Concept Maps: An active learning and assessment tool in Electrical and Computer Engineering

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1. INTRODUCTION

Engineering education and its reach beyond the traditional classroom setting to synchronous and asynchronous distance learning have necessitated new means for curricula development and assessment to achieve student learning. Concept mapping is considered as a very useful tool for active learning as well as for learning assessment and evaluation. Concept maps have been used extensively across multiple engineering disciplines. The literature includes several reports on the use of concept maps in Mechanical, Chemical, and Computer Engineering. However, the use of concept maps in engineering has varied from simply relaying a structured overview of the concepts to the students to employing them as a means for curricula evaluation and improvement.

This paper reports on the first phase of an NSF funded research project to develop wireless communication modules using concept maps. The paper presents a review of learning styles and their relation to the use of concept maps. A review of concept mapping applications in Engineering disciplines in general and in Electrical and Computer Engineering in specific is presented. A brief overview and comparison of concept mapping tools is also given. The use of interactive concept mapping tools via the internet is emphasized to address some of the points raised about the effectiveness of what we term 'static' concept maps. Finally, the paper addresses the proposed work's approach to employ concept maps as an active learning media as well as an assessment tool for student learning as compared to traditional learning styles.

2. LEARNING STYLES

A prevalent concern for educators encompasses student learning and mastery. The variations in student's abilities and perceptions often impede learning if they are not taken into consideration when planning curriculum and pedagogy. Researchers and educators have examined these learning differences through paying attention to the variety of ways in which students approach academic tasks, which has led to the evolution of a variety of learning style theories over the past several decades.

In order to maximize instructional outcomes it is important to be aware of and sensitive to the variety of learning styles that students use and prefer. Carl Jung (1927) was the father of learning style theory in that he noted the differences in the way students perceived, made decisions, and interacted.

Learning styles are generally characterized by a combination of how a person perceives, processes, organizes and presents information. A variety of different models have been developed in order to classify learning and thinking styles and to understand how they contribute to student learning and mastery. However, it is also important to make note of the fact that even though there is evidence to support that there are differences in the way that learners perceive information best and how they choose to approach learning, all students can benefit from the experience of having the opportunity to choose from a variety of modes through which to learn information.

2.1. Learning Style Models

In this section we present a brief review of the three main models of learning styles which include; Gardner's model of multiple intelligences, the VAK model (visual-auditory-kinesthetic), and Kolb's model of experiential learning.

The theory of multiple intelligences states that individuals have a variety of abilities that are relatively independent from one another. According to Gardner (1993), there are at least seven distinct categories of intelligence which includes interpersonal, intrapersonal, logical-mathematical, musical, bodily-kinesthetic, spatial and linguistic. Since individuals possess unique combinations of skills or strengths and weaknesses in a variety of abilities or intelligences, Gardner states that learning environments should be developed to fit the profile of abilities demonstrated by each individual. In a traditional educational environment, the reality is that one on one curriculum development is not feasible. Therefore, the development of curriculum that integrates a variety of learning styles and effective teaching strategies would provide a learning environment conducive to optimum student mastery of skills.

Gardner's theory of multiple intelligences can be taken further through integrating VAK, another classical learning styles model. The VAK model of learning styles refers to Visual-Auditory-Kinesthetic preferences to learning. These three basic modes of reception for learning consist of visual learning, or learning though seeing, auditory learning, or learning through hearing and kinesthetic learning, or learning through doing.

The visual-verbal modality is felt to be an important aspect of learning style when looking at computer mediated communication that is predominantly text based (Atkins, *et al.*, 2001) such as concept maps. Mayer and Massa (2003) conducted research in the area of visual and verbal learners within a multimedia learning environment. Their research conceptualized the visualizer-verbalizer dimension by testing whether it can be decomposed into three separate facets—cognitive ability, cognitive style, and learning preference. In research conducted by Mayer and Massa (2003), learning preference refers to choices made within the context of authentic multimedia learning tasks, where as cognitive style refers to ratings of more general questions.

