EDUCATING ELECTRICAL AND COMPUTER ENGINEERING MAJORS FOR A GLOBAL ENVIRONMENT

William Hornfeck
Ismail Jouny
John Nestor

Lafayette College
Electrical and Computer Engineering Department

Abstract

Electrical and computer engineers are more frequently being asked to work in an environment that relies on global partnerships and demands global awareness. This shift in engineering responsibilities fueled by worldwide connectivity and outsourcing activities imposes a challenge for engineering educators in the United States: re-examine their curricula to find ways to instill a global awareness in US educated engineers. Graduates of U.S. institutions are currently required to meet the Accreditation Board's Outcomes (a) - (k) as described in ABET2000 Criterion C. These outcomes call on engineers to be knowledgeable of contemporary issues and to embrace lifelong learning, but do not address the preparation of U.S. engineers to function on the world stage and with a global perspective.

This paper addresses the educational challenges in adjusting the Bachelor of Science in Electrical and Computer Engineering (BS/ECE) curricula to respond to the engineering profession's march toward globalization. Issues ranging from communication skills, ability to function on a multicultural team, understanding of global environmental issues, international treaties, and international intellectual property laws are discussed. Ideas on infusing these concepts in the curriculum are presented beginning with introductory coursework and ending in the capstone design experience.

Key words: ECE curriculum, globalization, ABET, undergraduate engineering

I. The Necessity for Global Awareness

Engineering problems referred to as grand challenges generally have global scope. Problems such as anti-terror measures, global climate change, energy, or waste management not only have worldwide implications, but require modern engineering methods to lead problem solvers to practical solutions[3]. The importance associated with educating engineers to tackle global issues is related to their urgency. Engineers are being asked to find technological solutions to problems that not only have global proportions, but present "tipping-point" deadlines. That is, beyond a point where solutions need to be found, is a region where perhaps no satisfactory solution is possible. Examples of such problems are global warming, feeding the world's population, or storage of nuclear waste. Problems such as these present engineering challenges that beg innovations, imagination, and technical know-how. In addition, such problems tend to have social, political, economic, and even psychological aspects.

Beyond the necessity of instilling a global awareness in our engineering undergraduates, is the already critical need to establish a foundational technical competence that is needed to understand technology at the micro level. Add to this the expectation that engineering students should master communication skills, teambuilding and teamwork, and the concept of systems-level thinking[4]. With all of this "on the plate" of the engineering educator, how do we add global awareness to the mix? The body of this paper describes the curricular challenges presented to engineering students and educators, as professions and professionals must ultimately function outside local, regional or even national boundaries. The Electrical and Computer Engineering (ECE) curriculum will be used in presenting several ideas for infusing global awareness in the undergraduate engineering experience.

II. <u>Electrical and Computer Engineering Curricula</u>

The curriculum in Electrical or Computer Engineering at most colleges and universities satisfies ABET accreditation requirements[2], [7] by means of four-year programs that generally begin with a First-Year introductory design experience, followed by a thorough exposure to analytical fundamentals, core courses in the engineering major, and finishing with a capstone design experience in the last year. There are generally no requirements, either within accreditation guidelines or within institution-specific curricula, pointing to educational goals that address the worldwide nature of their engineering field, or the momentum of the trend toward globalization.

At Lafayette College[1], the program in Electrical and Computer Engineering lists the following eight goals for students:

- Educate themselves continually
- Adapt to changing job challenges
- Function in a team and provide leadership
- Apply education in solving a broad range of problems
- Excel in their chosen area of professional activity
- Be involved in professional/public/community service
- Communicate in a mature and effective manner
- Appreciate business enterprise, technology management, and social and legal issues

As a first step, the list of goals should probably recognize globalization trends by mentioning global awareness at least once. There are perhaps four of the eight goals that could be modified to reflect an emphasis on globalization:

- Adapt to changing job challenges **<u>and to internationalization</u>**
- Function in a **<u>multicultural</u>** team and provide leadership
- Apply education in solving a **<u>global</u>** range of problems
- Appreciate **<u>worldwide</u>** business enterprise, technology management, and social and legal issues.

