The Perpetual Challenge: Finding a Complementary Balance of Depth and Breadth in an Engineering Curriculum – Approach of the Electrical Engineering Faculty

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The faculty of the School of Engineering conducted a thorough review of its ABET-accredited undergraduate degree programs to assess and evaluate possible changes to our curricula, both School-wide and ones specific to our programs. The aim of the intensive year-long study was to maintain the principal strengths of depth, yet allow more opportunities for students to gain additional breadth in preparation for success in a wide range of professional careers during the increasingly global nature of engineering in the 21st century.

As engineering educators, we are certainly aware that finding such an appropriate balance between depth and breadth of education, especially one with complementary aspects, is an ongoing challenge. The balance point is not stagnant, but varies from time-to-time and place-to-place depending on societal needs and technological developments.

The focus of this paper is to summarize our curricular changes, with their rationale, beginning with the ones that apply to all of our School's curricula. The major changes include reinstituting a common first-year of study to aid students in selecting a major, enhancing the capstone design sequence to encourage and facilitate more multi-disciplinary projects, and designating nine semester hours of existing credits as "professional electives" that can be, for example, in engineering, business, or foreign languages. The specifics of these curricular changes as adopted and adapted for our Electrical Engineering program are highlighted in this paper.

Introduction

The main goal of the extensive review of our School’s curricula was to identify curricular changes that build on the existing strong foundation within each degree program while providing additional opportunities for our engineering and computer science students to acquire the set of knowledge and skills needed to be 21st century technological leaders. The existing strong foundation includes technical depth combined with an extensive University liberal-arts core curriculum, and the mission, vision, and program educational objectives for the School and each degree program within the School.

This review assumed that future technological leaders will need a broad technical foundation at the undergraduate level with opportunities to gain competency with both disciplinary and multi-disciplinary design, real-world problem-solving, communications, ethics and professionalism, global and multicultural perspectives, innovation and entrepreneurship, teamwork, computing, sustainability, and business practices. We identified this set of competencies from various national reports on the state of engineering education in the USA, ABET accreditation requirements, as well as conversations with the School’s external advisory committee during the 2010-2011 and 2011-2012 academic years.1-10
The Curricular Review Process

Under the leadership of the Advisory Council for the Engineering School (ACES) consisting of the Dean, Associate Dean, and Program Chairs, the faculty completed a thorough review of each of our four ABET-accredited undergraduate degree programs (CE, CS, EE, and ME) during the 2011-2012 academic year. In addition to making sure that our new curricula satisfy the latest ABET criteria, including the Student Outcomes (SOs), we followed the guidance provided by our recently developed Program Educational Objectives (PEOs), stated as follows: The School of Engineering prepares graduates who will:

1. Be successful as practicing professionals in diverse career paths or in graduate school.
2. Distinguish themselves in breadth of perspective and the ability to solve complex problems.
3. Be effective communicators and team members, with many assuming leadership roles.
4. Be active in their profession and participate in continuing education opportunities to foster personal and organizational growth.
5. Demonstrate a concern for justice, ethical behavior, and societal improvement through participation in professional and civic organizations.

We recognized that we might not be able to accomplish all of our goals for all of our students during this stage of the review. We also recognized that as a small School within a small University, we need to fully utilize the existing strong programs offered within other academic units on campus as opposed to duplicating curricula. Some examples include the programs offered by the University-wide Studies Abroad Office and Center for Entrepreneurship, the School of Business Administration, and the College of Arts and Sciences (CAS). As such, we focused on providing more curricular flexibility to allow students to take greater advantage of these existing opportunities.

Summary of the Curricular Changes

A summary of the curricular changes, along with the rationale, follows. Our timeline for implementation was to formalize these changes during fall 2012 so that they are in effect for the graduation class of 2017 (students entering fall 2013). Students who started their degree programs prior to fall 2013 will be allowed to switch to the new curricula if they do so in their entirety; however, this will not be feasible for most students.