Kolb's Learning Style (Kolb, 1984) is based on a variety of renowned developmental psychologists' research in the area of learning and development. Kolb's learning style theory consists of a model with two dimensions and four stages. One dimension is the spectrum of tasks, ranging from watching the task to doing the task. The other dimension focuses on cognitive and emotional processes, ranging from thinking something through to reacting based on feelings or emotions. These dimensions combine to formulate the four stages of the model: activists, reflectors, theorists and pragmatists as outlined in Table I below (Kolb, 1984).

Table I. Kolb's four stages for learning styles (Kolb, 1984).

Stage	**Dimension**
The activist learning style	doing and feeling
The reflector learning style	feeling and watching
The theorist learning style	thinking and watching
The pragmatist learning style	thinking and doing

3. CONCEPT MAPS IN ENGINEERING

Student learning is the ultimate goal of the development of any curriculum. Many researchers have focused on different delivery methods that attempt to build on the incorporation of students' different learning styles. Concept maps (CMs) are just one way of these delivery methods that was used not only as a learning tool but also as an assessment and evaluation tool for the effectiveness of other delivery methods.

Concept maps are a graphical representation of knowledge. Key concepts are represented by nodes linked to one another through propositions outlining the relationship between the concepts. Concept maps can be organized in different ways, one of which is a hierarchical structure with the main concept at the top of the map branching into nodes defining their relationship to the main concept. These branch nodes may constitute the main concept for another concept map and so on. Inclusive to these nodes lays the ability to include more details about that subject area, 'concept', through learning aids that can address different learning styles.

Simply put, a concept map is similar to a puzzle. You need to look at the 'big picture' first and then start putting the small pieces of the puzzle together while sneaking a peek at the 'big picture' from time to time to be able to achieve your goal. In education, the goal is achieving learning where in order to achieve that goal; learners need to master the small pieces while keeping the 'big picture' in mind.

Mechanical, Chemical, and Computer Engineering disciplines have used concept maps as a learning tool. Darmofal, *et al.* (2002) used concept maps in a sophomore multidisciplinary engineering course at MIT to evaluate students' conceptual understanding of aerodynamics. In a study that explores the use of student-generated concept maps to assess students' understanding of the design process, researchers found that the types of concept maps generated followed the patterns suggested by Hart: branching, cat's cradle, web and linear (Sims-Knight, *et al.*, 2004).

Cornwell (1996) showed how concept maps can be used as an evaluation tool for the Mechanical Engineering curriculum as a whole and for courses within. He emphasizes that, for effective concept maps, different knowledge domains- novice and expert- exist. For students' evaluation, the synthesis level in Bloom's taxonomy which is equivalent to the expert CM *"is well beyond the level a student achieves by the end of the course"* as stated by Cornwell (1996).

Turns, *et al*. (2000) discussed concept maps as a useful tool for assessment at the course and program level. Lin (2001) used concept maps in support of logic design concepts in a Computer Engineering curriculum.

Lin (2001) states that *"Instead of passively accepting the information presented by paper, the Internet and the WWW provide an ideal vehicle for interconnecting the concept web to assist learning. The WWW is a rich-structured platform for learners obtaining the information which they need."*

4. SOFTWARE FOR GENERATION OF CONCEPT MAPS

One of the most powerful tools for creating concept maps was developed by the Institute for Human & Machine Cognition, IHMC. The IHMC CmapTools program "*empowers users to construct, navigate, share and criticize knowledge models represented as concept maps. It allows users to, among many other features, construct their Cmaps in their personal computer, share them on servers (CmapServers) anywhere on the Internet, link their Cmaps to other Cmaps on servers, automatically create web pages of their concept maps on servers, edit their maps synchronously (at the same time) with other users on the Internet, and search the web for information relevant to a concept map."*(Institute for Human & Machine Cognition, IHMC, http://cmap.ihmc.us/)

