Innovation in Engineering Education at the University of Wisconsin

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Abstract

Recently the College of Engineering has been revising the undergraduate curriculum with the aim of integrating the discovery of engineering and contemporary issues with the fundamentals of engineering science, design and analysis during their career at Madison. Our purpose is to better motivate students and instill in them a thirst for learning during their college career and beyond. In fact we are also attempting to carry this attitude to the graduate students via an Engineering Scholars Program. This paper describes these initiatives as well as the organizational and institutional issues that might be encountered at a major research university.

Introduction

As individuals we engage in an evolutionary life-long learning process. The stages of this evolution seem to focus on what we want to learn, what we learn and how we best learn. As we grow and mature we evolve from students in the classroom to students of the world, where learning never ceases, but changes in kind and emphasis. As educators, we need to recognize this evolution in our students and design our engineering curricula to not only be academically challenging, but also personally motivational for the diverse student population that will become the engineeers of tomorrow.

Engineering education must delicately balance the learning process between the understanding of facts (e.g., scientific), with their interrelationships and the desire to understand these facts. In our view overemphasis of the former may have given inadequate attention to the latter. This trend in education must be reversed particularly as the diversity of the engineering problems increases with the needed diversity of the engineering workforce. With this focus, the faculty of the College of Engineering at UW-Madison has begun to revise our engineering curricula to better balance the learning of fundamental principles with imparting the motivation to learn. The major focus is to provide diverse learning opportunities to the student, and constantly challenge them to become actively involved in the learning process.

At the core of this curriculum renovation we have focused on a few key elements that all students should have an opportunity to experience during their tenure as undergraduates - an introduction to the various engineering disciplines, an experience in contemporary issues in engineering, an exposure to the engineering design experience in an introductory freshman course, and a technical communications course sequence integrated with the previous topics through a learning community. These innovations in the curriculum extend across all engineering degree programs, and in the future could also be integrated into specific disciplines via design/research experiences for the undergraduates. In addition, graduates students can also become involved in these initiatives by our developments via an Engineering Scholars Program.

Introduction to Engineering: History

In 1993, the College set up an Ad-Hoc Curriculum Committee, consisting of a member from each degree major to examine the current engineering educational experience and to determine if there was need for improvement based on expectations from employer and alumni. The committee concluded that there was distinct need to improve our retention of women and minorities in engineering, with a broader goal of equalizing and hopefully improving the retention rate for all undergraduates. Quite independent of this effort, but simultaneous to it, Dr. Katherine Sanders with the assistance of Dr. Sandra Courter, from Industrial Engineering and the School of Education, began a teaching improvement program (TIP) with six engineering faculty that volunteered to be part of Sanders' PhD dissertation project. The faculty examined the learning experience within their areas and the College as a whole, exploring ideas they could use to improve their teaching and student learning. One improvement identified in the learning process was the need to provide the students with the motivation for learning early in their careers as well as challenge them with the opportunity to actively participate in the discovery of what engineering was, as well as the learning of the fundamentals. The opportunity to put

their ideas into practice came about with the aid of funding from the College and a grant from the Advanced Research Projects Agency for Technology Reinvestment Project awarded to the Engineering Research Center for Plasma-Aided Manufacturing. With this financial resource the Introduction to Engineering course began as a pilot in the Fall of 1994. The course now has grown to a point in which about one-third of the freshmen class voluntarily takes it as a technical elective in the first semester as Pre-Engineers.

Introduction to Engr: Structure & Content

This course has been offered over the last three years in the College and has evolved to a stable structure that allows it grow and change as needs arise. The goal of the course is provide freshmen engineering students with an experience that allows them to discover engineering in a realistic situation. Having the students work in small teams on a real hands-on design project for a real customer was chosen as the basic structure of the course. The design process was chosen because it had the attribute of being an excellent vehicle to expose the student to many of the important elements of engineering in the students first semester. It allows the student to see the common thread between the basic sciences, engineering sciences and their career goals. These following course goals are stated in the course notes, which are customized for each semester the course is offered:

- work constructively in a design team
- learn some engineering principles & language
- find and use information from diverse sources
- learn from and teach your colleagues
- get to know your customers and their needs
- communicate your designs effectively
- keep a personal record of your design project
- learn about various engineering professions
- appreciate the broader engineering issues

Specific faculty volunteer to teach the Introduction to Engineering course as a team in the spring prior to the fall semester in which it is offered. Then in late spring and throughout the summer these faculty meet to plan the specifics of the course; e.g., the weekly lecture topics, the content of the laboratories and outside speakers. The key objective early in the planning is the identification of a design project that has a real customer and that appropriately challenges the students in their design teams. The process for project identification is not straightforward and involves the experience of the faculty and their contacts in industry and the community. The past projects were designing access for physically handicapped people to buildings at the Old World Wisconsin historical site, designing a people counter for the Elvehjem Museum of Art, and designing a process for the recycle of cardboard for commercial businesses.

The course consists of two fifty minute periods where the students have a general meeting organized by individual faculty and a three hour laboratory each week where the students are divided into sections of twelve to sixteen students. The whole course is predicated on a team concept where the general meetings are organized and managed by a faculty team of seven to ten individuals. The laboratories are taught by an individual faculty member paired with a particluar undergraduate senior assistant as part of the laboratory team. In addition a graduate student is employed as a project assistant to organize all the laboratory supplies and logistics. The faculty and senior assistant organize the laboratory section into smaller student teams of three to five individuals to develop designs. After oral presentations of these design concepts, one design is selected for further development as a whole lab group. The students keep a lab journal and prepare two presentations: their small group's design to other lab members, and their whole-lab presentation to the course's students, faculty and customer. Students are continually encouraged to engage in a dialog with faculty and senior assistants through Email to assist in the learning process.

