AC 2007-411: INTERDISCIPLINARY ENGINEERING DESIGN PROJECTS TO ENHANCE THE RESEARCH EXPERIENCE FOR UNDERGRADUATES

Hamid Shahnasser, San Francisco State University

Christopher Pong, San Francisco State University
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ABSTRACT

With the fast-paced evolution of technology and globalization, undergraduate engineering education is facing many new challenges in the 21st Century. The need to revise the engineering curriculum to ensure that students are resourceful and competitive in this changing global, cultural, and economic environment cannot be overstated. Integrating hands-on research experience into teaching and learning objectives is one of the most effective mechanisms by which the quality of engineering education can be improved. In particular, one urgent task that must be completed to meet the needs of these new challenges is the development of year-long interdisciplinary projects for senior undergraduate students, which will prepare them to face an increasingly diverse society and workforce. This paper will first address what challenges the engineering education community is facing today. It will then discuss how faculty, students, institutions, technology, and the engineering community can contribute to the improvement of academic curricula. The paper will present some examples of the mechanisms that are used to develop engineering design projects to enhance research experience for undergraduate students. It will stress the importance of facilitating senior students to develop engineering design projects in order to bring research experience to a diverse group of participants and how this culminating experience can encompass and integrate the students’ knowledge gained during the previous years of their engineering schooling and infuse in it ethics and professionalism. Finally, student and faculty surveys will be conducted to evaluate the criteria used in the development of successful projects.

School of Engineering at San Francisco State University
Located in one of the most diverse, creative, and globally connected regions of our nation, San Francisco State University has grown over the past 40 years to become a nationally and internationally renowned, comprehensive public institution. Of SFSU’s total enrollment of around 29,200 students in 2004, about 60% are female and 40% are male. Reflecting the ethnically diverse composition of the urban area in which it is located, SFSU serves a significant number of minority students. Of those who declared their ethnicity in 2002-03, students of color comprise 63% of the undergraduate student body. By ethnicity, the student body is 37% White; 24% Asian; 14% Latino; 12% Filipino and Pacific Islander; 7% African American; 6% other and 0.8% Native American. Consequently, SFSU has been designated as a minority-serving institution by the US Department of Education.

The School of Engineering offers undergraduate degrees in four disciplines – Civil, Computer, Electrical and Mechanical – all of which are approved by the Accreditation Board for Engineering and Technology (ABET). As articulated in its mission statement, the School’s purpose is: “to educate students from a diverse and multicultural population to become productive members of the engineering profession and society at large.” The School of
Engineering combines excellence in teaching theoretical principles and engineering design concepts with practical hands-on experience within a curriculum designed to foster both technical proficiency and communications skills.

Average enrollment in the School is about 800 undergraduate students each semester. The student body is ethnically, culturally, academically and economically diverse. About 20% of the School’s students are women and 55% are ethnic minorities. Many are the first in their families to attend college. Most are classified as economically or educationally disadvantaged and find it necessary to work at least part-time to support themselves while in college. The vast majority of these students persist in their studies, complete their engineering degrees, and ultimately reap the benefits of significantly enhanced employment opportunities. The School offers a graduate degree, the Master of Science in Engineering, with two areas of concentration: Structural/Earthquake Engineering and Electrical/Computer Engineering. Currently, 85 graduate students are enrolled in these two concentrations, which feature curricula and schedules designed with the convenience of working engineers in mind.

The faculty of the School of Engineering is highly regarded for its strong practical engineering experience and excellent academic qualifications. The orientation and specializations of the faculty are eclectic and wide-ranging, offering expertise both in design and in basic and applied research. All faculty are committed to excellence in teaching, as evidenced by the careers they have chosen on the faculty of a comprehensive urban public university. In addition, the School is active in research and has been awarded nearly $3.5 million over the last five years in grants and contracts from sources including the US Department of Energy, National Science Foundation, National Security Agency, Air Force Research Laboratory, National Aeronautics and Space Administration, Pacific Gas & Electric, Agilent Technologies, AT&T, NEC and Sun Microsystems. The School also maintains strong ties with local industry, and the region’s many innovative engineering and technology companies provide an abundant pool of desirable internship and employment opportunities for our students.