1. **Common First Year:**

   **Action:** Move from a common first semester for incoming students to a common first year by replacing the major-specific course currently required in the spring semester of the first year with a new two-credit course, *EGR 111 Engineering Computing with Applications*. The faculty in each of the four degree programs identified ways to move, or eliminate their major-specific course from the first year.
**EGR 111 Engineering Computing with Applications** – 2 cr. hrs.
Introduction to programming in MATLAB®: numeric, Boolean, and string variables; flow control structures; vectors and matrices; and script and function files. MATLAB® will be studied in the context of multiple engineering disciplines with applications. (No prerequisites)

Note: This move will be relatively minor for our Electrical Engineering program since we have already had a similar course, EE 111 Introduction to Multimedia Processing (2 credit hours), for several years. The general principles of programming are introduced and students write MATLAB® programs to explore applications such as music synthesis, audio filtering, and image enhancement.

**Rationale:** Most of our students are traditional teenagers entering college directly from high school. While they have indicated an interest in engineering and/or computer science, most do not understand what engineers do, nor do they understand the differences between the majors. Currently, these students have to decide their major by the pre-registration period for spring semester (November of their first fall semester) after being on campus for a mere 2.5 months. Extending this decision until late February or early March of their first spring semester (pre-registration for the following fall) gives them more time to talk with faculty and upper-class students, complete EGR 110 Introduction to Engineering, attend student chapter meetings, and so on to better inform their choice of major.

The EGR 111 course will provide the students with a common background in MATLAB® computational software and more exposure to different engineering applications to help them as they decide a major. This background in MATLAB® can then be applied in their sophomore-level and higher courses, engineering practice, and graduate studies.

A common first year should also make it easier for undecided CAS students and students in other professional schools to switch to an engineering or computer science major before the start of their sophomore year, provided they take the necessary mathematics and science courses during their freshman year.

Note: Computer Science majors will not participate in the common second semester of the first year since it is viewed by the CS faculty to be more important for their students to take CS 203 Introduction to Computer Science at that time to maintain curricular flexibility in subsequent years. Students undecided between CS and an engineering major will be advised to take EGR 111, which they can use for elective credit should they decide to major in CS.

2. **Multi-disciplinary Capstone Design Experiences:**

**Action:** To encourage and facilitate multi-disciplinary design experiences, revise the current two-course design sequence at the senior level that consists of differing credit hours depending upon the program. In its place, create a uniformly consistent three-course, 6 semester hours design sequence that begins in the junior year and continues throughout the senior year. This new sequence includes the following components:
a) **Professional Practice Course:**

**Action:** Create and require a one-credit course, *EGR 300 Introduction to Capstone Project*, for all juniors during the spring semester. The course is intended to:

1. Prepare students for the senior year capstone design project,
2. Introduce techniques to assist with project management,
3. Discuss career options, including graduate school,
4. Participate in discipline-specific professional endeavors, and
5. Require students to select or propose a project, whether multi-disciplinary or discipline-specific, to be addressed during the senior year.

While faculty-led, this course will benefit from utilizing guest lecturers from the local engineering and computer science community.

**EGR 300 Introduction to Capstone Project** – 1 cr. hr.

Preparation for the senior capstone courses in the School of Engineering. Students practice project management tools and techniques and learn about the requirements for senior design projects. Project ideas proposed by clients from the University and the professional community will be discussed and assessed. Additional material is presented on career planning, professionalism and some discipline-specific topics. Students conclude the course by forming a team and preparing a preliminary project proposal.

(Prerequisite: Upper-division standing)

b) **Multi-disciplinary Senior Capstone Design Project Option:**

**Action:** Revise the current year-long capstone design sequence in the senior year to have uniformity between majors of two credits in the fall semester and three credits in the spring semester. There will be five versions of the two-course capstone sequence including a disciplinary version for each of the four degree programs, *CE/CS/EE/MEE 483/484 Capstone Project I and II*, plus a multi-disciplinary version, *EGR 483/484 Multi-disciplinary Capstone Project I and II*, available for those students who want to team with students from different majors to work on a project that requires diverse sets of expertise.