"The CmapTools client is free for use by anybody, whether its use is commercial or non-commercial. In particular, schools and universities are encouraged to download it and install it in as many computers as desired, and students and teachers may make copies of it and install it at home." (Institute for Human & Machine Cognition, IHMC, http://cmap.ihmc.us/)

Another tool is the Smart Ideas Concept-Mapping Software. This tool offers several features that make it appealing to visual learners in terms of colors and images. Users can generate multilevel maps and add hyperlinks to media files, text or another web page (SMART Technologies, http://www.smarttech.com). One of the attractive features is the compatibility of the generated maps with the Smart Board Interactive Whiteboard. In this format, instructors can effectively display the 'big picture' and walk their students through the interrelationships between concepts in a more traditional teaching style. This delivery method, in the authors' opinion, would create a perfect balance for the students who are experiencing concept maps for the first time and instructors who are wary of using new teaching techniques.

Smart Draw offers the possibility of using its powerful flowchart capabilities to create Mind maps. The maps generated make use of the powerful features included in SmartDraw® to give the learner the ability to navigate through hyperlinked nodes to different concept maps (SmartDraw, www.smartdraw.com).

Gaines and Shaw (1995) have created an interactive concept map tool which shares common features with the IHMC CmapTools program. In the Kmap tool "*The map gives an overview of the topic and acts as an index to available material. As the user mouses over a node a popup menu symbol appears. Clicking on this displays a menu that can be used to access the material, display text, play a sound, run a movie, and so on. The menu is generated from an underlying script, and user actions are reported to the script. The material accessed can be retrieved using either standard facilities for sound and movie playing within the application, or through commands which initiate another application and appropriate dataset. The actions can include the opening of other concept maps so that is possible to index a large body of material through layers of connected maps."*(Gaines and Shaw, 1995)

The aforementioned software are not the only tools available to generate concept maps but merely an example of what is available for educators to use. Another aspect of concept maps is the conceptual modeling. Several Knowledge Analysis and Design support languages (KADS) have exploited the concept of a knowledge domain representation to develop intelligent concept maps. These modeling languages are classified according to Flores-Méndez *et. al* as ranging from "specification" to "programming". Flores-Méndez *et. al* provide an excellent implementation for "*the knowledge level modeling of a simple diagnosis task in the Audio System Diagnosis domain*"(Flores-Méndez et.al). Even though a thorough review of knowledge engineering modeling is outside the scope of this paper, the authors would like to emphasize that generating formally specified and executable concept maps for problem solving methods (PSM) is an excellent tool for education.

Creation of intelligent concept maps will definitely address some of the points raised about the effectiveness of what we term ‘static’ concept maps. Static concept maps are ones that present the learner with the overview of the subject area and do not allow any interaction. Currently available interactive concept maps are what we term as ‘Navigational’ concept maps. These navigational concept maps allow learners to navigate between different concepts, link to multimedia files, browse to other web pages or resources. However a truly interactive concept map would be one with artificial intelligence built in to guide the learner in the learning process while catering for the different learning styles.

5. WORK IN PROGRESS

This paper reports on the first phase of an NSF funded research project to develop wireless communication modules using concept maps. The proposed work’s approach is to employ concept maps as an ‘active’ learning media as well as an assessment tool for student learning as compared to traditional learning styles.

The concept maps are initially created by the researchers using the IHMC CmapTools program to layout the overview concept maps and the hierarchical structure for the subject area. However, in our review of concept maps software we were concerned about the possibility of the learner losing track of the learning process as they were drilling in to the inclusive resources in the concept nodes. An abstract example of the main page for each course that leads students into the course is shown in Figure 1. Figure 2 shows an abstracted version of the module related to analog and digital signals which is a part of the Introduction to Engineering Technology course developed under this award.

