# A Concept Maps-based Approach for Knowledge Visualization and Autonomous Self-Assessment in Distance Learning Environments


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***Abstract*** — *Current educational environments rely primarily on a text-based syllabus approach to describing course content as well as whole curricula. This traditional approach is too limiting, especially when it comes to distance learning environments. It fails to delineate the relationship of concepts and skills covered in a given course to those covered in other courses. It also fails to show the knowledge base that a learner acquires by the end of his/her course of study as it relates to lifelong learning. New demands placed on distance learning environments call for more engaging learning experiences for learners. We adopt an approach that is based on using a knowledge visualization tool that can engage both learners and instructors, in an active learning approach, to construct a map for the knowledge, concepts, and skills that a learner possesses and those that he/she acquires during a course of study, as well as for self-assessment. We capitalize on findings from cognitive science research to engage students in an active learning, constructivist way to learning computer engineering knowledge, concepts and skills. We present our design of concept maps for knowledge visualization and self-assessment using graphical user interfaces. The concept maps are Web-based and enable a constructivist active learning approach and autonomous self-assessment via interactive modules that support situated learning of concepts. A demonstration using concepts of digital logic design is also presented.*



***Index Terms*** — *concept maps, knowledge visualization, active learning, autonomous self-assessment.*


## INTRODUCTION AND MOTIVATION

The focus of the new science of learning is on the cognitive processes that lead to deep understanding. Learning researchers have viewed humans as goal-directed cognitive agents who *constructively* seek information. A constructivist approach to learning is one that assumes that all knowledge is constructed from, and based upon, previous knowledge. This approach can be successful for knowledge formation of learners when previous knowledge of each individual is used as the basis or starting point for subsequent new instruction [1-3].

## NATURE OF LEARNING

Research on learning have shown that understanding a subject domain; such as science, depends on mastering a set of relations among important concepts in that domain. Successful learners develop an elaborate and highly integrated frameworks of related concepts, similar to those of experts. Moreover, such highly organized cognitive structures of the subject matter facilitate problem-solving and other higher level cognitive activities [2].

We capitalize on these findings to engage computer engineering students in an active learning, constructivist way to learning computer engineering knowledge, concepts and skills, also utilizing the principles of knowledge visualization.

## KNOWLEDGE VISUALIZATION

Knowledge visualization lies at the intersection of information graphics, graphic design and cognitive science [3]. The common objective for all knowledge visualization tools is to make visible an intellectual landscape. This landscape can be represented using a knowledge map that can serve as the framework or context for the purposes of knowledge sharing, decision-making and problem-solving [5,6].

One such knowledge visualization tool is a concept map or C-map. A C-map is a diagrammatic representation that illustrates concepts as nodes in a graph interconnected by links that represent the propositional relations between these concepts [2,7,8,14].

In our work, we believe that knowledge or concept mapping is merely the means to a more important end: that of supporting deep understanding of the subject matter. The manifestations of such deep understanding include problem-solving and design skills. Knowledge representation plays a central role in knowledge visualization. It must provide support for:

- the modular structure of the subject matter,
- the interconnections among knwoledge modules, and
- the constructivist knowledge formation for each learner.

In order to meet these requirements, a network structure of knowledge representation is needed. Moreover, in order to achieve deep learning and mastery of subject knowledge, each leaner must be actively engaged in constructing his/her own knowledge base. This can be achieved by letting each learner take full control of *incrementally* constructing his/her own knowledge base, by specifying the knowledge modules he/she is acquiring and their interconnections.

## C-MAPS OF DIGITAL LOGIC AND COMPUTER ORGANIZATION

As a first step, we have engaged learners to actively construct concept maps for the digital logic and computer organization concepts that are covered in two core computer engineering courses at our insitution. An example of such a concept map is shown in Figure 1.

Each student is required to build his/her own concept map *incrementally* as concepts are being covered in class. The merits of this apporach include:

- enagaging each student in a constructivist manner to build a visual representation of the knowledge structure [13] of his/her own knowledge base of the subjetc matter,
- supporting a modular knowledge structure around concepts of the subject matter,
- providing a common view between learners and their instructors/teachers,
- providing hyperlinks to concept-related material, such as: online resources, simulations, or additional related material, and
- providing hyperlinks to problem-solving activities such as laboratory assignments and interactive modules.

## DISCUSSION AND FUTURE DIRECTIONS

The development of a prototype for knowledge visualization has provided us with valuable insights on several fronts, including: how to engage students in an active learning constructivist manner, the merits of C-maps, and the nature of knowledge representation, as follows:

- Active Learning: is achieved when learners incrementally and constructively build their individual knowledge bases via a concept map representation. An important benefit to this approach is enabling both leaners and instructors to identify early on any misconceptions about the structure of the subject matter knowledge. That in turn will enable identifying misconceptions before they become rooted and before additional misconceptions are built upon them.
- C-Maps: concept map software is needed to make authoring a concept map less cumbersome and less time-consuming. It also needs a context-sensitive interface that enables a user to readily add hyperlinks. Moreover, the software should allow the creation of hierarchical relations bewteen maps.
- Nature of Knowledge Representation: one of the main presmises of our work is using a network structure of knowledge modules to represent the knowledge base of a learner and of the subject matter. We are working on providing a formal framework for the specification of knowledge modules as knowledge *quanta* as well as their rules of interconnections [9,10]. Moroever, we are investigating the use of machine learning algorithms [15,16] for the construction and evolution of such networks of knwoledge quanta.

## CONCLUSIONS

The work described in this paper is the means to an end: that of supporting deep understanding of subject matter knowledge and concepts for individual learners. The manifestations of such deep understanding include higher level cognitive skills, including problem-solving and design skills.

We have undertaken the development of a knowledge visualization prototype for our computer engineering students to engage them in an active learning constructivist manner for acuqiring the concepts of two core computer engineering courses. However, we believe that once knowledge is rooted on the fundamental premises presented herein, individuals can readily apply it to multiple learning and disciplinary contexts. This work will also support the important goal of providing a solid foundation for lifelong learning for each individual.

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## FIGURES AND TABLES

FIGURE. 1
CONCEPT MAP OF DIGITAL LOGIC AND COMPUTER ORGANIZATION CONCEPTS.

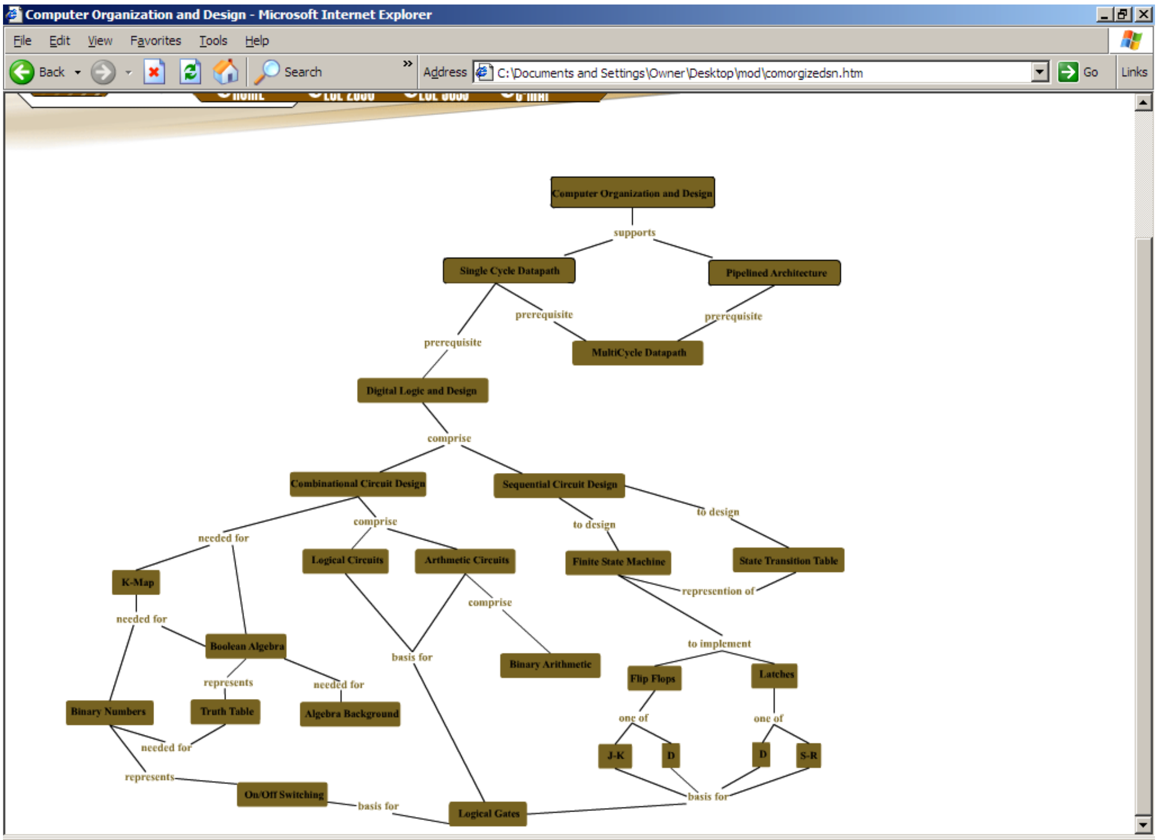


FIGURE. 2
CONCEPT MAP OF LOGIC GATES.

