History in Engineering Education: A Field Report

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This is a paper about history *in* engineering education, not about the history *of* engineering education. Still, it is useful at the start to take the historian's perspective and to remember that curriculum reform has been a recurrent theme of modern engineering education ever since its inception over a century ago. Changing technology, of course, has provided much of the impetus for reform. But so, too, has the continually evolving context in which engineers operate. The realms of business and government have simply refused to stand still. Those responsible for training engineers, if they wished to put their graduates in position to do meaningful work in the world, have had to revisit the curriculum from time to time with an eye toward preparing students to function in novel working arrangements that reflect both changing economic circumstances and evolving social values.

Perhaps never has this been so true than at present. Today's engineering graduates enter a work environment far different from the one their predecessors confronted just a few years ago. They are far more likely to find themselves working in teams that take full responsibility for key projects or for solving critical problems demanding timely response. Those teams may well include not just technicians, but people informed about economics and public policy and able to communicate their ideas to diverse audiences. Indeed, the most successful contributors will likely be those individuals who reach across disciplines and blur the lines between the technical and non-technical dimensions of the task at hand. It will help, too, if they are sensitive to matters of race, ethnicity, and gender. For the teams may well consist of a broad range of individuals, and the tasks at hand are those of a diverse culture and a global society.

The need to cultivate this new breed of engineer lies beneath the force currently driving most engineering curricular reform, ABET 2000. Though we can easily lose sight of the underlying philosophy as we attempt to satisfy these new requirements, the goals expressed in ABET 2000 clearly reflect the sense that engineers must possess a broader range of skills, have experience with team projects and design, and be sensitive to more than the technical side of their endeavors. These are the ultimate objectives, and they in turn serve the more fundamental purpose of keeping our graduates effective in the rapidly changing "real world."

All of this can appear quite daunting, for faculty and students alike. Pressed to keep up with rapid changes in technology, they must also broaden their focus, cultivate entirely new skills, and consider unfamiliar territory such as economics, policy, and ethics. In this paper, we suggest an unlikely avenue of potential relief: history. More specifically, we report our experiences over the past half dozen years with team-teaching a course entitled "Electrical Engineering in American Life." An outgrowth of earlier reforms intended to enhance retention of engineering students, this course has evolved in ways we believe make it an ideal instrument for implementing the letter and the spirit of the new criteria in engineering education.

The roots of our course go back to January 1993, when engineers and historians at Georgia Tech joined together to draft a proposal to SUCCEED, a national engineering education coalition funded by the National Science Foundation.[1] They imagined a course that would integrate humanities and engineering education in order to provide a broad context for understanding the role of engineering and the engineering profession in modern society. Primarily aimed at beginning students in electrical engineering who often found themselves mired in science and mathematics courses seemingly far removed from the actual practice of engineering, this pilot project developed a set of modular units. (They were, in order of consideration: "Engineering Creativity," "The Aesthetics of Electrical Engineering," "Access to New Technologies," "The Electric Car," "Technology as Management," "Making Technical Choices: Taking the Trolley," "Engineers and the Idea of Meritocracy," "Pollution, Policy, and Power Consumption," "Negotiating Technical Standards in Electrical Engineering," and "The Rise of the Semiconductor Industry.") Each of these ten units, which remain the core of the course to this day, incorporated historical and contemporary materials on engineering design or on issues related to engineering professionalism and linked that information to economic, political, and social considerations. In this fashion, the creative work of engineers, past and present, could be analyzed both in terms of technical detail and in terms of the human context in which engineering always takes place.

Taught first in Spring 1995 and repeated by the same instructors in Winter 1996, the course received warm reviews from both student and faculty participants. Though instructors agreed they should seek to incorporate more material related specifically to the process of engineering design, they felt satisfied the course had situated engineering within its larger context. In the process, it had given students a deeper insight into the richness of engineering practice. Use of historical examples enabled students to observe with the benefit of hindsight the diverse inputs that inform engineering projects and shape the engineering profession. Other materials and student reports helped connect the lessons of the past to contemporary engineering problems. On a more practical level, the pilot project established a basic template for organizing collaborative courses involving humanists and engineers. In addition to devising a means of melding historical and engineering content, instructors dealt successfully with basic pedagogical matters such as recruiting students, dividing credit hours, and evaluating student performance. The soundness of the approach was confirmed when the historians initially involved in the project left Georgia Tech and substitutes took over and taught the course without a hitch in Winter 1997.

While generally pleased with the initial results of these early trials, the instructors still considered the course a work-in-progress. Most of the units had individual merit, but they did not mesh well. Students received the material as a bunch of disconnected ideas rather than pursuing a set of coherent themes around which they could build a deeper understanding of engineering. Design still needed more emphasis. The group projects were conceived initially as building upon particular units, but not all units lent themselves to this sort of treatment. This approach, moreover, worked against the fundamental goal of breaking down artificial barriers and approaching engineering in a more holistic fashion. A paper on the electric car should incorporate issues such as professionalism, standards, and aesthetics, not exclude them because they belonged to another unit.

