It is Broke and it Needs Fixin'

Moshe Kam, 4 May 2010

The desire to reform the Engineering curriculum is a recurring theme in public speeches and essays, which are produced with some regularity by engineering educators and academic administrators. It is such a popular topic, that one wonders what will all the after-dinner speakers do if we actually did something about reform rather than continue to muse idly about it. One of their most favorite speech subjects – rousing but hardly ever meaningful – will be gone.

Yet in spite of its high rate of recurrence, talk of curricular reform would not go away. One of the reasons for its continued popularity is that we have not engaged seriously in such reform endeavor in a long time. In fact, the last time we have undergone a major overhaul of the US engineering curriculum was in the 1950s (e.g., Wildes and Lindgren (1985)). Much of what happened then was a reaction to the purported lack of preparation of engineering professionals for World War II, as well as concerns about ongoing technological competition with the USSR. Since then, there was another major large scale effort, guided by the National Science Foundation in the 1990s, aiming to reinvent the engineering curriculum and address concerns about deficiencies in engineering graduates of the time. Though this effort enriched the library of courses and projects available at various institutes (see, for example, Gateway (1999)) it fell short of making fundamental changes in the way engineering curricula are organized nationwide, let alone modify their organizing principles.

In this short note, I would like to provide, in necessarily abbreviated form, the key reasons why the time for major restructuring of the engineering curriculum has come again. Since this is an article for ECEDHA, I will focus on the ECE curriculum, but similar arguments can be made about other engineering disciplines. Necessarily, the claims I make here are broad – there are certainly some programs and some institutions that do not fall under these generalizations.

I make four basic claims:

(1) Our curricula are slow to recognize important developments in engineering practice.

(2) Our curricula are slow to recognize changes in the profession.

(3) Our curricula fail to be attractive.

(4) Our programs are alarmingly similar.

Claim 1: Our curricula are slow to recognize important developments in engineering practice

Rather than provide a long list of important developments ignored by our curricula, I will focus on the most important one, namely the role of modern computing in the engineering enterprise. There is no lack of recognition that computing tools such as algorithmic libraries and data organization tools have changed the way engineering is practiced. However there is still wide under-appreciation in academia of the fundamental nature of this change, and of the need to pay attention – inside the engineering classroom and lab – to the methodology and science that are behind computing tools.

The reality is that practicing engineers in all disciplines are spending an increasing fraction of their working career on tasks in computing. They work with computer applications and networks – which they increasingly include in their designs. They write code for testing and feasibility studies, but also for production and implementation (much of the code that runs on commercial products was written by engineers, not by computer science majors). It is often not an exaggeration to consider many of our engineering graduates as computing professionals who focus on a subset of applications (in, say, microwave circuit design or heat distribution in buildings). These are not engineers who also do computing. These are computing professionals with an engineering application. Not being students of Computer Science, however, these engineers often received very little systematic schooling on the basic aspects of computing, and are often quite ignorant about areas that affect their work directly – such as effective programming, computer security, data structures, and algorithm design and analysis.

Had we designed our engineering curricula today from first principles, being informed of what engineers actually do, we would certainly have included computing as a heavy fundamental ingredient in every engineering curriculum. Given that we are using a curriculum that evolved from the 1950s – when computing tools of the current flavor had very minimal role in engineering practice – we tend to ignore the depth of the subject and pretend that computing is an add-on, an easy to study technical tool that comes into the scene only after the 'real' subjects were covered. In reality, computing is a central, even critical subject. In some areas (such as Control Systems and Signal Processing) it is in my judgment that computing is much more important than many of the comfortable but antiquated methods that we insist our students must digest.

Claim 2: Our curricula are slow to recognize changes in the profession

The engineering workplace has changed significantly in the last twenty years. Some of these changes are geographical, some relate to relations with other disciplines, some stem from shifts in the balance between products and services, and other relate to the duration and nature of employment at engineering enterprises.

Each one of these trends deserves a separate and thorough treatment, but in this note I will examine only the first, the (lack of) impact of changes in the geographical distribution of engineering labor on the engineering curriculum. The shifts in the geographical distribution of engineering labor from the early 1990s to the present time are recognized widely in the professional community, as well as in the popular press (see, for example, the entertaining if fundamentally shallow Friedman (2005)). Yet, most engineering program show no reflection of these shifts in the way students are educated or prepared for practice. As one example of many, let us look at *study abroad* programs. Consider the system-wide *Education Abroad Program* of the University of California (EAP, 2010). The program offers programs in France[1] and Hungary[2] for graduate students in almost every conceivable major… except for engineering majors. New York University (NYU 2010) also offers a study abroad program – in 10 venues around the world – and in each one of those venues students in 10-20 majors are eligible to participate. None of these majors is in engineering (one venue allows Computer Science students). A search on the Study Abroad page of Purdue University (Purdue 2010) provides a better picture, since Purdue does offer study abroad to students of Engineering. Still the search returns nine (9) Study Abroad programs for students in the College of Liberal Arts, but only three (3) for students in the College of Engineering.

