CHANGING TIMES AND PARADIGMS

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Colleagues at a large public university I recently visited are doing some excellent research on first-year engineering students—what attracted them to engineering, how they view engineering as a curriculum and career, how they feel about their first-year courses (it isn't pretty!), their confidence levels before and after those courses, and why the ones who drop out do so. I sat in on one of their weekly meetings, and one of them—an education professor—expressed bewilderment and dismay that with so much known about what makes teaching effective, engineering programs persist in using the same old ineffective methods. She wondered if there was any point in continuing research directed at improving a system that is this intransigent.

I've heard the same thing from others engaged in educational reform—it's definitely an uphill battle, and it's easy to get discouraged when your focus is restricted to a single campus. Taking a broader view, though, things don't look that bad. Engineering education went through a major sea change once before, and the signs are that it is doing so again. I tried to offer some words of encouragement at the meeting and thought I'd repeat them here for readers engaged in similar lonely battles.

First, a little history. From the late 19th century through the 1950s, engineering education was a combination of lecture and hands-on instruction closely tied to industrial practice, and the faculty consisted primarily of experienced engineers and consultants to industry. In the mid-1950s, America seemed to be falling behind Russia in the space program and calls were issued for an increased curricular emphasis on the mathematical and scientific foundations of engineering. In the years that followed, external funding opportunities for basic research skyrocketed, faculty started to be hired primarily for their potential as researchers, and most laboratory and field experiences disappeared from the engineering curriculum to be replaced by lectures on applied math and science. The paradigm shift from practice to science was essentially complete in most engineering schools by the early 1970s.

In the 1990s, a rising chorus of complaints from industry about the inadequate preparation of new engineering graduates for industrial jobs started to be acknowledged inside the academy. In addition, evidence began to emerge from both cognitive science and empirical classroom research that the prevailing instructional model ("I show derivations of formulas in class, then you plug into the formulas and do similar derivations in assignments and on tests") was ineffective for promoting learning and the acquisition of critical thinking and problem-solving skills. Teaching workshops began to be heavily subscribed at engineering conferences and on campuses around the country, and NSF-funded programs and individual campus initiatives—such as Project LE/ARN at Iowa State—began to involve hundreds of previously traditional engineering faculty in education reform. Another major step was ABET's adoption of new accreditation criteria that required engineering programs to address both technical and social outcomes in their curricula, all but forcing them to adopt nontraditional methods in their classroom instruction. (You clearly can't equip students with the ability to work efficiently in multidisciplinary design teams or give effective technical presentations by giving them a few lectures on those topics.)

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These developments have given rise to a national movement toward a more active, cooperative, problem-based instructional model for engineering education. While the new approach cannot yet be said to have become dominant and some universities seem determined to resist it (and ABET) to the bitter end, evidence of its eventual ascendancy is mounting. In the remainder of this article I want to share some of the evidence I've recently seen.

I've given teaching workshops on campuses around the country since the late 1980s in which I discuss active and cooperative learning, and I usually ask the participants to raise their hands if they use those methods in their classes. Ten years ago, two or three hands would typically be raised. Now, 25–50% of the participants indicate that they use active learning and lower but still significant percentages use cooperative learning. This trend was also indicated by a 1997 survey of over 500 engineering faculty at eight schools who were shown to be representative of their faculties in most important respects. Many of the respondents reported regularly using active learning, team-based assignments, and other student-centered methods.[1]

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I frequently see impressive instructional innovations on campuses I visit and learn about others in the literature and at conferences, the most dramatic of which involve project-based and problem-based learning. Extensive research has shown that students learn best when they perceive a clear need to know the material being taught. Project/problem-based learning (PBL) uses this principle by introducing course material on a just-in-time basis in the context of realistic engineering problems and projects. This instructional strategy has been used for many years at the Colorado School of Mines and McMaster University, and numerous published articles report its successful adoption at other universities around the world. An outstanding example is ChemEngine (*www.chemengine.net*), a student-owned and operated consulting firm at Virginia Commonwealth University that tackles engineering problems for industrial clients and has saved those clients millions of dollars in its few years of existence.

PBL has become the foundation of some course sequences and clusters and departmental curricula. Texas A&M and several other schools in the Foundation Coalition have transformed their freshman engineering programs, integrating the basic science and math courses traditionally taught in isolation and emphasizing their interrelationships and applications to engineering problems. In the spiral curriculum in chemical engineering at Worcester Polytechnic Institute, traditional content is taught on a just-in-time basis in a sequence of project-based courses. In each year of the curricula of several engineering departments at the University of Queensland in Australia, one or two project courses are taught that anticipate and integrate the material taught in parallel traditional courses. Several entire universities have taken one form or another of PBL as the basis of *all* of their curricula, including the University of Aalborg in Denmark and Olin University in Massachusetts.

This is not to say that engineering education reform is a done deal. If you look into a random class at a random engineering school today, you are still likely to see a professor deriving equations on a board, or (worse) flashing PowerPoint slides of derivations to half-asleep students in a half-empty room, and administrators abound who still argue that this approach somehow promotes learning (research evidence to the contrary notwithstanding). It may indeed turn out that ten years from now the old teacher-centered approach will *still* dominate engineering education. I doubt it, though, considering **(a)** the active, cooperative, and problem-based courses and curricula springing up at universities everywhere, the concurrent growth of engineering-based programs that equip faculty and graduate students to implement those instructional strategies, and the new ABET criteria that (if seriously enforced) will compel their use, **(b)** the power of instructional technology to provide stimulating interactive lessons and the growing occurrence and effectiveness of its use at both traditional and on-line institutions, and **(c)** an awareness among high school graduates that alternative methods exist and an increasing unwillingness on their part to put up with the old approach (a point that clearly came out in the study mentioned at the beginning of this column). Again, these things are never certain, but with all that going on it's clear to me that the new paradigm is the horse to bet on.

References

1. <http://www.ncsu.edu/felder-public/Papers/Survey_Teaching-Practices.pdf> ❐

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