**EGR 483 Multi-disciplinary Capstone Project I** – 2 cr. hrs.

A major design experience based on the knowledge and skills acquired in earlier course work, incorporating appropriate standards and multiple realistic constraints, and requiring the expertise of two or more disciplines. Projects have some combination of the following characteristics: realism, communication, exposure, teamwork, learning, and related opportunities. Each project consists of at least two students pursuing different majors. Students are required to meet all disciplinary-specific requirements for their majors separate from the design project. (Prerequisite: EGR 300)
EGR 484 Multi-disciplinary Capstone Project II – 3 cr. hrs.
Continuation of a major design experience based on the knowledge and skills acquired in earlier course work, incorporating appropriate standards and multiple realistic constraints, and requiring the expertise of two or more disciplines. Projects have some combination of the following characteristics: realism, communication, exposure, teamwork, learning, and related opportunities. Each project consists of at least two students pursuing different majors. Students are required to meet all disciplinary-specific requirements for their majors separate from the design project. (Prerequisite: EGR 483)

Note: The EE and CS programs already share a common 6-credit hour capstone design project sequence at the senior year. It consists of common lectures by the coordinator/instructor to guide the students in the selection, preparation, and implementation of their design projects. Joint teams of EE and CS students are encouraged. The main change to our current EE/CS capstone design project sequence is that one credit of design project preparation will be moved from the fall semester of the senior year to the newly created EGR 300 Introduction to Capstone Project course in the second semester of the junior year.

EE 483 Electrical Engineering Capstone Project I – 2 cr. hrs.
A major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate standards and multiple realistic constraints. Projects have some combination of the following characteristics: realism, communication, exposure, teamwork, learning, and related opportunities. (Prerequisite: EGR 300)

EE 484 Electrical Engineering Capstone Project II – 3 cr. hrs.
Continuation of a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate standards and multiple realistic constraints. Projects have some combination of the following characteristics: realism, communication, exposure, teamwork, learning, and related opportunities. (Prerequisite: EE 483)

Rationale: Many real-world engineering and computer science projects include teams of engineers and non-engineers with different expertise and perspective working together to solve complex technical problems. In addition, ABET Criterion 3 Outcome (d) states that students should have the ability to function on multi-disciplinary teams. This change will expose all students to the components of multi-disciplinary projects. It will also enable interested students to more easily gain a multi-disciplinary experience with students within and outside the School of Engineering as a formal part of their senior capstone projects. In addition, this change will allow the School’s faculty to assess and evaluate the use of multi-disciplinary capstone projects.

3. Nine-credits of Professional Electives:

Action: Revise the CE, CS, EE, and ME curricula to include nine-credits of professional electives. The professional electives may be a combination of courses (each 3-credits or more unless approved by the program chair) offered by the University at the 200-level or higher.
and pre-approved by the student’s advisor. The professional elective credits may be used towards courses offered by the Donald P. Shiley School of Engineering, a University minor, or an approved course cluster. Professional elective credit may not be awarded for AP, IB, & CLEP examinations or ROTC credit since the intent is for the student to use this option to enhance their engineering education as undergraduates.

Faculty in the four degree programs have identified changes to the current curricula to allow for these professional electives while maintaining rigorous programs that satisfy ABET criteria and considering the future educational needs of their disciplines. This action was accomplished by modifying the technical requirements for each major while minimizing the impact to the total number of credits required for graduation. To free up credit hours for increased curricular flexibility in the Electrical Engineering program, we changed some required courses to be electives; including, automatic control systems, communications systems, and microprocessor interfacing & communications. The result is that the Electrical Engineering program increases slightly from 130 to 131 semester hours for graduation.

Electrical engineers improve people's lives by designing, testing, and supporting a wide range of products and systems; such as, medical imaging, renewable energy, robots, wireless communications, computers, and all sorts of electronic devices. As such, the EE faculty identified the following potential areas of focus for our majors through their choice of electives: communication and control systems; computers and robotics; electronics and instrumentation; and energy and power systems. We provide a list of suggested technical electives, categorized into different areas of focus, for students and faculty, particularly for advising during pre-registration week for the next semester. Duplication of courses listed in each category of electives is not an issue as it further helps them understand that a technical elective course is often useful in multiple areas of interest.

**Rationale:** In general, the three ABET-accredited undergraduate engineering degree programs (CE, EE, and ME) offered by the School of Engineering are highly prescribed and do not include the option for students to select courses outside of their major, other than the courses needed for the University’s core curriculum. [The ABET-accredited CS program differs somewhat in this regard, there are a few exceptions in the EE degree program, and there are some exceptions for mathematics and science electives.] Our curricula are way above the ABET engineering science credit requirements and expectations. The result is that students find it difficult to take elective courses outside of their majors in the School that may be helpful for their particular area of interest, e.g., biomedical, robotics, sustainability, energy, etc. In addition, students find it difficult to take advantage of other University programs that may be of interest and/or offer direct benefits to their careers, e.g., University minors, E-Scholars, study abroad, foreign languages, etc.

