Professional Design Laboratories: Bridging the Gap Between Classroom and Industry in the Senior Year

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The Electrical Engineering Department at Michigan Technological University is integrating senior design projects with its elective communication-systems course sequence to create an innovative senior-year experience. Our newly established Undergraduate Communication Systems Laboratory, sponsored by NSF, parallels the industry work setting of practicing wireless system design engineers. In this paper, we describe the innovative aspects of this project.

Background

Engineering education has been widely criticized for turning out graduates who are poorly prepared to enter industry. ABET has called for more design content in engineering curricula.[1] ASEE has made extensive recommendations for curricular improvements.[2] Among other action items, the ASEE report, *Engineering Education for a Changing World*, calls for accelerated curricular change to incorporate team skills, collaborative learning, communication skills, leadership, a systems perspective, undergraduate research, engineering work experience, and ethics, among other items. In response, curricular reforms are underway at many institutions, including Michigan Technological University (MTU).[3-11]

To address some of these deficiencies, we are implementing a revised BSEE program at MTU. We require our students to take a course in creative problem solving during their first year. In this course, we set the stage for open-ended problem solving, high standards of professional behavior, and teamwork. Also, design, ethical concerns, and practice with communication skills have been integrated into core courses required of all undergraduate EE majors. Finally, we have set aside approximately 50% of the senior year for completing the transition of our students into practicing professionals. We are experimenting with several approaches to the senior-year experience. This paper describes our plans for communication systems students.

Collaborative Education

A growing body of literature shows that students learn more effectively when they actively work in teams and help one another.[12-15] One example is Peer Instruction, developed for introductory physics courses by Eric Mazur at Harvard University.[12] In this method, a concept is presented by the lecturer, and then a related question or problem is posed. Individual students work on the problem for a few minutes. Then they form small groups to discuss and modify their answers. Finally the answers are tallied, and if the results are satisfactory the lecture proceeds to the next concept. Teams work together only for a few minutes on relatively simple well-defined problems. Thus, Peer Instruction is well suited to large classes in which the goal is for students to master a large number of basic concepts.

Another example of collaborative learning at a more advanced level has been carried out in chemical engineering by Richard Felder at North Carolina State University.[13] In this program, students work in teams for the duration of a course to learn course material and complete homework assignments. Felder has successfully carried this program through a sequence of five courses. These teams work together for a longer period on more substantial problems than in Peer Instruction.

Problem-based instruction[16] is a similar approach in which carefully chosen problems are posed by the professor. Students respond by identifying what they need to know, learn the material needed to solve the problem, and then apply the knowledge to solve the problem. Then the professor poses a new problem and the process is repeated.

The Undergraduate Communication Systems Laboratory

We have established an undergraduate laboratory for communication systems that parallels the industry work setting of practicing electrical engineers. Selected students (about 25 in number) will spend two full days per week in this setting during their senior year. We are employing the basic principles of collaborative learning and problem-based instruction in the laboratory, however the problems are open-ended and of larger scope than in the examples cited above. Positive interdependence coupled with individual accountability is fostered in a problem-based learning environment. Regular assessments of group functions are conducted in a manner similar to that employed in industry. Finally, interpersonal skills, including leadership and decision making, are nurtured.

The Undergraduate Communication Systems Laboratory:

1. Integrates open-ended design projects with elective course work in communication systems and signal processing.
2. Provides laboratory instrumentation and materials (such as integrated circuits, passive components, mixers, DSP development systems, amplifiers, filters, and so forth) for hands-on projects.
3. Provides students with a rich selection of intellectual resources for carrying out projects and researching related principles (including video lectures, books, journals, manufacturers' data books, and trade publications).
4. Provides computers, relevant software, and access to the INTERNET.
5. Solicits project ideas, partial financial sponsorship, and close guidance to ensure a realistic program from industry.

6. Provides communications infrastructure so student design teams can interact frequently with remote industry project sponsors.
7. Provides facilities for student teams to meet, study, design, and construct projects.
8. Gives students an excellent education in the basic principles of communication systems and signal processing.
9. Allows for flexible scheduling of subject material and related assignments as appropriate for each team's projects.
10. Actively encourages participation by women and minority students.
11. Provides a supportive environment based on the principles of collaborative education in which students can readily obtain help from their peers, graduate students, and faculty.
12. Encourages high standards of professional ethics.
13. Provides a forum for students to intensively practice oral and written communication skills.
14. Conducts periodic seminars to educate our student participants regarding career and diversity issues.

Accommodation of Student Cognitive Preferences

Several studies have shown that a variety of preferred approaches to learning exist among engineering students.[17,18] Traditional courses favor some learning styles and discourage others. Many creative students have left engineering as a result of mismatches between their cognitive preferences and the way that many engineering courses are taught. We feel that such students will remain in engineering as a result of the curriculum changes we are making (such as the freshman course in creative problem solving, inclusion of realistic design problems in our new core courses, and senior projects). In the Laboratory, students are encouraged to use approaches that best match their mode of learning. Our aim is to create an environment in which all students can find ways to excel.

Video Resource Materials

We are experimenting with providing lectures by video tape. We are starting with video tape mainly because we have many of the requisite resources, but we expect to eventually migrate to CD-ROM and use of the INTERNET for delivery. The supporting course material will be divided into modules, and a series of video segments will be prepared for each module. All modules will include written notes, references to literature, practice problems, and laboratory exercises. (Topics for the modules include: mixers, signal-space concepts, PRK modulation, carrier-recovery techniques, convolutional codes, and so forth.)

