A major study questions whether engineering undergraduates are being prepared for 21st-century careers.

BY MARY LORD
Robert Frost’s poem “The Road Not Taken” probably doesn’t top the required reading list at many engineering schools—but perhaps it should. Recent findings from a sweeping longitudinal examination of the undergraduate engineering experience suggest that the familiar routes may not always serve today’s students or society.

The Academic Pathways Study (APS), a five-year, multi-campus research initiative involving more than 5,000 students and dozens of scholars nationwide, challenges many assumptions about instruction and learning. The resulting data, some of the richest on engineering education ever amassed, reveal both reassuring strengths and surprising deficits. While students develop strong technical proficiency, professional skills, and engineering identities, many grow less satisfied and engaged with school as they progress. Men and women differ in some significant areas, from confidence in math skills to how they approach design problems. And undergraduates find it difficult to migrate to engineering from other majors.

The research also raises questions about whether programs are adequately preparing students to tackle 21st-century global challenges—or even to pursue the profession. “There’s a pretty big gap between what engineers do in practice and what we think we’re preparing them for,” observes APS investigator Karl Smith, civil engineering professor at the University of Minnesota and cooperative learning professor at Purdue University’s School of Engineering Education. Despite four years of engineering-related courses and activities, for instance, some undergraduates are uncertain about what engineers do. A sizable minority of advanced students in any discipline lacked a basic understanding of such core concepts as the difference between heat and temperature. When asked, for example, how a single lightning strike could kill 56 elk in a Colorado herd, only 2 of 10 fourth-year electrical engineering students displayed a correct grasp of voltage.

The Real World

LAUNCHED IN 2003 with a National Science Foundation grant to the Center for the Advancement of Engineering Education (CAE EE) led by the University of Washington, in partnership with Stanford and Howard universities and the Colorado School of Mines, the Pathways study was designed to “bring in the student voice as a way of thinking about what engineering programs should look like,” explains co-principal investigator Sheri Sheppard, professor of mechanical engineering at Stanford. Researchers followed 40 engineering students at each of four diverse institutions from their entry in the fall of 2003 through senior year in the spring of 2007. With each student, they conducted seven in-depth surveys and yearly interviews, tracked academic performance, and administered batteries of tests and questionnaires. The 160 recruits also were compared with hundreds of peers on the same campuses as well as against a broad national sample. The result is one of the clearest windows to date on the state of undergraduate engineering education.

A surprising 40 percent of seniors didn’t see school experiences as contributing significantly to their knowledge of engineering practice. Of the 10 undergraduates interviewed in depth by Holly Matusovich, an assistant professor in Virginia Tech’s department of engineering education, three showed a similar lack of understanding. Matusovich, who worked on part of the APS as a graduate research assistant, says faculty “need to be more explicit about what we’re teaching in class and how do you use it.” With her own introductory design students, she injects examples from her 12 years in industry. She explains where linear regression came in handy, for instance, or admits she never used a particular software package but knows plenty of engineers who did. Matusovich recently even extended her explicit instruction to include effective PowerPoint presentations.

Seniors, the study showed, tended to cut classes, turn in homework late, and report less satisfaction with instruction than did younger students, even though they interacted more with faculty and had smaller classes and greater opportunities for project-based learning. “One would hope that as students get into their majors, they would get more interested, and they don’t,” observes Cynthia Atman, a professor and director of the Center for Engineering Learning and Teaching at the University of Washington. She suggests faculty could help “blur the lines” between classroom and professional practice by explaining how engineers use the concepts they’re teaching, possibly by integrating “grand challenges” into coursework.

Seniors had lower confidence in their interpersonal skills than in their math and science skills but considered them less important professionally, revealing a gap between classroom learning and real-world practice that could have far-reaching implications. “When we project what’s really going to be needed to help them compete in the world, it’s their people skills, their creativity, and probably not their analytical skills, that will make them worth six-figure salaries,” says Ruth Streveler, an assistant professor of engineering education at Purdue University and one of the core group of APS scholars.

