An Integrated Approach to Teaching Engineering Courses

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ABSTRACT

Many undergraduate engineering students have difficulty understanding the connections between the different engineering courses they are required to take. Too many of them focus on learning just the details of a specific course without any consideration of how the concepts fit with those of other courses. The integrated approach to teaching engineering involves a "systems view" to the curriculum. In this approach, one or more systems are presented to the students early in their engineering program. Throughout their courses, the students are reminded of where they are in the system. A specific example is discussed of how this approach is being used as a test case with five courses in the electrical engineering curriculum at the United States Air Force Academy. The resulting improvement in student performance is also discussed.

INTRODUCTION

The typical undergraduate engineering student sees most of his or her courses as a collection of facts and formulas. Most students focus on memorizing these facts and formulas and how to use them to solve specific problems. The focus of their efforts tends to be the problems presented through examples in assigned readings, homework, and laboratory exercises. They concentrate on learning very specific applications of the concepts and ideas presented in the course. This approach to learning gives the students a very narrow view of the material presented in a particular course.

This problem is of particular concern in an environment where the student has a limited amount of time to devote to a particular course. In this case, the student will prioritize the focus of his/her study efforts to concentrate on those areas that seem most likely to appear on an examination. In essence, the students are learning in a vacuum: learning to pass an examination, rather than to understand the broader applications of the material.

The motivation to use the integrated approach described in this paper came from a desire on the part of the authors to improve the understanding of students in senior-level electrical engineering courses. At this level, students should have a rudimentary understanding of how the major concepts presented in an undergraduate engineering curriculum "fit" together. For example, they should see that a fundamental understanding of linear systems is a key to understanding the basics of analog communications.

THE INTEGRATED APPROACH

The overall objective of the integrated approach is to foster an understanding of the interrelation between concepts presented in different courses, thereby strengthening the student's comprehension of an entire field of engineering. In essence, the method involves shifting some of the student's focus from the details and onto the "big picture." This is not done at the cost of understanding those details, but rather to explain them in the light of how they mesh with other topics.

To fully understand the importance of certain topics, students must have a global view of an entire field of engineering. They must understand the purpose for the smaller part and how it supports the larger whole. Without this understanding, the student has a collection of seemingly unrelated facts and theories; the synergistic importance of these facts and theories is lost.

This suggests that a "systems approach" to engineering topics might best serve to foster the desired understanding in the student. The specific interactions of components and subsystems and how they support the overall system gives the student a frame of reference. According to Dr. James E. Stice, one of the important factors in engineering education is to "create meaning" for the student [1]. In other words, help the student to make sense of the concept, relate it to something else with which the student is familiar, and help the student to see how the concept is used in a system. Thus, the systems approach combines the new concept with other ideas that the student understands.

For example, when teaching a student about filters, using the example of tone controls (treble and bass) on the student's stereo might help them better understand what a filter actually does. Since the student is familiar with how the tone controls change the sound of music played through the system, he/she might better understand how the filters affect the frequency response. This also gives the student insight to the cause and effect associated with use of filters in a system. In this manner, the student experiences problem solving on systems level, observing those parameters that are determined by the state of subsystems and components. This approach helps to complete the picture for the student.

Another advantage to this systems approach is that students apply previously learned material to new problems. It moves them out of the realm of approved solutions to specific problems and forces them to consider new ways of thinking about certain topics. This changes the student's perspective from memorizing facts and procedures to understanding concepts and ideas. They start to learn that engineering is a process, not a procedure; that facts and theories are tools, rather than the final result.

Showing how concepts from other courses apply to systems and in situations that are new to the student helps to reinforce those concepts. Focusing on ideas common to other courses gives the student a new way of looking at an old idea. Additionally, students learn the practical side of engineering concepts they are studying. By using real systems and problems as examples, the students are exposed to actual applications of engineering theories. These are particularly interesting to the students when the problems come from systems or events with which they are familiar. Some examples are examining the engineering considerations involved in the Titanic disaster, analyzing the communications link from the Mars Pathfinder, or even studying the engineering involved in automobile systems.

The underlying strategy to the integrated approach is to give the students a motivation for studying the particular concepts presented in a course and to give the students a firm understanding of how those concepts relate to systems and other concepts with which they are familiar.

A SPECIFIC APPLICATION OF THE INTEGRATED APPROACH

We used the integrated approach to teach two senior-level courses in electrical engineering during the Fall '97 semester. The courses are EE434, Discrete Time Signals and Systems (a course in digital signal processing) and EE447, Communications Systems I (a first course in analog and digital communications). Our application of the integrated approach centered around a basic communication system, as shown in Figure 1.

Our intent was to give the students a frame of reference in which to relate their previous courses with the ones they were taking. Each functional block of the communications system was described, including how the related course concepts applied to that block. A brief summary of this description is as follows.

The objective of the communications system is to convey information from a source to a physically separated sink. Information from the source is assumed to be in some sort of signal format. The information signal is first processed through a signal conditioning block that converts the signal to a form compatible with the modulator. The modulator impresses the signal on a high frequency carrier which is amplified and transmitted through a channel. After passing through the channel, the signal is received, and the transmitted carrier is processed through a demodulator to recover an estimate of the original signal. This signal estimate is converted to a form compatible with the intended information sink and sent to the sink.