In addition to design project related issues, the general meetings are a perfect opportunity to help the students learn about the various engineering professions. Throughout the 1990's we have noted a consistent trend that the number of students entering pre-engineering are increasingly unsure of what specific major they want to pursue; e.g., civil, electrical, or mechanical. Part of this uncertainty stems from their lack of knowledge about the differences in the disciplines and what are the range of eventual careers that engineers may assume. Thus, one of the major activities in the course is to discuss with the students what are the uniques aspects of the various engineering disciplines and to bring in practicing engineers from the various disciplines to discuss their career path, their experiences and what influenced them to choose their profession.

Finally, these general meetings can serve as the time when the students can begin to appreciate the contemporary issues that engineers must face in their professions which involve the business, legal and social aspects of their technological developments. The faculty also use this general meeting time to explain and discuss issues related to engineering ethics, diversity issues in the workplace, environmental impact of technology, issues of industrial safety and risk, business planning related to engineering developments and total quality management.

Course Assessment and Related Issues

There are a number of issues that must be addressed when a course like this becomes part of the curriculum; i.e., how does one assess the course, should all students be required to take such a course, how are faculty credited for their participation, how can this course be coupled to curriculum reforms within specific disciplines and with changes in campus requirements. Let us consider each of these issues and suggest current trends, since changes to the College curriculum is still evolving.

The pilot course in 1994 was evaluated by the campus Learning through Evaluation, Adaptation and Dissemination Center (LEAD). The purpose of the evaluation was to understand the effect of the new course on students, based on quantitative and qualitative information. The evaluation occurred during and after the course by individual and group interviews by the LEAD center staff as well as quantitative tracking of the students as they progress in their college careers. The evaluation gave the faculty "real-time" feedback during and following the semester for planning of the course in subsequent semesters. Quantitative retention data based on their classifications in subsequent years is also analyzed and compared to freshmen who wanted to take the course and were on its waiting list. Based on data at the end of 1995 we find that 96% of the students who enrolled in the course were still in the college compared to a 75% from the waiting list. Also about 40% of the students had selected a specific engineering major compared to 25% from the waiting list. These data indicate that a higher number of students completing the course stay in engineering and had chosen a major.

The reasons for these positive effects are varied, but qualitative data suggests the personal, supportive team environment of the course is an effective motivator for learning and retention. In addition, the fact that the students chose to take the course also was a key that helped the students make a career choice and develop a sense of professional identity as engineers. This suggests that leaving the course as an elective with a limited enrollment is a good strategy for the present.

For those students who opt not to take this course we have an alternative course for freshmen which exposes them to the various engineering disciplines and the contemporary issues in engineering. It is our opinion this exposure is essential for students to make an informed decision on their career and appreciate the broader issues. The course again utilizes a team of faculty who present to the students information about various engineering careers as well as contemporary issues affecting the engineering discipline. In addition, engineers from various industries reflect on their careers.

In spring of 1996, the University of Wisconsin established General Education Requirements for all entering freshman. The major impact for entering freshmen into engineering is a uniform requirements for two courses in communication. In the past, various engineering degree curricula required one or more courses in verbal and written communication; e.g., technical writing. Now the faculty has established a consistent set of courses for all students entering the college. The first is a technical communications course to be taken in the freshman year and the second is writing and composition course to be taken later in their undergraduate tenure, which builds upon the elements of the first course.

What can make this new curriculum approach a more effective learning experience is that we have developed Learning Communities between this Freshman Technical Communication course and the Introduction to Engineering course. This learning community involves the concurrent registration of students who take both courses into laboratory and recitation sections where the design projects of the introductory course can be synergistically used as subjects for the students' verbal and written technical communication exercises. It also allows the students to study together across course boundaries and establish a more coherent community for learning and scholarship.

Future Trends in Curriculum Development

The activities discuss havemainly focused on the freshman experience for pre-engineering students. However, such curriculum renovations have only begun and further developments in some of the upper division undergraduate and graduate curricula are expected; e.g., integrated design or undergraduate research courses, a Masters of Engineering professional degree, or incorporation of some principles on aspects of engineering education into the graduate experience. Let us consider some of these curriculum developments.

A natural extension of the introductory engineering course is the development of a series of independent study courses at the sophomore, junior and senior years in which an on-going project is the focus of a team effort of students. The student team would span all three years of experience with the each team member contributing to the overall design or research objective guided by faculty and graduate students. Two examples of such an approach is the student design competition in Mechanical Engineering for the Future Car and the undergraduate research effort in Nuclear Engineering in which a team of students built the MEDUSA plasma physics tokamak. Each is a good example of this vertical integration of the

engineering educational experience with students being guided and learning within a community of other students. The engineering curriculum now takes on the coherent picture of education of the fundamentals of mathematics, the physical sciences and humanities as well as a core curriculum of engineering practice through design and undergraduate research (Figure1). In fact as the engineering discipline becomes more technologically challenging we feel the appropriate degree level for most students is a Masters of Science or a Masters of Engineering over a five year educational time frame.

A final trend in education is a more complete training of doctoral students in engineering educational pedagogy. As these students near the end of their graduate careers and they have an earnest interest in university academics as an eventual career path, they should gain experience in the process of post-secondary education. This goes beyond simply a stint as a teaching assistant during their doctoral study or teaching improvement training, but should encompass a discussion of the whole career of a professor; teaching, service and research. A pilot program is to begin this summer in the College as we host the Engineering Scholars Program, as part of a three-year joint effort with Carnegie Mellon University sponsored by the National Science Foundation. Initally, it is to focus on the College of Engineering, but should eventually encompass the broader perspective doctoral students in science and engineering, as it becomes an integral part of the university doctoral educational experience.