This change will allow students, in consultation with their advisers, some degree of curricular customization for a School of our small size. We recognize that many students will choose to continue to take technical courses in their majors that will serve them well; however, others will be able to enhance their undergraduate degrees in different ways.
An additional consequence of this change is that there will no longer be just two defined tracks within CE (civil and environmental) and EE (electrical and computer with little difference currently between them). [CS and ME do not have tracks within their programs.] Consolidating the tracks within the programs allows the students to focus their electives beyond simply two choices within each program.

**A Key Professional Electives Course:**

**BUS 364 Innovation** – 3 cr. hrs.
Examines the key elements of innovation generation and managing innovation from both individual/team and organizational perspectives. Positions successful innovation outcomes as contributing to a firm's competitive advantage. Explores innovation as a creative problem-solving capability that is applied to a wide variety of market opportunities and social/institutional challenges. (Prerequisite: Junior status. BUS 360 recommended.)

**Action:** While only the CS majors will be required to take an existing three-credit innovation course, **BUS 364 Innovation**, engineering majors can choose to use one of their professional electives for this option. At this time, requiring all of the students in the Engineering School to take this course is burdensome for the Business School. However, this change provides an opportunity for both Schools to assess and evaluate the benefits for students over the long term.

**Rationale:** The current CS curriculum does not include a designated course that covers business fundamentals. [All engineering majors take **EGR 351 Engineering Economics**.] Having basic understanding of business is important for undergraduate engineering and computer science majors given the impact of business decisions on technology projects, and vice versa. After reviewing the various options, including discussions with faculty in the Business School, the CS faculty determined that **BUS 364** is the most appropriate course since it combines some business fundamentals with the process of technological innovation.

**Other Examples of Professional Electives Courses:**

**EGR 387 Service Learning in Engineering** – 1 cr. hr.
Faculty-directed student outreach experience in community settings. Before enrolling, a student must meet with a faculty member to define goals for the project. May be repeated for up to 3 credits. (Prerequisites: Junior standing and permission of instructor.)

**EGR 430 Global Engineering** – 3 cr. hrs.
Introduction to how to design, make decisions, and communicate more effectively in a competitive global working environment for engineers and computer scientists. Students are introduced to globalization with a case study format and real industrial projects ranging from design to supply chain and logistics problems. Students are required to participate in the international field trip that complements the course and occurs during the mid-semester break.
Plan to Assess and Evaluate the New EE Curriculum

The plan to assess and evaluate the new EE curriculum that will officially begin with the incoming freshman class of Fall Semester, 2013, is expected to include several comparative components based on the results of internal and external examinations, the number of broadening academic pursuits by students, and an alumni survey.

To ensure that the technical aspects of the students’ education are not negatively affected in a significant way, we can monitor the results of our internally-created EE Comprehensive Examination administered to all EE graduating seniors during the middle of the Spring Semester. The results can be compared to those that we have for several years for the pre-2013 curriculum. In addition, a similar comparison can be undertaken on the results obtained by our EE graduating seniors who take the national Fundamentals of Engineering (F. E.) Examination.

To assess and evaluate some of the expected positive aspects of the curricular changes, the number of students who pursue a minor, Entrepreneur Scholars (E-scholars)© program, study abroad, or co-op program can be tracked. On a longer-term basis, alumni survey responses regarding career progression, etc., can be analyzed.

Summary

It is important that we have curricula that teach our undergraduate students how to learn and enable them to be confident in their abilities as they prepare for professional practice or graduate studies. The changes described in this paper that lead to greater curricular flexibility and choices for our students also means that it will be easier for them to schedule valuable complementary learning experiences into their undergraduate studies.

We had many faculty discussions over several months, particularly on the nature and extent of the professional electives in the curricula; that is, what is the optimum balance between depth and breadth of study for our students at this time in history. We eventually and collectively arrived at the curricula changes reported above to be implemented beginning with the 2013-2014 academic year.

Experience shows us that such assessments and evaluations are both challenging and perpetual in their nature and importance. This has not been the first such in-depth examination of our curricula, and it is important for our students, the engineering profession, and society that it not be the last.

Bibliography