional tool, when created using the ***CNT*** tool. The strength and novelty of this tool lies in its ability to attach resources to the Concept Maps and to perform dynamic updates to those linked resources whenever there are changes to the mySQL database that is connected to the Concept Map. The advantage is a growing set of resources for a specific subject, which supports student learning. The specific context discussed in this paper was the usage of using Concept Maps as part of the textbook *Signal Processing First*, for the course *Introduction to Signal Processing* in the School of ECE at Georgia Tech.

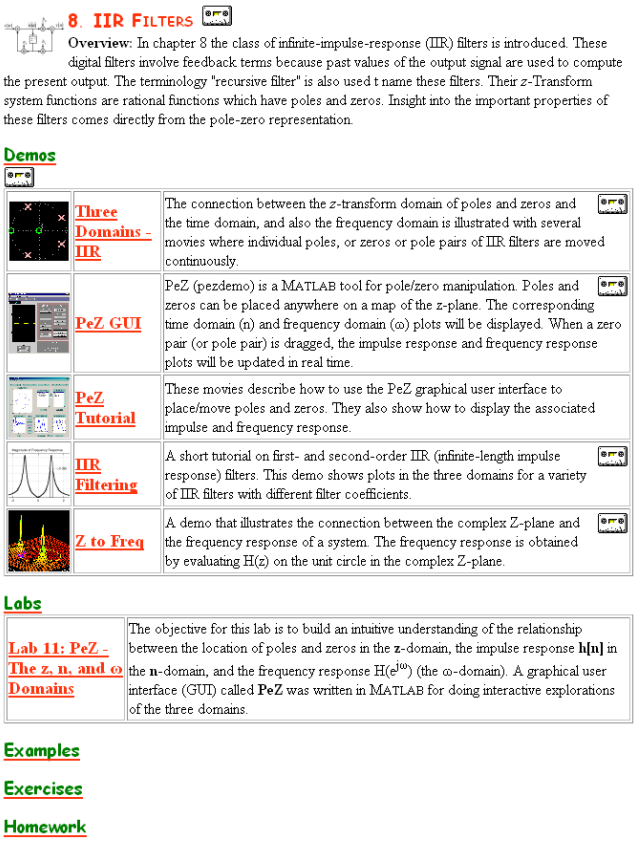

FIGURE 4
HTML-BASED CHAPTER OVERVIEW FOR THE RESOURCES IN CHAPTER 8 OF *SIGNAL PROCESSING FIRST* [11].

Ongoing work will explore the use of Concept Maps and ***CNT*** as a directed tutorial environment. Students are using ***CNT*** to construct a Concept Map, to review the content associated with that map, and to continually modify their maps as their understanding grows. We have a database of captured video lectures that will be connected to the maps using multimedia indexing techniques. We are measuring both the usability of the tool, the level of repository access, and improvements in student understanding and performance.

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REFERENCES

[1] Novak, J.D., "Concept Mapping: A useful tool for science education," *J. Res. Sci. Teaching*, Vol. 27, No. 10, 1990, pp. 937–949.

[2] Leake, B.D., Naguitman, A., Canas, A., "Assessing Conceptual Similarity to Support Concept Mapping," *Proc. Fifteenth Intl. Florida Artificial Intelligence Research Society Conf.,* May 14–16, 2002, pp. 168–172.

[3] Turns, J., Atman, C.J., Adams, R., "Concept Maps for Engineering Education: A Cognitively Motivated Tool Supporting Varied Assessment Functions," *IEEE Trans. on Education*, Vol. 43, No. 2, May 2000, pp. 164–173.

[4] Darmofal, D.L., Soderholm, D.H., Brodeur, D.R., "Using Concept Maps and Concept Questions To Enhance Conceptual Understanding," *32nd ASEE/IEEE Frontiers in Education Conf,* Boston, MA, Nov. 2002.

