How Will the New Engineering Education Criteria Affect Physics?

Two years ago, when the influential Accreditation Board for Engineering and Technology unveiled its new set of criteria for engineering education, it wasn't exactly front-page news. But in the physics community, word soon began to spread: ABET was no longer explicitly requiring engineering students to take a year of calculus-based physics. Physicists prone to worry even speculated that engineering departments might drop, or at least substantially reduce, the physics component of their curriculum.

Such "service" courses for nonmajors are, of course, the bread and butter of many physics departments. Each year in the US, about 95 000 engineering majors enroll in introductory physics, and many of them, especially those in physics-intensive disciplines like electrical and mechanical engineering, go on to take several more physics courses. Without those students, a lot of departments would have trouble justifying their existence, especially in light of recent drops in physics degree production at all levels.

So what do the new criteria mean for physics departments? First, a little background. ABET, based in Baltimore, Maryland, is the sole agency responsible for evaluating and accrediting engineering degree-granting programs in the US. Although accreditation is voluntary, most state licensing boards require engineers to graduate from an ABET-approved program, and over 95% of US engineering programs do carry the board's seal of approval. ABET therefore wields considerable authority in setting the engineering education agenda.

Physics departments may soon have to rethink the "service" courses they teach to engineering majors.

ABET began accrediting schools in 1936, and over the next six decades, the criteria it used to make its evaluations expanded in both degree and specificity, explains Dan Hodge, the agency's accreditation director, "until finally we recognized that the criteria were tending to stifle innovation." And so, "starting with a clean sheet of paper," Hodge says, ABET rewrote its criteria. Under the new system,"programs first need to define objectives and then establish processes to measure how effective they are in reaching those objectives." Schools are then evaluated by teams of outside reviewers, who visit a campus, talk with students and faculty, look at course syllabi and textbooks and check out laboratory facilities and equipment.

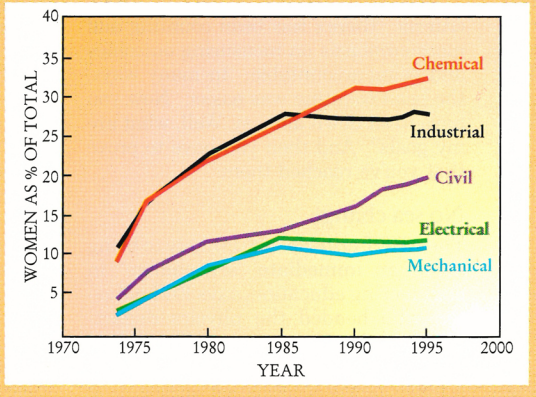
This academic year marks the first in which schools are being reviewed under the new criteria, known as EC2000 (and listed on the ABET Web site at http://www.abet.org). Through the year 2000, schools have the option of being evaluated under the old system. After that, however, any school seeking ABET accreditation will need to conform to the new criteria. (Departments are typically evaluated every six years, so an institution could postpone adopting the new criteria until 2006.)

Proficiency in physics

So is it true that the new criteria no longer require engineering students to take physics? Yes and no. Like the old criteria, the new system still requires engineering majors to take "one

Physics Anxiety in Engineering

Why do so few women major in electrical engineering? Or mechanical engineering? Or nuclear engineering? When it comes to representation of women, it turns out these fields do about as poorly as physics, awarding between 12% and 16% of their undergraduate degrees to women. Conversely, the representation of women in industrial, environmental and chemical engineering is nearly three times as great. (The graph at right, from the Engineering Workforce Commission, shows the distribution by field of US engineering degrees awarded to women from 1974 to 1995.)



A quick comparison of the course requirements in various engineering fields reveals another interesting difference: The higher the physics content, the lower the proportion of women. Could it be that—gulp—physics is responsible for the underrepresentation of women in these fields?

That's what the staff at Cornell University's Women's Programs in Engineering suspected. With support from the Alfred P. Sloan Foundation, they conducted a survey of 500 women engineering majors at eight universities, to find out why they had chosen their particular fields. What they found was that many of the women who had chosen chemical, environmental or industrial engineering did so because of "negative experiences in physics" at either the high school or college level. Those in physics-based engineering majors, by comparison, were twice as likely to report having had positive experiences in physics.

Survey author Julie Anne Schuck believes that physicists don't intend to turn away women students. "Most physicists I've interacted with really want their students to learn," she says. "But they may be constrained by class size or other administrative problems." To help overcome students' physics anxiety, the Cornell office published a pair of booklets, one for instructors and the other for students. Not surprisingly, many of the booklets' suggestions—such as using cooperative learning and hands-on activities—echo those made in earlier reports on improving the classroom climate for physics majors.

Highlights of the survey report, as well as the instructor's and student's guides, can be downloaded from Cornell's Physics Anxiety Web site, at http://www.engr.cornell.edu/ss/womens_pgms/phys_anx. html.

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year of a combination of college-level mathematics and basic sciences . . . appropriate to the discipline." But the old specification of a year of calculus-based physics (and a year of chemistry) is gone. Instead, depending on the engineering field, students may need to demonstrate "proficiency in" or "ability to apply knowledge of" physics. As Hodge puts it, "Now the question is, Can a program demonstrate that students really understand the material, regardless of whether or not they passed the course?"

