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Agents for Change in Engineering Education

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Abstract

The engineering profession as a whole is struggling to describe and define itself. This dilemma is caused by the rapid changes in technology and significant market changes taking place in many major industries that seek to employ entry-level engineers. For colleges and universities, the new latitude associated with ABET's Engineering Criteria 2000 forces an introspective view of our profession. This paper describes the technological, professional, and social agents which influence changes in the engineering profession in general and the electrical engineering field in particular. The various agents for change in academic and engineering environments are linked to the considerations in planning a four-year Electrical & Computer Engineering degree program.

I. Introduction

As technologies advance and society changes, the engineering profession must inevitably adapt[1]. Technological agents of change such as advances in computing, telecommunications, and the Internet are reshaping existing businesses and creating new industries resulting in a demand for a new mix of technical skills from engineering graduates. Technological changes in turn have created social agents of change which fundamentally influence the way we live and the products and services the public desires and demands. As a result, the engineering profession has undergone a transformation that has fundamentally reshaped the way engineers work and how we evaluate the success of engineering projects and engineering education. While these developments may seem overwhelming, they must be viewed as an opportunity to define who we are and how we will educate the next generation of Electrical, Electronics, Communications, and Computer engineers. Electrical Engineering departments must answer the questions "what should we be?" and " what should we teach?". As we search for these answers we also should seek to develop philosophies, teaching methods and curricula that will enable the next generation of professionals to match or exceed the monumental advances of previous generations of engineers. This paper explores the technological, social, and professional agents of change which must be recognized and understood in order to successfully meet these challenges. The concluding section of the paper describes the principle characteristics of the curriculum in Electrical and Computer Engineering at Lafayette College. These features reflect the changes in the professional environment which we believe our graduates will encounter in the years ahead.

II. Technological Agents of Change

"Even when the external and scientific requirements for the birth of an idea have long been there, it generally needs an external stimulus to make it actually happen; [a person] has, so to speak, to stumble right up against the thing before the right idea comes" - - Albert Einstein

Momentous change tends to become plainly obvious only after the evidence for its presence becomes overwhelming. The field of electrical and computer engineering is replete with examples of this assertion such as the microprocessor, solid state electronics, and the World Wide Web. Technological changes of this magnitude have a profound effect on engineering curricula. However, the time constant associated with changes in what and how we teach becomes smaller as information technologies advance. The effects of Gutenberg's printing press in fifteenth century were monumental; however it took a relatively long time before books were readily available to the general public. Likewise, at the turn of the twentieth century the need to provide electrical power for motors and light bulbs spurred the development of power generation and distribution systems. This technological change spawned a new field called electrical engineering resulting in the creation of Electrical Engineering departments, including the one at Lafayette College in 1915. The broader implications of universal access to electrical power were certainly not apparent to engineers or educators in those early years.

Most recently, computing, telecommunications, and the Internet have spurred dramatic technological changes. In the time span of one generation of professionals the computer has evolved from a specialized machine accessible to a few scientific professionals to the ubiquitous information appliance for office, home and school. In only a few years the Internet has given us access to an incredible amount of information. Computers and the Internet also have had a profound impact on the way we teach. The compressed time span over which such profound changes have taken place requires that educational objectives and methods not only respond to these changes but also respond very quickly. Institutions of learning at all levels are scrambling to implement active learning in "smart classrooms". While the changes associated with the Internet may seem almost instantaneous, there will be some delay before we recognize the full impact of this increasingly available technology, particularly in the area of engineering education. What are the technological agents currently taking shape that will demand the attention of electrical and computer engineering educators in the near future? A short list would include Internet II, Biological Systems, Engineering Complex Systems, Virtual Design Environments, Ubiquitous Computing, and Electrical Energy Resources.

III. Social Agents

"A great wind is blowing, and that gives you either imagination or a headache." -- Catherine the Great

Social and political changes have a significant influence on the engineering professions and, by association, engineering education. For example, at the height of the Cold War, Engineering R&D was very intimately tied to NASA and the Department of Defense initiatives. There was even the suggestion during the Vietnam War that an engineering welfare system existed for the benefit of highly educated but otherwise unemployable engineers. Spin-offs from military and space research, which spurred economic development in subsequent years, have largely dispelled that notion.

The Cold War ended with the breakup of the Soviet Union; the United States has all but restored diplomatic relations with Vietnam; NASA budgets have been dramatically reduced; and the outlook for engineering careers has been altered by these events. The commercial sector and the start-up company are now the hot career tracks. NASA and the military, which twenty-five years ago would spin off technologies for use in the commercial sector, now rely on innovations from private enterprise to supply many of their state of the art components and systems. We must strive to ensure that we continue to teach engineering in a context that emphasizes the social impact of our work.

We also must recognize that a moderately skilled or minimally educated workforce cannot provide the human resources to sustain a modern technological nation. A technologically educated and literate population is critical to ensure a stable democracy. Engineering education is a part of the education infrastructure of the nation. While we may not be satisfied with the current level of proficiency in math and science of our high school graduates, colleges must sustain undergraduate education programs which naturally follow K-12 education experiences. We also must monitor school choice initiatives and their potential impact on our programs. K-12 *and* college programs must both be high-quality to assure educational success in engineering.