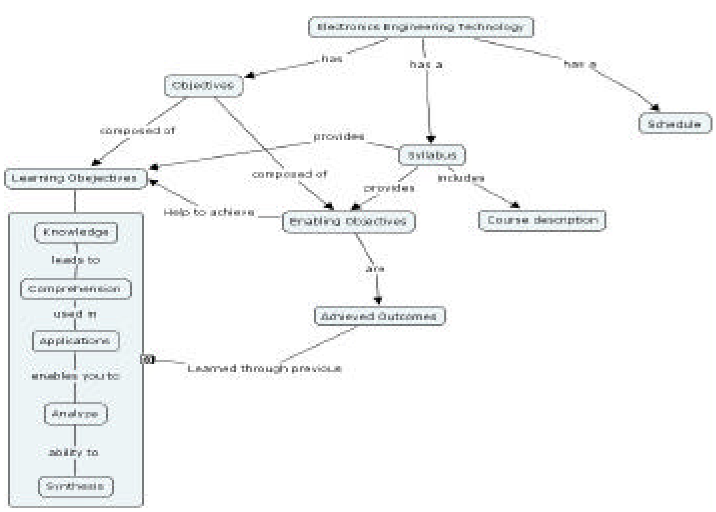

Figure 1. Course Main Page

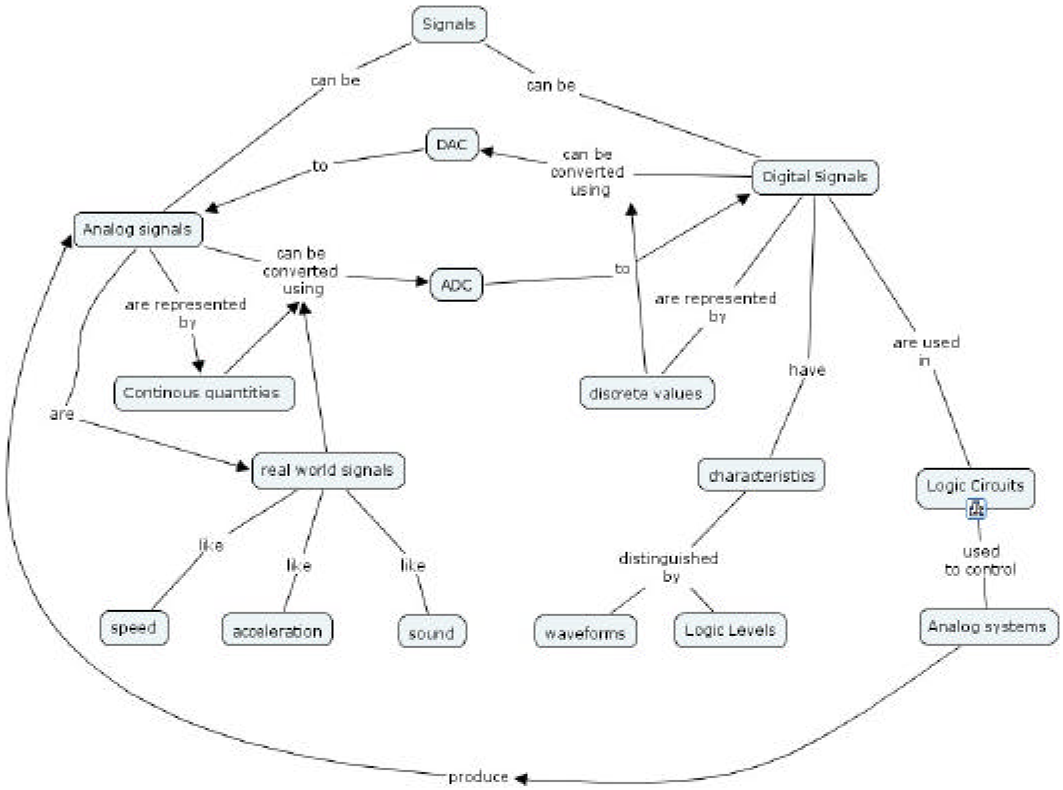

Figure 2. Signals Concept map

It is possible when investigating a specific concept to navigate through multiple windows, more detailed concept maps, and hence be faced with a perception problem of where it all fits in the 'big picture'. As an example, when the user clicks on logic Circuits in Figure 2 a new window opens up which is shown in Figure 3, outlining more details about logic circuits. These types of concept maps are what we term as' Navigational' concept maps.