Each of the different functions in the diagram is explained as an application of the concepts presented in associated electrical engineering courses. EE333 is a signals and systems course that explains how signals are processed through linear systems, including amplifiers and filters. EE443 is an electromagnetics course that describes signal propagation and transmission media, including antennas and fiber optics. So as this communications system is explained, the students see how some of their previous courses "fit" into the system.

Follow-on topics to the current courses are also discussed. EE444 is an applied electromagnetics course which builds on the concepts from EE443 to present a more in-depth study of antennas. In the same manner, EE448 builds on the concepts from EE447 to present detailed coverage of advanced digital modulation systems.

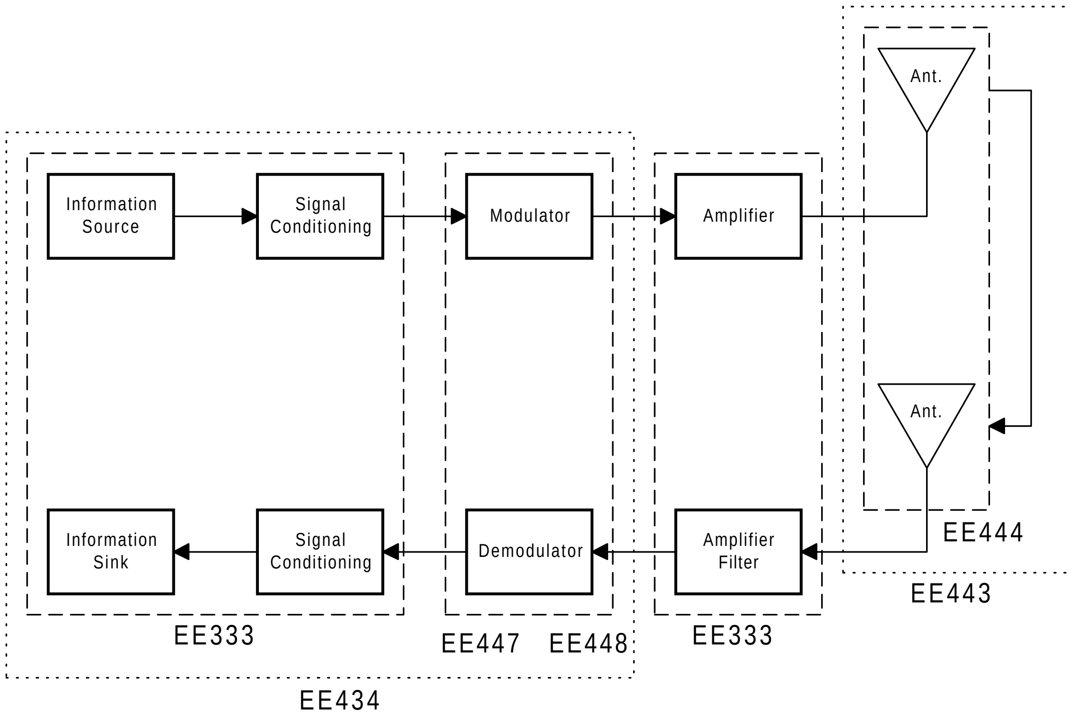

Figure 1. Basic Block Diagram of a Communications System

The theories and concepts for basic communications (EE447) are presented as a follow-on topic to the material from some of the student's other courses. Digital signal processing (EE434) is presented as another means of implementing the analog processing functions in part of the communication system. So the students see the progression from one course to the next as they study the functions and concepts associated with each block of the communications system.

The intent is not to narrow the student's view of communications, but rather to broaden it by giving them a "big picture" example. Without this, the students tend to focus on the specifics of modulation and lose their perspective of how this relates to a real system.

RESULTS

As shown in Table 1, student evaluations under the integrated approach (Fall '97) show much improvement over the previous offerings (Fall '96). These results are combined evaluations from both EE434 and EE447. One significant result is the increased interest of the students in the course material. The students also see the courses as being more relevant to their overall program as engineers. Additionally, the academic performance (as reflected in the grade point average, GPA, for students in these courses) was much better. From the Fall '96 to the Fall '97 offerings, the course GPAs increased about 0.4 (on a 4.0 scale).

Rated Area	Fall ’96	Fall ’97
Stimulated Student Interest	Well Below Average	Slightly Above Average
Intellectual Effort	Average	Above Average
Relevance of Course	Below Average	Well Above Average
Organization and Clarity	Well Below Average	Well Above Average
Overall Evaluation	Well Below Average	Well Above Average

Table 1. Comparison of Student Evaluations

CONCLUSIONS

Using an integrated approach to teaching engineering courses helps students better understand engineering concepts and theories. By giving the students a big picture of where the particular material fits into a system, the students are able to comprehend the significance of the concepts and relate them to topics with which they are familiar. The students learn more about how to apply engineering concepts to new problems, rather than learning approved solutions to well-known problems.

Employing the integrated approach in engineering courses seems to motivate students and produce better academic performance.

[1] J. E. Stice, formal presentation to the faculty at the USAF Academy, "‘Engineering’ Education: A Top Ten List," 16 Oct 97.

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