Stanford’s Sheppard expected that as students advanced to more project-based learning, “they’d be getting the message that these communication skills are key to the practice of
TEACHING

Instead, seniors are no more convinced than freshmen about the importance of these skills in practice. Matusovich has found in related research that while faculty understand the importance of communication, teamwork, and other “soft” skills in engineering work, they rarely report explicitly teaching them. Notably, the most socially confident students had plans to head toward non-engineering jobs upon graduation, APS research found.

Stanford’s Sheppard offers a snappy solution: Have a panel of alumni return after 10 years to talk to design classes about what skills they use on the job. “I virtually guarantee” students will see the importance of communication, teamwork, and the ability to lead and persuade, says Sheppard. “If you don’t have these, you won’t get your work done.”

Confidence Gap

SOME OF THE most intriguing insights center on different levels of confidence between men and women. Grades, study habits, and other metrics indicate that female undergraduates are as proficient and well prepared as their male peers. Yet while men gained confidence in their ability to solve open-ended problems as they advanced from freshman to senior year, women’s confidence levels didn’t budge. “Confidence is relative to your peers,” notes Atman. Women, she says, may just be “harder on themselves.”

Through senior year, and despite evident academic success, women had less confidence than men in their mastery of math and science, although both sexes grew more self-assured in their ability to apply their skills. The college experience “has done nothing to close the confidence gap,” concludes APS investigator Debbie Chachra, assistant professor of materials science at the Franklin W. Olin College of Engineering, even though “by a lot of measures, our women are actually leading the way: grades, teamwork. They are who we want our engineers of the future to be.” Her work with University of Washington research scientist Deborah Kilgore exposed a widespread perception among male undergraduates that women gained admission with weaker math and science credentials. This attitude, together with a paucity of female role models, may undermine women’s self-confidence. “You think you can do something because you see people around you doing it,” Chachra explains. Both women and minorities get less “social affirmation” in a discipline largely dominated by white males, resulting in less of a “sense of belonging and the sense you can accomplish things,” she adds.

Men and women also conceptualize engineering differently. Female engineering majors typically approach design with the goal of understanding the problem better while their male counterparts consider it “building something.” Sheppard notes that “when thinking about what it takes to be successful in engineering, women tend to emphasize the importance of leadership, communication, and teamwork skills, as well as business acumen, more so than men do.” Women also “think globally, a bit more broadly about gathering information,” observes Washington’s Atman. When tackling a design problem to create new retaining walls to prevent another Mississippi flood, for instance, female undergraduates saw the project in the broader context of social and environmental impact; the males typically focused on more technical details, such as construction costs and materials. A “big takeaway” is for faculty “to be aware of variability,” Atman says.

The APS offers a roadmap for changing engineering culture, one that investigators are already applying. For example, say Atman and Sheppard, “diverse teams can be helpful” when teaching about design. Findings also are filtering into classrooms. To ensure that all students, not just self-confident males, gain “genuine competence from genuine experience,” Olin College’s faculty take care to assemble student teams with diverse skills and more than one female.

To create a “safe space” for less confident students to participate in class, Matusovich invited them to do homework problems on the board, nudging those offering muddled responses toward the correct answer.

The larger question is whether engineering programs can alter their internal structures and culture to engage a broader array of students. That includes creating easier routes for non-engineers to migrate in from other disciplines. While most freshmen stick with engineering, only about 1 in 10 majors starts in another field, far lower than most concentrations. “The problem with engineering is there are many pathways out but very few pathways in,” notes APS investigator Karl Smith.

Encouraging students to forge new pathways into engineering and to graduate better prepared may require educators to pursue unfamiliar routes, too. But that could make all the difference.

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Title: Not What Students Need

Source: ASEE Prism 19 no5 Ja 2010 p. 44-6

ISSN: 1056-8077

Publisher: American Society for Engineering Education
1818 N St. NW, Suite 600, Washington, DC 20036

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