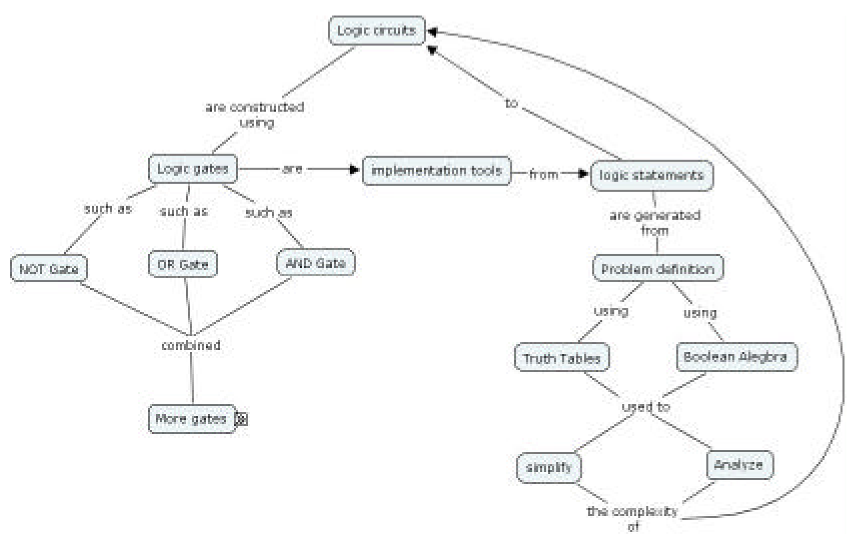

Figure 3. Logic Circuits Concept map

Hence, in our approach to address this, the authors will attempt to use a flash presentation of concept maps utilizing two delivery methods. The first one using a file tab structure where the learner would navigate from the main concept map to the second tab while maintaining on the side a tree structure of the concept map, Figure 4. A link, on the second display tab used for secondary or detailed concept maps, will always allow the learner to navigate back to the 'big picture'. The second delivery method would use a zoom in-zo[illegible]out display. By clicking on one of the concepts in the main map, the [illegible]ld zoom in on a more detailed concept map or any resources ava[illegible]riate. In the 'zoom in' view, a site map structure would be ava[illegible]er keep track of the structure as well as a link to navigate [illegible]

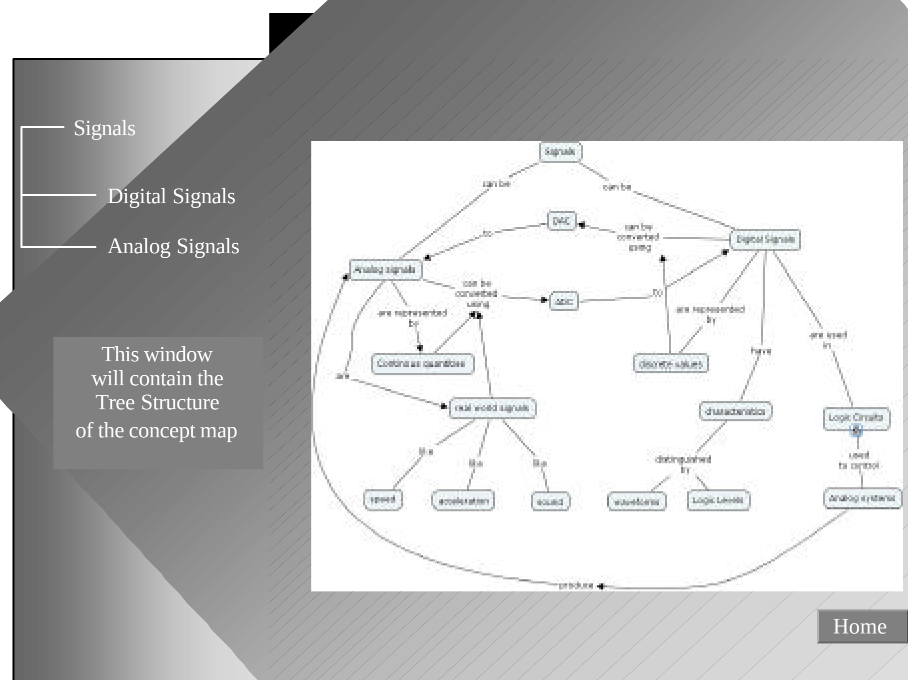

Figure 4. Visualization [illegible]ucture.