**FACTORS FOR ENCHANCED QUALITY OF ENGINEERING EDUCATION**

Some of the important ingredients that form and contribute to the enhancement of engineering education are briefly discussed below. Later on we discuss, lifelong learning, technological development in education, mentoring, advising and finally assessment that are all part of this enhanced engineering education and are part of the challenges that we are all facing.

1. **Research Experience for Undergraduates:**
   Bring research opportunities to the classroom and laboratory is one of the most effective ways to promote the integration of research and teaching. Through the support of research projects conducted by faculty members, student participation can greatly enhance the learning environments and help maintain faculty intellectual vibrancy, both in the classroom and in the research and professional community.

2. **Leadership and Team Building Skills:**
   The engineering profession appreciates team building skills and leadership. Engineering projects are always multi-disciplinary tasks. Engineering educators should seek creative venues to foster
student leadership and teamwork skills. For example, engineering schools can team up with professional organizations to provide leadership-training workshops. Schools can offer interdisciplinary design projects as student graduation requirements. Through these efforts, students will become aware of the importance of teamwork and its impact on the successful completion of the project. Fostering students’ leadership and teamwork skills must be viewed as an important component of educational and professional goals in order for U.S. engineers to remain competitive globally.

3. Managerial and Communication Skills
The engineering curriculum should always include engineering management components. While the engineering profession emphasizes the need to have a solid science, mathematics, and engineering foundation, it is also expected that engineers, moving through their career advancement will take responsibilities at the management level. The engineering management component of the curriculum should address topics such as the legal, financial and business environment, decision-making, project planning, project management, team building, quality control, safety, and effective communications [1]. Consideration of these topic and a full appreciation of their importance in the domestic and global marketplace, will meet the engineering professional’s needs that come with career advancement.

An article written by Ford and Riley indicated various ways in which engineering and communication disciplines can work together coherently to ensure that the ABET criterion that encompasses effective communication is represented in engineering curricula [2]. In their article, they offered various examples of useful portraits of writing across a given curriculum, interdisciplinary courses, integrated programs, and a variety of support systems including writing and communication centers and online resources at universities.

LIFELONG LEARNING OF CONTEMPORARY ISSUES
Due to the short-life cycle of engineering evolution, engineering educators should help students recognize the need and importance of life-long learning of contemporary issues. Engineering curricula should promote coherent approaches to form partnerships with professional communities, to provide engineers with comprehensive learning opportunities as their careers advance.

TECHNOLOGICAL DEVELOPMENT IN EDUCATION
With the rapid evolution of education delivery technology, engineering educators should embrace technological developments to provide more alternative means of education. Conventional face-to-face classroom lectures and hands-on experimentation continue to be the most effective methods of educating engineering students. However, there is an urgent need to develop and adopt innovative pedagogical tools using the most current technology. For example, many on-line Internet courses are an effective means of making life-long learning possible. In addition, some simulation experiments can be taught through virtual lab exercise or through Web-based curriculum. While the cost for high education continues to rise, the effectiveness of offering Web-base courses may provide a cost-effective alternative for learning. A study done by Cohen and Ellis indicated that there was strong agreement on the relative importance of
various potential indicators of quality in certain courses delivered via an on-line medium [3]. Many of the articles referenced in that paper gave details of transitioning to an on-line learning environment. An article by Hsieh and Hsieh gave a detailed narrative about the development and evaluation of modules on a Web-based intelligent tutoring system regarding a programmable logic controller’s timer and counter instruction [4]. In their report, students made statistically significant learning gains from taking the Web-based modules.

ACADEMIC ASSESSMENT AND EVALUATION
Academic assessment has been viewed as a vital segment of higher education learning. Assessment of learning outcomes is a basic measurement of whether learning has occurred and the extent that learning objectives have been achieved. It evaluates the learning environment and the results of learning objectives. Without appropriated assessment tools, it is impossible for the educational institution to evaluate the quality of the curriculum it offers. The assessment should break down into two layers. The first layer is the course assessment and its learning outcomes evaluation. At this layer, the instructor should carefully evaluate students’ learning, conduct a meaningful self-assessment, and complete a report in which the instructor decides, based on the learning evaluation, if students’ learning objectives have been met. He/she should revise the course annually based on the self-assessment results. On-campus and/or off-campus peer reviews may be initiated at this level if it is deemed necessary. The next layer is the curriculum assessment and evaluation. Other than individual instructors, on-campus peers from other related disciplines, alumni, professional leaders, and experts from professional organizations, may be asked to participate in the curriculum assessment. The goal is to provide routine feedback that allows the institution to evaluate the quality of its program as a whole.