It's left to the individual program to say what courses will meet the criteria, Hodge says. A bioengineering department, for example, may want to emphasize biology over physics. And a large research institution may focus on preparing students to go to graduate school, while a small regional school may be primarily interested in training students to work in local industry.

It's quite conceivable that some schools will make no changes in their curriculum. "I doubt that many engineering programs will reduce their physics requirements," Hodge adds. "Most realize that the foundations of engineering are physics and math."

Even so, physics departments would do well to consider the new criteria, says Ruth Howes, a physicist at Ball State University. At a recent American Association of Physics Teachers conference on undergraduate physics education that she cochaired, the ABET criteria were one of several hot topics of discussion. "The upshot is that if the engineering faculty is not happy with the way in which the physics department is teaching, they can threaten to teach the physics themselves," Howes says. Departments that have taken the time to produce a high-quality freshman physics course should do fine, she says. "On the other hand, if the person teaching the intro course is lecturing off yellowing notes written in the fifties, that department's probably in big trouble."

Robert Ehrlich, a physics professor at George Mason University, agrees. Two years ago, after hearing rumors about ABET's new requirements, Ehrlich sent out a questionnaire to the deans of all 200 US engineering schools, to find out how they liked the physics courses being taught to their students. On a scale of –5 to +5 (+5 being "very satisfied"), nearly 50% of the 84 respondents gave physics a high rating (+3 or above). And, not surprisingly, those who were least satisfied were the most likely to want to "have physics taught within the engineering school." Among the deans who gave physics a negative score, three-quarters expressed such a desire, compared to only 17% of those who rated physics highly.

Less bean counting

ABET's new criteria "are giving a lot of folks in education a headache," says Barry Farbrother, head of the electrical and computer engineering department at Rose-Hulman Institute of Technology. Many schools had criticized the old criteria as "too prescriptive and stifling," he notes. "Now some institutions are saying, Who asked for all this?"

Farbrother himself likes the "leeway to maneuver" that the new criteria afford. As it happens, his department streamlined its core curriculum several years ago, having discovered that, much like the old ABET criteria, the required course list was "bursting at the seams." The department now requires half the amount of physics it once did. At the same time, there's more room for electives, which students may choose to fill by taking advanced courses in physics or applied optics.

At Rose-Hulman, "engineering is the kingpin," Farbrother says, accounting for nine out of ten degrees awarded. "The other departments tend to view themselves in a service role."

That's true, says Arthur Western, Farbrother's counterpart in physics. The revised engineering curriculum "has got us thinking long and hard about what kind of upper-level courses we can offer so that the engineering students will take them as electives." For example, the physics faculty is now developing a new concentration that centers around semiconductor materials and devices.

Western notes that in the new ABET criteria, "there's less bean counting and more emphasis on measuring outcomes and being accountable. In many ways, the bean counting was easier. Now you have to sit down and say, Well, what are my goals? And then you have to prove that you've reached them."

No sea change

The ABET criteria are unlikely to bring about an immediate "sea change" in engineering education, says Ed LeMaster, who headed the physics department at the University of Texas Pan American before becoming chair of the school's newly established engineering program in 1992. "For one thing, the engineering faculty have come up through the old system," he says. Having worked both sides of the physics–engineering fence, LeMaster observes that "physics departments don't want to talk to the engineers unless they feel threatened." But a more cooperative attitude would be to everybody's advantage, he says. "Physics departments might even find that there are more courses they can offer the engineering students." At his school, the engineers have been discussing asking the physics department to offer electives on optics and acoustics.

Bernard Gallois, dean of engineering at Stevens Institute of Technology, sees the new criteria as "a good opportunity to revise how physical science is taught to engineers. We [at Stevens] have stepped ahead of the plate in that regard." Last year, the engineering faculty decided to overhaul its curriculum. Among the first steps was to "ask the physics department to work with us," Gallois recalls. "Their traditional approach to teaching physics was antiquated and didn't relate to modern engineering practice."

At first, many on the physics faculty felt threatened by the engineers' plans, says Stevens physicist Kurt Becker. "People didn't like the idea of having to do things differently." But within a few months, Becker says, "we saw that rather than a threat, it could be an enormous opportunity for us to do something innovative."

Stevens' new engineering curriculum, introduced this past fall, halves the number of credit hours for the traditional freshman-level mechanics and electricity and magnetism, and adds a sophomore-year "modern physics" course. The new lab-based course starts with waves and oscillation, explored from various angles—classical, electrical, acoustical, optical—and then moves in the second semester to quantum effects, with an emphasis on engineering applications. The course covers "the physics of the 20th century that spawned all the technologies we're so familiar with now," says Gallois.

Most physics professors are still unfamiliar with the new ABET criteria, notes Ball State's Howes. "It's going to be a few years before this thing really hits." But many departments already realize that a business-as-usual approach won't work. "The students we see entering college are changing, the workplace for physicists is changing and the discipline itself is changing," Howes says. "There are a number of ways physics departments can respond, not only in their programs but also in the way they teach, that will make physics more attractive to a wider variety of students."

It's not just physics that will change, says Becker. In discussions with colleagues, he says, there's been general agreement that universities will soon have to decide whether they will stress the fundamental aspects of science or the applications-motivated side of science. "To put it in simple terms, Are you going to be an MIT or a Harvard?" Becker says. "No single university can be everything to everybody." **JEAN KUMAGAI**