In addition to considering matters of content and organization, we needed to confront one other issue. Contrary to original intent, the course was not attracting overwhelming numbers of first-year electrical engineering students. Instead, it drew a cross-section of students of all ranks from a variety of majors, including many from outside of engineering entirely. What we had was a diverse collection of students interested in gaining some perspective on the nature of engineering and its relations to society. For engineering students, this typically meant stepping back from specialized techniques of problem-solving to see engineering in its full context. For many others, it involved gaining some appreciation for the inherent pleasures of technical design and comprehending how technical factors often constrain social choices. Our most important objective, we realized, was to meld these two cohorts. If we could do that successfully, we would accomplish our fundamental goal of fostering a deeper appreciation of the rich complexities of engineering practice.

During subsequent iterations of the course, which we have taught during one term each of the past four academic years, we have refashioned the material and assignments with this objective in mind. First, we repackaged the units and organized them into three groups. Students now spend the first third of the class considering a set of fundamentals: 1) Personality, Design, and Aesthetics; 2) Professionalism and Meritocracy; and 3) Engineering Standards and Access to New Technologies. This approach enables us to get students thinking about core issues that run through virtually all of the remaining units and should be of primary concern in their group projects. Coincidentally, it also gathers most of the examples taken from communications technologies (telegraphs, telephones, radio, television, and fiber optics) into one section of the course. We can thus present a set of basic technical concepts early on in the term.

From there we move to a collection of units organized around the idea of choice and regulation of technologies. Here, our examples come primarily from the realm of electric power, so again we can deal with basic technical concepts in a clear, coherent manner. We also can introduce students to basic ideas from engineering economy such as cost-benefit analysis, public goods, and depreciation of assets. We begin with a unit on the AC/DC controversy, which forms a nice bridge from our earlier material on standards and provides a good vehicle for presenting the technical basics of electrical machines and power transmission. Next we turn to a lengthy unit on electric utilities during the twentieth century. This incorporates ideas about engineering efficiency and economy and deals extensively with government regulation. We conclude with two case studies, the electric car and electric trolleys. Here we really home in on the idea of choice in technologies, both in design and through the economic and political processes that establish incentives. These units also provide students with models of how they might organize their own projects, which typically focus upon elements of choice in contemporary engineering problems.

A final pair of units moves us into the realm of electronic computers, optics, and the digital era. One unit provides a historical overview of the emergence of computing and solid state devices, while the other focuses upon the issue of electronic surveillance. Our goal here is to view the current dominant technologies of electrical engineering in light of the concepts and examples presented earlier in the course. By highlighting analogies to previous experience, we hope at once to demystify current technologies while also fostering a deeper appreciation of the complex social, economic, and ethical considerations involved with those technologies.

Among other benefits, the new arrangement of units has helped us address issues of design and engineering practice more fully than in previous versions of the course. Students now get brief tutorials on the fundamental engineering principles underlying the basic technologies considered in each group of units. Equipped with an understanding of these fundamentals, they can better assess how individuals such as Thomas Edison and teams of technicians went about the work of design and refinement. To aid them in this effort, we have steadily incorporated readings from sources such as *The American Heritage Magazine of Invention and Technology*, which offer detailed but readable accounts of the inventive activities of principal figures in the history of electrical engineering.

In addition to restructuring the material considered in class, we have altered the group project assignment in subtle but significant ways. Instead of tying the projects to a particular unit, we have encouraged students to seek out topics on their own. Ideally, they should focus upon a current technology or technological project involving electrical engineering. (Recent examples include everything from medical imaging to electronic encryption to the stun gun.) The project, which involves both written work and an oral presentation, should examine the chosen technology or project in all its dimensions—technical, economic, social, political, and ethical. Students apply principles studied in class, often in historical context, to contemporary affairs.

To the extent possible, we insist each group contain a mix of students from engineering and other majors. This helps bring different perspectives to bear. Beyond this, it puts group members in precisely the sorts of settings that characterize much engineering today. Engineers must learn to communicate and to work cooperatively with non-engineers. They cannot simply retreat to the comfort of the “technical aspects” of the matter at hand, but must meld the technical with the social, the economic, the political, and the ethical. In this sense, the group project becomes a practicum in modern engineering. Even those students not intending to pursue careers in engineering gain first-hand experience in the ways an informed citizenry influences technology and engineering design.

Without necessarily intending it, with these changes we aligned our course almost perfectly with the objectives embodied in the ABET 2000 criteria. The course material and assignments combine an appreciation for design with an emphasis upon the social, economic, and ethical dimensions of engineering. Unlike some other approaches, our course considers ethics not just as they pertain to professional conduct and workplace relations, but as something that informs choices made throughout the process of engineering design and development. Students come to appreciate why the most successful and influential engineers are generally those who comprehend the full breadth of their endeavors and perceive how their technical work interacts with other elements of society and culture. They learn about the importance of compromise and communication, and through their projects they have an opportunity to hone their own skills in these areas.

Our experiences over the past half-decade or so have thus amply justified our initial hope that by integrating history and engineering we could enhance undergraduate education in engineering. The course has routinely filled to capacity and has received very positive evaluations. A committee of faculty from across the Institute has embraced it as one of a handful of courses satisfying the ethics requirement in electrical engineering. Many of the ideas developed for our course have recently been incorporated into a required senior course in electrical engineering entitled “Project Engineering and Professional Practice.” Most important of all, we have established a model that might not only diffuse to other departments of electrical engineering, but which might also be adapted to other disciplines of engineering.

References

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