MENTORING AND ADVISING
An engaging engineering educator can be an effective advisor and mentor for students. According to Bjorklund’s study on the effect of faculty interaction and feedback on the gains in student skills, he provides insight into the relationship between faculty-student interaction and students’ perceptions of selected skills and attitudes [5]. The study was based on data gathered over a period of two years from more than 1500 students taking the first-year design course offered at 19 Penn State campuses. The results strongly indicated that there was a correlation between students’ gains in design and professional skills and faculty interaction with students through constructive feedback.

Engineering educators should be open to the student perspectives. Student creativity should be fostered and encouraged. Educators should also encourage two-way dialogue and discussion of real-world issues with students. Faculty should serve as mentoring role models and offer valuable academic and professional advice to students. Indeed, mandatory advising has become part of faculty teaching assignments at San Francisco State University (SFSU). At SFSU, engineering students are required to seek curriculum advice during advising days during each semester. Mentoring and advising have been recognized as important mechanism for effective learning. Through MESA engineering program students receive individual advising, tutoring and mentoring and they are guided in applying for assistantships and scholarships such as The Harriett G. Jenkins Pre-doctoral Fellowship Program (JPFP), Workforce Development Initiatives (WDI) and others that leading organization such as United Negro College Fund Special
Programs and others offer. MESA advisors and our NASA Administrator’s fellow guide and mentor the students in preparing and applying for such scholarships.

PROFESSIONAL ETHICS
Codes of professional ethics are the most vital standards governing engineering conduct. However, their significance in the engineering curriculum tends to be overlooked. Many educators assume that professional ethics have no significant impact on the students’ technical and professional skills. It is commonly viewed that students should learn ethics after they enter their engineering profession. Therefore, many students are not taught about engineering ethical standards during their engineering education. However, educators generally assume that knowledge of these standards is essential for the student to maintain high ethical standards and for advancement in their profession. By learning and applying these standards during their engineering education, students will be better prepared to enter the local and global engineering communities as productive and ethically sound professionals. Today, with the rapidly changing engineering profession, engineers have greater short-term economic and financial rewards through technological innovation than at any other time in the past. Therefore, today’s engineering students urgently need an education that includes learning the concepts of engineering ethics and what it means to maintain a high ethical standard.

PROJECTS THAT ADDRESS MULTI-DISCIPLINARY CURRICULUM
The development of year-long interdisciplinary projects for senior undergraduate students, which will prepare them to face an increasingly diverse society and workforce, has been a major culminating engineering experience requirement for engineering curricular at San Francisco State University.

Although the foundation of all engineering principles may be similar, the application of various engineering fields can be quite different. Inter-disciplinary projects, that incorporate various engineering disciplines, can be effective ways to train and educate students to be familiar with other engineering professions. Requiring students to participate in team-based projects as culminating experience is highly appraised by accreditation agencies. Typically, students are required to commit one-year or one-semester toward the completion of design projects that simulate the real world [6]. At the end of these projects, students are required to submit final extensive written reports and make oral presentations of the results. While exploring the possible projects, students should take into consideration constraints, such as economic, environmental, sustainability, manufacturing, ethical, health and safety, social, political and global issues.

Notably, the interdisciplinary telecommunications program at the University of Colorado at Boulder was awarded the Bernard M. Gordon prize for innovations in engineering education by the National Academy of Engineering. It provides a unique example that features new frontiers in engineering education. This program, founded in 1971, was formed as a joint effort between the electrical engineering, political science, business and sociology departments. The curriculum covers the fundamentals of computer communication, wireless communication, law and policy, standards, economics and social impact. This program takes advantage of telecommunications technology to serve a much broader student population. It also expands the time and cultural boundaries, which offer a venue for students to learn and work effectively at a distance with
others. This program shows the potential benefits to the engineering profession of having engineers with both a technical background and knowledge of law, policy, regulations, finance and economics [7].