The editing of a list of program goals is one thing; however, changing the curriculum to better reflect the globalization emphasis is quite another. In a broader sense, how does an existing engineering degree program implement features that promote a global awareness for students—including the lecture hall, outside the classroom, and as part of the overall undergraduate experience? At the same time, this must be accomplished while honoring the institution's requirements, ABET's requirements, and the students' expectations of a modern, comprehensive, and cohesive curriculum. The body of this paper will explore a number of strategies for changing ECE curricular components and student experiences so that a greater appreciation of themselves as global engineers is achieved by graduates.

III. Challenges to Embed Globalization

The effort to introduce international issues and global concepts is not solved simply by adding a previously missing course to the ECE curriculum. Similar to other requirements associated with ABET's Outcomes (a) - (k), this outcome must be achieved by means of educational elements spread across the four years of undergraduate work. A consequence of this distribution of responsibilities in educating the global engineer is the need for faculty acceptance of their role in achieving this goal. Not every faculty member will be prepared for contributing in a meaningful way, and not every faculty member will be convinced that this must be done.

A statement of goals that alludes to engineering students' appreciation and preparedness for a global profession carries with it the requirement to assess the accomplishment of the stated goals. As with other 'soft' goals, assessment is particularly difficult. What evidence should be accumulated to demonstrate that all of your graduates achieve goals associated with global awareness, especially when the educational underpinnings are distributed across the four-year experience?

Finally, can the globally-oriented outcomes be achieved without the requirement of an international experience? In particular, can this outcome be achieved without an extended experience or collaboration with a non-anglophile culture?

A. Communication Skills

We believe that an engineer with good communication skills should be able to relay technical and non-technical information verbally, in writing, and electronically (multimedia format) to native English speakers as well as to non-native English speakers[10]. To meet this challenge, traditional writing and reading courses are insufficient. At Lafayette, ECE majors are required to take two technical courses designated as writing courses. These [W] courses require a minimum of twenty pages of process writing, and one is taken in the sophomore year and the other in the senior year. This experience strengthens their ability to communicate technical material effectively. In their senior design course, students are expected to write reports, make presentations, create a project website, prepare a poster, and satisfy other requirements that enhance not only their ability to communicate verbally but also electronically using various multimedia options. In addition to these two courses, ECE students are required to take two seminar style [W] courses that require extensive writing on non-technical subjects. These seminars often include discussions among students of various backgrounds and countries of origin. Furthermore, about a quarter of our students participate in a semester-long study abroad experience in Germany[11] or Spain. Others participate in study abroad experiences of shorter duration, and these can vary from Thailand to New Zealand in terms of global reach. Such opportunities afford students firsthand experience in communicating with non-native English speakers in technical and non-technical courses. We believe that these opportunities at Lafayette and abroad help prepare our engineers to become better global communicators of technical and non-technical material and to use various forms of universally accepted communications media.

B. Multicultural Teams

Modern engineering projects tend toward large systems and diverse teams of engineers working together. Industry has sent a clear message to colleges, universities and engineering accreditation organizations that graduates having experience working in teams are the expectation. This is not surprising, especially considering the complexity of modern technology and the nature of the grand challenges that face the engineering community. By and large, schools have responded by not only developing curricula where team exercises are embedded, but spreading such courses across the curriculum.

A more challenging goal is to populate undergraduate engineering teams in a way that assures multicultural experiences for students. Obviously, those engineering departments and engineering schools with a high degree of diversity are best suited for this goal. Whatever the level of diversity in engineering classes, faculty should be sensitive to the notion that multicultural teams should be the goal when organizing project work. Students, when allowed to choose team members, are more likely to form rather homogeneous groups. Educators can control this by being more proactive in the process of not only team assignments, but in team building exercises. It is likely that, with diverse student teams, two benefits accrue: (1) more interesting approaches to problems, and (2) students graduate better prepared to work in environments where multicultural groups are more the norm.