[5] Larranaga, M., Rueda, U., Elorriaga, J.A., Arruarte, A., "Using CM-ED for the Generation of Graphical Exercises Based on Concept Maps," *Proc. of the Intl. Conf on Computers in Education (ICCE'02)*, 2002.

[6] Cañas, A.J., Carvalho, M., Arguedas, M., "Mining the Web to Suggest Concepts during Concept Mapping: Preliminary Results," *XIII Simpósio Brasileiro de Informática na Educação – SBIE – UNISINOS 2002*, Nov. 2002, Brazil. [Available Online] http://cmap.coginst.uwf.edu/pubs/

[7] Carnot, M.J., Dunn, B., Cañas, A.J., "Concept Maps vs. Web Pages for Information Searching and Browsing," [Available Online] http://cmap.coginst.uwf.edu/pubs/

[8] Jonassen, D.H., "Concept Mapping as cognitive learning and assessment tools," *J. of Interactive Learning Research*, 8 (3/4), 1997, pp. 289–308.

[9] Caliburn, J.W., "Using concept maps to sequence instructional materials," *J. Collaborative Science Teaching*, Vol. 15, No. 4, Feb. 1986, pp. 377–379.

[10] Dabbagh, N., "Concept Mapping as a Mindtool for Critical Thinking," *J. Computing in Teacher Education (ISTE)*, Vol. 17, No. 2, 2001, pp.16–24.

[11] McClellan, J.H., Schafer, R.W., Yoder, M.A., *Signal Processing First*, Pearson Education, Inc., Upper Saddle River, NJ, 2003.

[12] King, P.H., Walker, J.M.T., "Concept Mapping Applied To Design," *Proc. of the 2nd Joint EMBS/BMES Conference*, Houston, TX, Oct. 2002.

[13] Walker, J.M.T., King, P.H., "Concept Mapping as a Form of Student Assessment and Instruction," *Proc. 2002 ASEE Annual Conf. and Exp. ,* Montreal, Canada, June 2002.

[14] Walker, J.M.T., King, P.H., Cordray, D.S., "The use of concept mapping as an alternative form of instruction and assessment in a capstone biomedical engineering design course," *Proc. 2003 ASEE Annual Conf. and Expo. ,* Nashville, TN, June 2003.

[15] Marshall, B., Zhang, Y., Chen, H., Lally, A., Fox, E., Shen, R., Cassel, L.N., "Convergence of Knowledge Management and E-Learning: the GetSmart Experience," *Joint Conference on Digital Libraries (JCDL) 2003*, Houston, TX, May 2003, pp.135–146.

[16] Bulmer, M., "An Interactive Concept Map for Statistics," *Conf. on Effective Teaching and Learning at University*, The University of Queensland, Brisbane, Australia. [Available Online] http://www.tedi.uq.edu.au/conferences/teach_conference00/papers/bulmer.html

[17] Cornwell, P.J., "Concept Maps in the Mechanical Engineering Curriculum," *Presented at the 1996 ASEE Annual Conference*, Washington D.C., June 1996.

[18] McClellan, J.H., Borkar, M., Velmurugan, R., Krudysz, G., "Automated Creation of Resources for HTML based Concept Maps," *Presented at MERLOT Intl. Conf*, Vancouver, B.C., Canada, Aug. 2003.

[19] ***CNT***: http://www.cdee.gatech.edu/software/cnt/cnt.exe

[20] IHMC Concept Maps: http://cmap.ihmc.us

[21] GetSmart: http://rocky.dlib.vt.edu/~rshen/ConceptMap/GetSmart.htm

[22] WebMap: http://ksi.cpsc.ucalgary.ca/articles/WWW/WWW4WM/

[23] Embeddable-Maps: http://ksi.cpsc.ucalgary.ca/articles/ConceptMaps

[24] http://members.shaw.ca/priscillatheroux/visual_thinking.htm

[25] Inspiration: http://www.inspiration.com/home.cfm

[26] MindGenius: http://www.ygnius.com/

[27] ConceptDraw: http://www.conceptdraw.com/en/products/mindmap/main.php