Five interdisciplinary projects are discussed below as examples of how SFSU has integrated research and teaching within an interdisciplinary curriculum. The first project was a joint project between electrical and mechanical engineering students. The students designed a ¼ scaled down version of a vehicle that was powered by solar panels. All of the students were involved in the whole process, but the primary responsibility for the vehicle body design was with the mechanical engineering students. Their goal was to design a lightweight aerodynamic vehicle. The electrical engineering students were responsible for designing the battery charging system, which included the motor drive, the ability to perform regenerative breaking, and obtaining current from the solar panels. This project taught the students about teamwork, and allowed them to develop a greater appreciation of other engineering specialties and how they interrelate to bring a project to its successfully completion.

The second project was a joint project between mechanical engineering and civil engineering students. The students designed a scaled down version of a boat that was powered by solar panels. All of the students were involved in the whole process, but the primary responsibility for the boat body design was with the mechanical engineering students. Students program the autonomous boat to gather water quality data from a nearby lake. Mechanical engineering students learn to operate a simple autonomous vehicle and design of experiments to gather useful data while civil engineering students participate in the analysis of the water quality from the data collected from the mechanical engineering student team. Junior and senior level students have the skills for this project.

The third project was a joint project between electrical engineering and mechanical engineering students. Students probe the campus wireless network using an autonomous robotic vehicle. The vehicle is equipped to log network access points and location to map the campus network (“wardriving”). The data will be used to investigate the possibility of using the access points for navigation. Students learn to operate and modify autonomous vehicles as well as aspects of wireless network security and range finding. Junior and senior level students can participate in this project.

The fourth projects used an ESP 6000 controller to construct a shaker table for the undergraduate civil engineering curriculum. During this project, electrical engineering students built a shaker table for the structural engineering curriculum. This project demonstrates how the ESP 6000 controller, a driver for a stepper motor, the stepper motor, and one belt driven linear axis, can be used to construct a simple shaker table for structural vibration experiments. This shaker table can also be used to show how structural periods, stiffness and damping are determined. Meanwhile, constructing this kind of shaker table can also be part of engineering design projects for the electrical engineering curriculum. This approach incorporates both electrical and structural engineering experimentation, which allowed research opportunities for undergraduate students.
The fifth project’s goal was to design an automatic violin-tuning device which, when placed on the fine tuners of a violin, will accurately tune the instrument with minimal interaction by the user. The only requirements of the user will be to place the device on each fine tuner, pluck each string, and remove it from the instrument once the tuning process is complete. In this project an electrical engineering student, a computer engineering student and a student with background knowledge in the music collaborated.

PROJECT REPORTING AND EVALUATION PROCESS
Students are given specific instructions for preparing a successful project report. The report outline includes:
- Title page
- Project Description
  - Purpose: to introduce reader to your project
  - State objectives for doing project
  - Detailed description of what you are doing/going to do. (NOT HOW)
  - Describe project requirements, restrictions, and criteria.
- Methodology
  - Describe methodology that is used to analyze and design the facility.
  - Describe “tools” (computer programs, lab tests, etc) you are/will be using.
- Schedule
- Individual Responsibilities
  - List each team member followed by responsibilities in each task.
- Constraints
  - Discuss each of the constraints that were identifying in the early phase of the project.
- References

Learning Outcomes Assessment is an important goal of our engineering faculty [8,9,10]. An outcome assessment based on students self-assessments and faculty mentor assessments are made at the end of the semester. Students are given a survey form for self-evaluation, which includes each participant’s role and how well team carried out the project. Students also are asked to evaluate other team also.

In addition, at the end of program, faculty also takes part in self-evaluation surveys and writes evaluation report as part of the course outcome assessment effort.

CONCLUSION
We have briefly reviewed and discussed challenges the engineering education community is facing today and how faculty, students, institutions, technology, and the engineering community, can contribute to the improvement of academic curricula. The paper presented some examples and the mechanisms that are used to develop engineering design projects to enhance research experience for undergraduate students. It also stressed the teaching and learning assessments and that student and faculty surveys need to be conducted to evaluate the criteria used in the development of successful projects.
REFERENCES:


