Web-Based Tool for Learning an Integrated View of Engineering¹
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Session: Tools, techniques, and best practices of engineering education for the digital generation

We present a web-based tool that we have developed with the view of improving the manner in which electrical and computer engineering (ECE) students acquire knowledge that (1) cuts across traditional course boundaries in the undergraduate ECE curriculum and (2) ties practical applications or products to concepts and techniques from different ECE courses. In developing this tool, we have focused upon the learning of such interconnection knowledge by ECE undergraduates in the context of 4 courses at Boston University: Electromagnetics (EC455), Signals and Systems (EC401), Digital Signal Processing (EC416), and Microprocessors (EC450). In this paper, we begin with a discussion of the nature of interconnection knowledge and an overview of the mechanisms relied upon by traditional ECE programs for having their students acquire this important type of knowledge. We then discuss a web-based tool called LIVE for “learning an integrated view of engineering” that we have developed to further augment the process by which engineering students acquire such knowledge. The paper concludes with results from a preliminary survey indicating a high degree of student satisfaction with our prototype web-based tool as a means of acquiring interconnection knowledge.

Nature of interconnection knowledge

We view interconnection knowledge that crosses course boundaries and ties course content to practical applications and products as belonging to one of four basic categories, each of which we now discuss and illustrate with examples.

Convergence Knowledge: This type of interconnection knowledge enables one to understand and appreciate how basic concepts learned in earlier courses combine together to converge to more specialized concepts or techniques in later courses. This type of knowledge would be useful to students in earlier courses by providing them a context in which to learn the basic concepts. It would also be useful to students in later courses by providing them clear interconnections between the new concepts and techniques they are currently acquiring and the more basic concepts they might have (or were supposed to have) acquired in earlier courses. An

¹ This project is funded in part by the National Science Foundation through its Division of Undergraduate Education (Award No. 0736827).

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example of the LIVE tool’s display of convergence knowledge is shown in the “concept map” of Figure 1 where each node represents a concept and each directed link originates from a concept that is “needed” in building up to the concept pointed to by the link [1-4]. In Figure 1, the Fast Fourier Transform (FFT) is the top-most concept that is usually learned in a course on Digital Signal Processing. Figure 1 illustrates how some basic concepts (periodic signals, complex exponentials, orthogonality, absolute summability, and Fourier Transform) from a pre-requisite course in Signals and Systems are needed to appreciate the concept of the FFT.

![Figure 1: A concept map illustrating “convergence knowledge,” in which a variety of concept nodes feed into a top-most concept node. The lower-level concept nodes converge to form the higher-level concept node.](image)

**Congruence Knowledge:** This type of knowledge gives one an understanding and appreciation of parallels, analogies, or similarities among concepts in courses that are at least superficially quite different in their respective content. For example, a student may learn about complex exponentials in a course on Signals and Systems and about plane waves in a course on Electromagnetics but may not yet have come to the realization that at a certain level of mathematical abstraction they are essentially the same concept. The purpose of congruence knowledge is to explicate such interconnections via “concept maps” of the type shown in Figure 2. The bidirectional link between the two nodes is used to indicate that at some level of abstraction there is congruence between the linked concepts.

**Diversity Knowledge:** Another major type of interconnection knowledge is one which ties any given concept in a course to various practical applications or products. A “concept map” from the LIVE tool illustrating diversity knowledge for the concept of an “algorithm” is shown in Figure 3. Applications in which the concept is needed include DSP chips, arithmetic logic units, computer operating systems, etc. This type of knowledge is particularly important in motivating
students to learn basic concepts in earlier courses when the ultimate applications would be dealt with much later in the curriculum or in some cases not at all.

Figure 2: A concept map illustrating “congruence knowledge,” whereby two concepts have a bidirectional link between them that indicates parallels, similarities, or analogies between those concepts.

Figure 3: A concept map illustrating “diversity knowledge,” in which a concept node points to different applications in which that concept plays a role.

Confluence Knowledge: This knowledge relates a product (such as a cell phone) to the different types of knowledge that may be found in different courses in the overall curriculum. An example of a “concept map” from the LIVE tool for a cell phone is shown in Figure 4. Each node in the outer ring of the concept map of Figure 4 would also have its own concept map of the convergence type that runs through the various courses in the curriculum.
**Figure 4:** A concept map illustrating “confluence knowledge,” in which an application or product node points to different concepts that are useful in understanding how that application or product works.