C. Global Environmental Issues

The issue of global warming and attendant climate change, although a serious threat to humankind, is at the same time a challenge to technologists and actually brings the idea of global environmental engineering into focus[9]. This is probably the principal area where engineering majors are encouraged to think globally regarding solutions. It is also an area where unsound or poorly informed opinions tend to dominate the debate. The challenge to engineering educators is to graduate well-informed and highly analytical students who are able to separate rhetoric and political agendas from the quantitative basics of global environmental issues. Students must be encouraged to read and listen critically when hard science is at odds with popular jargon.

Lafayette College, not unlike other colleges and universities, has all-college requirements in the curriculum. For engineering students, an array of courses is offered that satisfy a first-year seminar requirement, and a sophomore-year seminar requirement involving “values and science and technology.” There are several courses within the framework of these first- and second-year seminars that deal with issues of worldwide environmental challenges. Requiring engineering students to complete a seminar specifically aimed at global environmental topics could be appropriate. Such courses are taught by engineers or scientists and concentrate on quantitative measures of our global resources and the engineering challenges associated with sustainability. Different seminars focus on differing issues, e.g., Energy Resources and Uses, Environmental Problems, Sustainability of Built Systems, Energy, Environment, and Society, and Technological Development in the Third World, to name a few. With a sufficient number of existing courses that deal with the global environment, a significant shift in the faculty's teaching responsibilities would not be burdensome.

D. International Considerations

As the practices of engineering have become a global activity, engineers have needed to become more familiar with international regulations, treaties, law, and intellectual property policy. For example, most electronic products are now designed in conformance with the European Union's Reduction of Hazardous Substances (RoHS) Directive, which sets limits on the use of six substances (Lead, Mercury, Cadmium, Hexavalent Chromium, Polybrominated Biphenals, and Polybrominated diphenyl ether) in products if they are to be sold within the EU. Students should be aware, for example, that these restrictions have had a major impact on electronic manufacturing.

E. Intellectual Property Laws

International treaties now coordinate a significant range of intellectual property law[6]. For example, international treaties sponsored by the World Intellectual Property Organization (WIPO) set requirements for copyright laws of signatory nations, leading to the U.S. Digital Millennium Copyright Act of 1998. This law is important from an engineering standpoint because it makes illegal the design of circuitry for the circumvention of copy protection, limiting what may be created and sold in the marketplace. For patents, both domestic and international patents must be obtained to protect engineers' inventions. Engineering students need to be exposed to these concerns in their courses.

IV. Curriculum Infusions

Having discussed challenges to the incorporation of global considerations in electrical and computer engineering programs, the four subsections that follow point out the ways in which the ECE degree program at Lafayette College has begun to embed global concepts in its curriculum. The overarching goal of this initiative is to bolster our students' preparedness for thinking, collaborating, working, and even living beyond national boundaries.

A. Nontraditional Coursework

Electrical and Computer Engineering majors are required to take a seminar type course in their first year that focuses on a specific contemporary issue, involves classroom discussions and multiple writing assignments, and often entails out of class experiences such as field trips. Another required seminar in the sophomore year covers principles of moral theory, and introduces students to issues of intellectual property and contemporary engineering ethics[8]. In addition, ECE students are required to take a minimum of four social science and/or humanities courses satisfying specific breadth and depth requirements. Two free electives are often taken in the social sciences or the humanities. Although not required, a significant percentage of engineering students take foreign language courses and some can enroll in an interdisciplinary course known as “technology clinic,” where a group of engineering and non-engineering students work on a real life problem having regional significance.