[1] "Natural and physical sciences, humanities (antiquity, classics, French literature: Middle Ages and 18th and 19th century), French and foreign literature, geography (contemporary problems in Europe, Asia, Africa, and the environment), and the social sciences."

[2] "Academic foci include economics, environmental studies, European studies, history, international relations, legal studies, medieval studies, and political science, as well as interdisciplinary programs in gender and culture, human rights, nationalism studies, social theory, and Southeast European studies"

Not surprisingly, the participation of engineering students in study abroad program (during a time characterized by strong globalization of the engineering profession) is lagging behind the participation of students in the arts and sciences. A little thought on what an engineering student in a typical regimented and highly structured engineering curriculum would have to endure if s/he left for a semester abroad can help. It would demonstrate how the current rigid curriculum in engineering is not ready to even start addressing 'global' issues.

Claim 3: Our curricula fail to attract

Enrollment trends of US undergraduate students in engineering are well documented (e.g., Gibbons (2008)). They show growth of approximately 20% overall of from 1999 to 2008, in line with the general growth of the undergraduate population in the United States during the same period. Several curricula – most notably ECE – have however seen *decreased* undergraduate enrollment over this period (from 91,582 ECE full time undergraduate students in 1999 to 73,343 in 2008, a decline of 20%). Moreover, the percentage of B.Sc. degrees in Engineering awarded to women has hovered about 20% since 1999, with no meaningful gains. There was no progress during the same period in attracting under-represented minorities to the US Engineering College[3]. This lack of progress comes in the face of numerous programs and attempts focused on women and under-represented minorities.

No enterprise whose main expansion plans have failed in this manner would continue "business as usual." Yet – focusing on ECE for the moment – we have by and large done exactly that. Most of us maintained the structure of our old curricula, and confined 'reform' to small and cautious modifications on the margins. It is unlikely that such 'reforms' would bring long term respite – especially when some of the traditional areas taught in ECE Departments are now adopted energetically by other disciplines such as Mechanical and Biomedical Engineering.

Expanding the discussion from ECE to the Engineering College in general, it is unlikely that we will stand a chance to attract to Engineering the brightest and the most enterprising without new exciting curricula. These must be as academically challenging as well as tied to social impact; interesting and intriguing; highly individualized; and characterized by both personal choice by the student and personal attention to the student by the faculty. Engineering curricula that are epitomized by 200-student Calculus I first-year classes, and when engineering is finally introduced to students in their third year solely through mathematical models and simulations are unlikely to get the job done.

Claim 4: Our curricula are alarmingly similar

To illustrate the similarity claim, I conducted several times an experiment which compared the curricula of ten (10) different Electrical Engineering programs selected from among programs with "good" reputation. The reader is invited to repeat the experiment with his/her favorite programs. The programs were selected from among schools in different parts of the country, different environments (rural/urban), and different target audiences. In one of my experiments, one of these programs was known to have most of its graduates continue to professional schools in Law and Medicine. Two have a very high fraction of graduates who proceed directly to graduate school. Several are known to have most of their graduates secure a job in industry. I tried to "mix and match."

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[3] In this context it is appropriate to mention that in 2010 nearly half of the students in Law Schools and Medical Schools in the US are women (the numbers were less than 20% in 1970).

Then I looked at the curricula of these programs, and tried to discover the extent to which one can associate characteristics of the curriculum with the known 'nature' of the program. Would the titles of the courses in the 'industry-bound' program be different from the titles in the 'graduate school bound' program? Would a program in a region known for massive production of hydroelectricity have lab experiments reflecting this characteristic (and different from the experiments in a program where electricity is strongly associated with coal)? By and large, the answers to these specific questions (and many other similar questions) were always negative. In fact, the curricula were nearly identical, quite standard, with the same titles, same labs, same tracks (and the same mission and vision statements as well…) Again, if you doubt what I claim here – perform your own experiment; I found great uniformity throughout.

We can argue at length why we have achieved such homogeny. Perhaps it represents "the best of all worlds," the ideal curriculum into which we have collectively and happily converged (I doubt that). Perhaps it is a result of the accreditation regime under which US programs are obligated to operate (I tend to believe that). In any case, the sameness of our programs is an alarming sign. Such sameness is not the hallmark of a vibrant field where different approaches and new experiments take place all the time. Rather, it is a sign of stagnation.

While not able to outline here the complete case for curricular reform, I hope I provided enough evidence that we may be facing a real problem. As the significance of strong high-quality engineering workforce increases, the engineering education enterprise in the US appears to be rather idle. Our market share did not grow in many years, and we are not making inroads into new target populations. Our curricula are standard and most lack excitement. We appear slow to incorporate changes in the professional and work environment, and many of our programs are rather bland and overly uniform.

I think we owe ourselves a good kick in the pants.

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