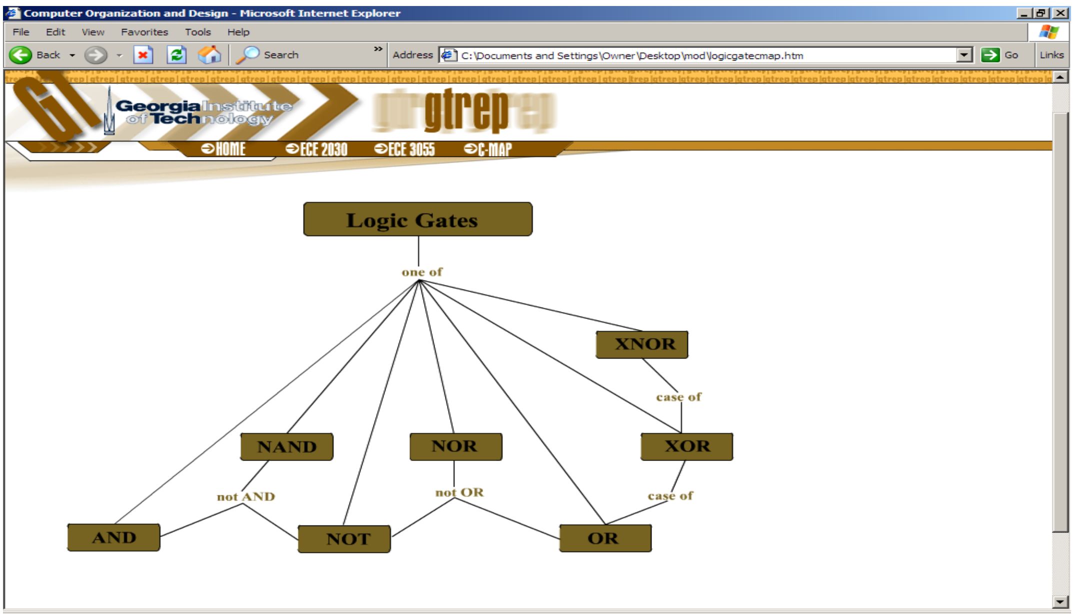

FIGURE. 3
EXAMPLE OF INTERACTIVE MODULE FOR A DIGITAL LOGIC CIRCUIT.

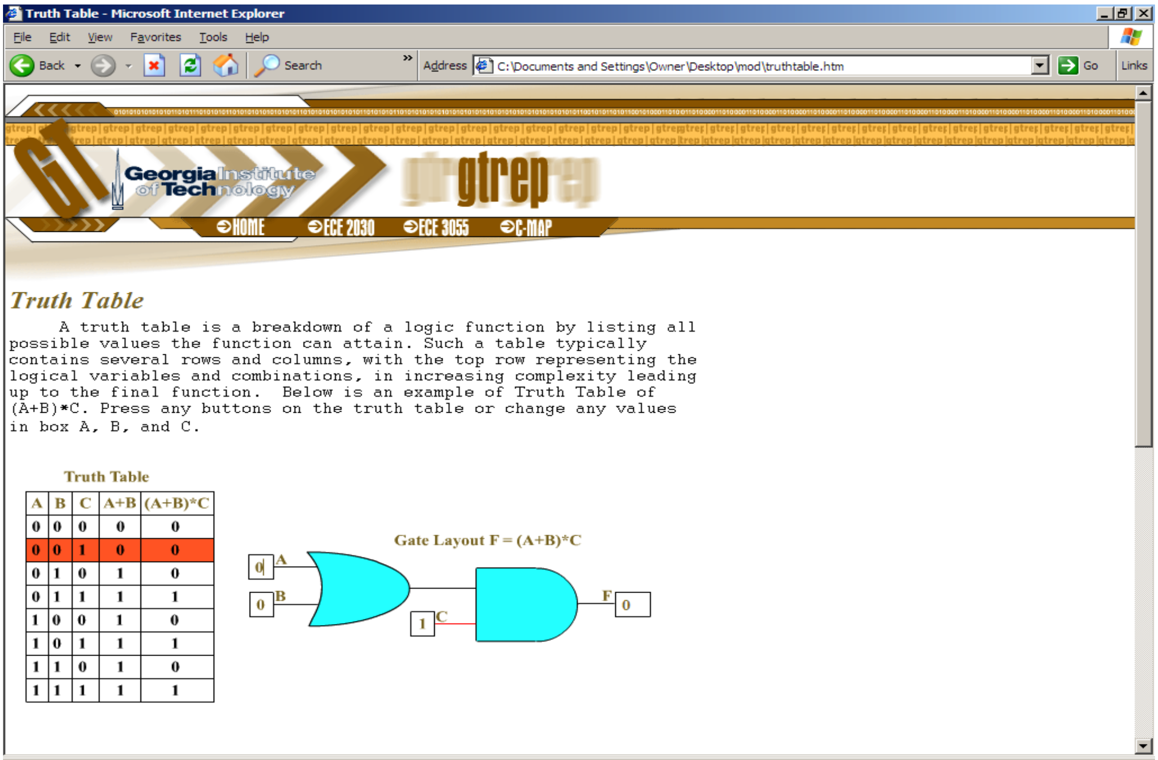


FIGURE. 4
EXAMPLE OF INTERACTIVE SELF-ASSESSMENT MODULE FOR A COMBINATIONAL DIGITAL LOGIC CIRCUIT.