Lafayette College has an active Chapter of Engineers without Borders (EWB). Students have gone to South American and African locations to implement solutions to local infrastructure problems, while acquiring truly global experience. Along with the engineering experiences, a social awareness is fostered by working in an environment where the student is the “foreigner.” Another especially successful nontraditional learning opportunity is Lafayette’s Alternative Spring Break (ASB) program. In this program, engineering students eschew the usual southern beach scene to perform community service where it is especially needed.

B. Core Courses

The ECE curriculum has five technical stems that include Signals & Systems, Computer Software, Computer Hardware, Applied Physics, and Circuits & Electronics. There are three major design projects integrated with courses on Software Engineering, Solid State Electronics, and Controls. There are also two major design projects in the senior year (discussed in a later section); one involving a wireless networking protocol implemented on a Field Programmable Array, and the other is less constrained and currently involves converting solar energy into quality 60 Hz electrical energy. Students are expected to design using realistic constraints as described in ABET Criterion 3(c), and therefore are expected to take into consideration various political, health, safety, sustainability, manufacturability, economic, and ethical issues. Students are expected to approach these constraints not only from a local/domestic point of view but also from a global perspective. Issues in sustainability, environment, safety, etc., are universal by nature and warrant global consideration. Members of the Department’s Program Advisory Board often attend design reviews or presentations and help our students through their experiences in real-world (often global) engineering endeavors.

C. Elective Courses

Relative to other coursework, it is perhaps least difficult to infuse global concepts into elective courses. Within the ECE curriculum, the usual elective areas are:

- Solid-State Electronics
- Control Systems
- Communications
- Signal Processing
- Computer Architecture
- Biomedical Systems
- Power Systems

This is by no means a comprehensive list, but it serves to illustrate the point. That is, international initiatives to solve global problems can be cited in any of these courses, if only for the sake of example. In other cases, such initiatives can be used as a more significant part of the course such as design problems.

Elaborating somewhat on this point, Solid-State Electronics courses could include material on photovoltaic technologies and the global application of solar arrays for electrical power generation. A worldwide need for improved methods of search and rescue in the event of natural disasters could be a topic for courses in Control Systems or Robotics. Communications courses could address anti-terror measures and the engineering associated with international law enforcement. Satellite imaging is used for environmental monitoring and this presents especially effective examples of signal processing challenges worldwide. Computer Architecture issues associated with smart structures, weather forecasting, and earthquake prediction are global topics and ideal materials for coursework. The global issue of energy generation is quite readily incorporated into Power Systems courses. Virtually all elective areas could be used to infuse global engineering challenges into the ECE curriculum.

D. In the Senior Design Project

ECE Students at Lafayette College take a two course sequence of design projects during their senior year. During the first semester, students in small groups (2-3 students each) work together to design a wireless network interface using a Field Programmable Gate Array (FPGA) and some attached RF hardware. Lectures in this course cover the Design Process, Manufacturing of Electronic Systems (including the internationalization of manufacturing), Basics of Intellectual Property (Patents, Copyright, Trademark, and Trade Secrets), and Environmental Concerns (including the issue of overseas recycling). In the second course, students apply this knowledge in a large team project. The current project involves developing a solar energy system that produces 120V 60Hz AC power using a 2-kilowatt photovoltaic system and a LiFePO4 battery energy storage system. The same global considerations that were cited in the first semester can be amplified in the larger team-oriented design experience.

V. Conclusion

Engineers and scientists face challenges in both complexity and scope of modern problems. Many of the complexities go beyond the purely technical and involve collaboration across national and cultural boundaries[5]. Likewise, the scope of today’s major technical challenges places them in the category of “grand challenges” whose solutions have worldwide implications. Today’s Electrical and Computer Engineering graduates need preparation that respects the global nature of the profession that awaits them. The challenge of teaching the Electrical and Computer Engineering curriculum with this in mind has been outlined in this paper. In addition, some strategies presently being employed within the ECE degree program at Lafayette College have been pointed out. It is stressed here that educating engineering majors for a global environment is not accomplished by adding a previously missing course to the curriculum; it is realized across the four years of the undergraduate experience.

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