Compared to traditional classroom lectures, providing material on videotape or CD-ROM has several advantages:

1. Students can access material in the order and at the pace that best matches the requirements of their project.
2. Students can be admitted to the Laboratory at the start of any quarter. They can join existing

teams or form new teams as appropriate. This flexibility will encourage student participation in our co-op program, further strengthening our ties with industry.

3. Video material can readily incorporate demonstrations having complex equipment setups. (We propose to continually strengthen our video resources by including videotape presentations of past student projects.)
4. More effort can be expended in preparing a given module and its supporting material because it will be reused. This will leverage the creative talents of faculty and make better use of intellectual resources.
5. A program of continuous improvement can be more readily applied to the video material.
6. CD-ROM technology provides an interactive environment that allows students to branch to topics and to examine them at depth as individually needed.
7. The material is exportable.

Communication Skills

Students have greater opportunity to practice their written and verbal skills in the proposed laboratory. For example, students make a written application for acceptance into the laboratory, much as they do in securing industrial positions. Teams prepare project plans and give periodic written and oral progress reports to faculty, other students, and industrial partners. Students returning from external employment interviews give oral trip reports to the group. Furthermore, each student is required to maintain a laboratory notebook documenting his/her work. Each project will culminate in a formal written engineering design report and oral presentation.

Matching Project Scope to Student Capabilities

Based on our past experience, we anticipate a range of student ability in tackling open-ended problems. It is important to match project scope to the capabilities of the student teams. If the projects are not challenging, little is learned. On the other hand, if projects require knowledge, resources, and skills far exceeding student capabilities, failure and discouragement are the likely result. We start students entering the program with relative simple projects that can be successfully completed in a few weeks. As the student teams build skill and confidence, we present them with successively more challenging problems, culminating in an open-ended project sponsored by an industrial partner. We will adjust the steepness of the learning curve for each student team.

Ensuring the Participation of Women and Minority Students

The MTU EE Department currently has 615 undergraduates including 68 women, 11 African-Americans, four Hispanic-Americans, and 97 Asians/Asian-Americans. We have worked hard to increase our female and minority enrollment. For example we have conducted regular summer programs to introduce women and minority high-school students to the field of Electrical Engineering.

We have also worked hard to ensure that female and minority students have role models on the faculty, and the department currently has two female faculty out of a total of twenty-five. Our Women in Electrical Engineering (WEE) group works to create a nurturing and supportive environment for our women students, both graduate and undergraduate.[19] The WEE Program is working with the Professional Design Laboratory to encourage participation by women and minority students.

Dr. Noel Schulz is conducting seminars in the laboratory relating to sexual harassment, networking through IEEE and other technical organizations, and other topics of importance to new electrical engineers. Through these seminars, our students become educated about issues related to diversity in the workplace. Furthermore our women faculty have close out-of-class interaction with women and minority students in the Laboratory, providing them with a supportive environment.

The Role of Faculty

Some attention has been given to the possibility that communications technology may make traditional universities obsolete.[20] However, our view is that the roles of both faculty and their institutions will change, but they will not vanish as a result of technological advancements in delivering education. The result of properly directed change will be better, more-relevant education without an increase in cost. For example, students and faculty at many universities can share educational resources over the INTERNET. We plan to integrate this capability into our design environment to complement the materials that we develop.

Faculty will function as managers of the facility, conflict resolvers, technical advisors, and evaluators. In part, the role of faculty will be parallel to that of section heads in industry. The faculty will also select and author pedagogical materials for use in the project and disseminate these materials.

Furthermore, the ongoing research activities of the faculty (and graduate assistants) will be carried out in full view of the undergraduates. We propose to incorporate two or more graduate student projects suggested by industry into the predominant undergraduate laboratory environment. Thus faculty and graduate students will be visible and accessible role models for the undergraduates, and they will also provide a range of intellectual and experiential resources to the undergraduates, much like the environment found in industry where a range of technical experience and skills is available to design professionals. Faculty offices will be located adjacent to the Professional Design Laboratory to facilitate interaction with students on an as-needed basis.

Implementation Schedule

During the 1997-8 academic year, a pilot group of 15 seniors completed their degrees under our new curriculum. Six of these seniors completed a project to build a demonstration digital communication system consisting of a data clock, a pn data source, a carrier source, a PRK modulator, a simulated bandpass channel, a Costas carrier recovery subsystem, a matched filter, a data clock recovery subsystem, and an error detector. System error rate performance versus E_b/N_0 was measured and compared to that of an optimum PRK system with an additive white Gaussian noise channel.

Also, we have incorporated many of the features of our new curriculum into the senior communication-systems course sequence for students graduating under our old curriculum. The experience that we gain will be used to make adjustments for our 1998-9 program.

During 1997-8 we also experimented with other less structured approaches to the senior-year experience. For example one of the senior groups is working on a project entitled "Investigation of Electric Current in a Moving Ionic Solution" sponsored by Mercury Marine Corporation. Another group is working as a design team to automate the dome on the Electrical Engineering department's optical Amjoch Observatory. The dome had manually operated motors to open the dome window and rotate the dome. The 16 inch telescope is operated by software using the SKY program to track stars. The team is developing interface hardware and control software to operate from either an on-sight computer or a remote (campus) networked computer. The network can be either wire or wireless and allows for image acquisition as well as telescope/dome control. The team, made up of students in Control, Computers and Power/Machinery, accepted the challenge and arrived at a very workable control solution.

In 1998-9 all students will be graduating under our new curriculum and full scale operation of the Undergraduate Communication Systems Laboratory will begin. We plan to report on our experiences with this laboratory in subsequent papers.

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