IV. Agents of a Professional Nature

"Society is always taken by surprise at any new example of common sense." -- Ralph Waldo Emerson

As computing, telecommunications, and Internet technology developed they have transformed the way companies do business. It is now possible for large companies to implement global design teams that can work around the clock by electronically passing project information from the East Coast to the West Cost to the Pacific Rim and to Europe, etc. It is also now possible for engineers to practice from home or set up virtual companies by harnessing the power of the personal computer running powerful engineering design software.

As a result, the classical engineering endeavor of attacking an open-ended problem and expanding the solution space by creating something that has never been is only a subset of the skills needed by the modern engineer. The profession now requires the mastery of a number of collateral skills including computer proficiency, written, oral, and electronic communications skills, a sound knowledge of project management and business principles, and an understanding of international culture. The undergraduate engineering curriculum must change from the current model, which is a collection of content-driven, stand-alone courses, to a model that incorporates elements of these diverse skills. Joseph

Bordogna, Deputy Director of NSF, has remarked that engineers "will need both abstract and experimental learning, the ability to understand certainty and to handle ambiguity, to *formulate and solve* problems, to work independently and in teams, and to meld engineering, science and practice." Some engineering educators have touted the engineering major as becoming the liberal arts education of the upcoming millenium.

However, we must realize that that we can neither (and probably never could) teach all of the relevant technologies within a four-year curriculum nor introduce all aspects of the collateral skills (e.g. communications, business, etc.) desired by current employers. Therefore, we must stress the development of self-motivated learners who are conscious of a global society and are prepared to engineer the next generation of systems. These systems will require: the application of intelligent tools; globally competitive skill sets; the ability to cope with complexity, risk and uncertainty; strong interpersonal skills, awareness of system life cycles; and early consideration of environmental, safety, and health concerns. The teaching and learning dynamic of the classroom should be linked to student research and discovery outside the classroom.

These professional agents of change have resulted in a fundamental change in the philosophy of the Engineering Accreditation Commission of ABET [2,3]. Recognizing that technologies and society are dynamic while accreditation guidelines were prescriptive and static, the Accreditation Board adopted Engineering Criteria 2000. We may debate the effectiveness or goodness of the eight criteria which constitute ABET's EC2000, but it is difficult to find fault with the common sense mantra: an accreditation body has the responsibility to assess and evaluate not what is taught but what is learned. What is measured in critical assessments has a profound effect on human or institutional actions. ABET's Engineering Criteria 2000 will, quite aside from its merits, change the way we teach engineering, and in turn the way we practice in the profession.

V. Summary

"Out of intense complexities, intense simplicities emerge." -- Winston Churchill

It is not in the nature of academic departments to abandon curriculum structures very quickly. Likewise, it is not in the nature of industry to abandon product lines very quickly. However, both academia and industry must recognize that technological, professional, and social advances are moving more swiftly and obsolescence is a partner to these advances. We must design the engineering curricula for the next millenium with these thoughts in mind.

This year, prompted by internal and external changes of the nature described above, Lafayette College has changed its Electrical Engineering Department to an Electrical and Computer Engineering Department. This change occurred after 82 years and later than name changes at most other engineering schools, which begs the question: was it later than it should have been?. Lafayette College also changed its Bachelor of Science degree in Electrical Engineering to a Bachelor of Science degree in Electrical and Computer Engineering. This change was sooner than most other engineering schools, which begs the question: was it sooner than it should have been? While there are no correct answers to these questions we did examine various agents of change carefully before instituting these changes.

Engineering curricula at Lafayette College are responsive to social and professional agents of change. An introductory course in engineering required of all students introduces the concepts of design, team skill, project management, and communications skills. Students work in groups of five to design, manufacture, and test devices which can be put into streams to measure water pressure and temperature for environmental monitoring. They work closely with our five full time shop technicians to gain an appreciation for quality engineering drawings and communications, interpersonal, and scheduling issues. To expose students to professionalism and the economic analysis of engineering projects a course in engineering ethics also is required. Lafayette College also offers a course called the Technology Clinic where a team of six students representing engineering, the sciences, and the liberal arts work on an industry sponsored project. Lafayette College also has an active Interim Abroad session which is open to all students including engineers. This year engineering students are taking advantage of the Interim Abroad session and are studying in Germany, England, Africa, China and Greece.

In our new Electrical and Computer Engineering degree program we have also attempted to address technological, professional, and social agents of change by requiring a balanced mix of computer software, computer hardware, and traditional electrical engineering courses. We have enhanced our senior design sequence to include two full courses where students will learn both team and individual design skills. Furthermore, we have designed our new curriculum to accommodate options for a computer science minor as well as a semester study abroad experience in Belgium. A detailed description of the recently adopted ECE degree program at Lafayette College is found in these same proceedings [4].

Similar to most engineering problems, answers to engineering curricula issues are not deterministic. To respond to technological change is an imperative. The effectiveness of a change in higher education programs will eventually, if not immediately, be assessed. On the other hand, the discipline to identify meaningful change and avoid a knee jerk reaction to the latest fancy or fad also is imperative. To resist change in favor of the relative comfort of the status quo is certainly a strategy to be avoided. Those who profit from the various agents of change are those who can accurately predict the implications of technological, business, or social changes. Unfortunately, these implications are often difficult to foresee. There is truth in the adage that things may be visible yet unseen.

Bibliography

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