Formative evaluation of the two de[illegible]complished through sharing the product with educators thr[illegible] list servers and will be tested on groups of students for knowled[illegible] Another stage of the work is to achieve 'active' learning by allowing [illegible] to create their own concept maps using a database of concepts. This will [illegible]ble the evaluation and learning assessment of students' knowledge.

6. SUMMARY

In conclusion, the paper presented a review of different learning styles as well as different concept maps generating software. An emphasis on the difference between ‘active’, ‘navigational’, and ‘interactive’ concept maps have been discussed. The methodology conceived to develop wireless communication modules using concept maps through an NSF funded research project was also presented. The proposed work’s approach to employ concept maps as an active learning media as well as an assessment tool for student learning as compared to traditional learning styles was outlined.

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.REFERENCES

Atkins, H., Moore, D., Sharpe, S., & Hobbs, D. (2001, June). Learning style theory and computer mediated communication (Report No. IR-021-194). In *Proceedings of ED-MEDIA 2001 World Conference on Educational Multimedia, Hypermedia & Telecommunications*. Tampere, Finland.

Brian R Gaines and Mildred L G Shaw. Collaboration through Concept Maps. retrieved on January 27, 2006, <http://ksi.cpsc.ucalgary.ca/articles/CSCL95CM/>

Cornwell, P.J. (1996). Concept Maps in the Mechanical Engineering Curriculum. *Proceedings of the 1996 ASEE Annual Conference*, Washington D.C.

David Darmofal, Diane H. Soderholm, and Doris R. Brodeur. Using Concept Maps and Concept Qusetions to Enhance Conceptual Understanding, *32nd ASEE/IEEE Frontiers in Education Conference*, November 6 - 9, 2002, Boston, MA, 1-7.

Gardner, H. (1993). *Multiple intelligences: The theory in practice*. New York: Basic Books.

Hsiu-Mei Lin,Using Concept Mapping as an Instructional Strategy to Support Logic Design Learning, *International Conference on Engineering Education,* August 6 – 10, 2001 Oslo, Norway, (6E8) 16-21.

Institute for Human & Machine Cognition, IHMC. <http://cmap.ihmc.us/>

Jennifer Turns, Cynthia J. Atman, Member, IEEE, and Robin Adams (2000). Concept Maps for Engineering Education: A Cognitively Motivated Tool Supporting Varied Assessment Functions, IEEE Transactions on Education, **43** (2), 164-173.

Judith E. Sims-Knight, Richard L. Upchurch, Nixon Pendergrass, Tesfay Meressi , Paul Fortier, Plamen Tchimev, Rebecca VonderHeide, and Madeleine Page (2004). Using Concept Maps To Assess Design Process Knowledge, *34th ASEE/IEEE Frontiers in Education Conference*, (F1G) 6-10.

Jung, C. (1927). *The theory of the psychological type*. Princeton, NJ: Princeton University Press.

Kerka, S. (2000). Multiple intelligences and adult education. *Trends and issues alert* No. 17, ERIC Clearinghouse on Adult Career and Vocational Education.

Kolb, D. A. (1984). *Experiential Learning: Experience as the source of learning and development*. New Jersey: Prentice Hall.

Mayer, R. E. & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of Educational Psychology,* **95**(4), 833-846.

Roberto A. Flores-Méndez, Pim van Leeuwen, and Dickson Lukose, retrieved on January 27, 2006 <http://ksi.cpsc.ucalgary.ca/KAW/KAW98/floresmendez/>

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