**Delivery of Interconnection Knowledge in Traditional Programs**

Traditional ECE programs have produced many generations of engineers who have successfully acquired interconnection knowledge. Mechanisms for delivering such knowledge have included:

- Each course instructor taking the responsibility for reviewing required knowledge from pre-requisite courses.
- Each course instructor taking the responsibility of previewing the content of courses for which the current course is a prerequisite.
- Each faculty advisor helping advisees to select courses to take for which they already have the prerequisites and that interest them (typically by way of what the ultimate application is).
- Personal research by a student to find the “relevance” of a course to practical real-world applications.
- A Senior Design Project which encourages students to discover how the confluence of knowledge from different courses can be used to create/invent various types of products and/or applications.

Clearly, in the traditional paradigm for acquiring interconnection knowledge there is a great degree of dependence on the initiative taken by individual faculty and students. It would be advantageous if students could be provided additional material on interconnection knowledge to supplement the traditional delivery mechanisms. It is in this spirit that we have designed the web-based tool for presenting students with “concept maps” related to the various types of
interconnection knowledge.

**LIVE Tool Software and Interface**

The LIVE tool is built on a software platform called Cmap Tools, which was developed by the Florida Institute for Human and Machine Cognition (IHMC) and is publicly available at http://cmap.ihmc.us/conceptmap.html. Currently, the LIVE tool is organized as a single network of over 1000 concept nodes that are linked by directional and bidirectional links. The user can navigate over the various links and nodes to explore the four basic types of interconnection knowledge. Each node also has “attached” material that (1) describes the concept and its relationship to concepts immediately preceding it in the convergence hierarchy and (2) provides the student with “quiz” questions to test his/her knowledge of the associated interconnection knowledge. The “home page” of the tool (See Figure 5) allows the user to begin a search based on selection of an academic program (e.g. electrical engineering), an academic course (e.g., introduction to microprocessors), an engineering application (e.g., cell phone), or an engineering concept (e.g., impedance). Clicking on any of these produces a scrollable list from which to select the item of interest. When the item is selected, the tool presents the user with a graphical representation of the portion of the global concept map that is most relevant to that item. The user can select to zoom in or zoom out from that starting point as desired. Finally, there is also the option to select any item of interest by searching for it among alphabetical lists of concepts, applications, courses, and programs.

![Figure 5](image.png)

**Figure 5:** A snapshot of the home page of the LIVE tool. On the left panel, the user may select to explore by program, by course, by application, or by concept. When searching by application, the right panel illustrates how a scrollable list of applications in alphabetical order appears.
Assessment of LIVE Tool

A preliminary assessment indicates that the LIVE tool could potentially be a very useful aid for ECE students in regard to their acquisition of interconnection knowledge. We asked ten ECE students (4 males, 6 females) who have already completed the 4 ECE courses currently addressed by the LIVE tool, to learn to use (for about a half hour) and then to explore (for at least an hour) the concept maps of the LIVE tool. They were then asked to answer the following questions:

1. How helpful would the LIVE tool have been when you were an undergraduate?
2. How helpful did you find the LIVE tool in aiding your own interconnection knowledge?
3. How easy was it for you to learn to use the features of the LIVE tool?
4. How easy was it for you to navigate through the concept maps in the LIVE tool?

They were asked to respond (anonymously) to each question with a score on a rating scale from 1 to 5, with a score of 1 representing “not helpful at all” or “not easy at all,” and a score of 5 representing “very helpful” or “very easy.” The results of the survey are shown in Table I. On each question, the mean rating by the 10 respondents was between 4 and 5 and the standard deviation ranged between 0.5 and 1.0. The highest mean rating (4.6) was on question 1, indicating that the pool of 10 subjects thought that the tool would have been very useful when they were taking their ECE undergraduate courses. The mean of 4.0 on question 2 also indicates that many of the subjects found that the LIVE tool was helpful in building up their own interconnection knowledge, even though they have already taken the courses. The responses to questions 3 and 4 also indicate general satisfaction with the “ease of use” of the LIVE tool.

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Table 1: Table of the ratings (1-5) for each question in the LIVE tool survey responded to by 10 ECE students. A rating of 5.0 means “very helpful” on questions 1 and 2, and “very easy [to use]” on questions 3 and 4. A rating of 1.0 means “not helpful at all” on questions 1 and 2 and “not easy at all [to use]” on questions 3 and 4.
References


Biographies

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