EVOLVING PATHS

Engineering and technology skills are becoming as valuable in the courtroom, boardroom, and medical lab as in the engineering lab. As career vistas broaden for engineering students, should the engineering curriculum change?

By Beth Panitz

Alicia Harvey's day is a flurry of phone calls. One cable company after another calls the Hewlett-Packard sales engineer, whose job it is to explain to them how to use the high-tech HP testing equipment that they've purchased. The 23-year-old University of Denver engineering graduate doesn't design any of the equipment; her task is to keep the customers happy with it. She chats with them about the equipment, listens to their concerns, and walks them through any technical difficulties they may have with it—work that is far from that of the stereotypical engineer who spends his or her days working alone on design or research.

But these days it seems like that stereotypical view, if ever it held much truth, is nothing but a myth. In fact, many engineers like Alicia Harvey are putting their technical skills to work in jobs that may not traditionally be considered "engineering."

Guess Who's Hiring More of Our Graduates?

To some extent engineering has always provided a foundation upon which to build other careers. Patent lawyers, for instance, have long recognized the benefit of having a technical grounding. But today engineering is becoming a popular foundation for a variety of other careers, especially in business, say engineering educators. Engineering graduates are landing jobs at financial consulting firms, at Wall Street companies, and, like Alicia Harvey, at high-tech companies as sales engineers.

At Rensselaer Polytechnic Institute (RPI), for example, less than one-half of the graduates from 1985–95 who responded to a survey reported that their first position out of school was strictly an engineering job. Mark Rice, of RPI's Center for Entrepreneurship, reports that many of the graduates who do start in technical positions eventually move into management positions or become technological entrepreneurs.

Few engineers follow the once-popular track of working in a technical position for a big company for 40 or so years, says Ronald Bennett, director and chair of manufacturing systems and engineering at the University of St. Thomas.

Edward Ernst, AlliedSignal Professor of Engi-

neering at the University of South Carolina, says that employment of engineers in other fields has become pervasive, and proves his point by recounting a conversation he had a few years ago with his school's job placement officer.

"Guess who's hiring more of our engineering graduates than any other company?" the officer asked.

Ernst proceeded to name the typical employers—"Bell South, IBM, General Motors . . . ." But the name at the top of the list was none other than Arthur Andersen, a world-renowned financial consulting firm that hires engineers to manage its complex computer systems.

An Engineering Degree for Nonengineers

Can an undergraduate degree really prepare students for two careers—especially if one is as demanding as engineering? And, why would a student who wants a technical background, but doesn't want to be an engineer, complete the whole rigorous engineering curriculum? Lester Gerhardt, associate dean of engineering at Rensselaer Polytechnic Institute, says one solution is to offer a different engineering degree to students who want an engineering background, but do not want to be engineers. This engineering degree for nonengineers "would expose students to many of the disciplines, but not in as much depth," he says.

A few schools are already offering programs similar to those Gerhardt envisions becoming popular in the future. Lafayette College, for example, offers a bachelor's of arts (called an A.B. for the Latin *artium baccalaureus*) in engineering that is "not intended for those who want to be design engineers," says David Veshosky, a civil and environmental engineering professor who teaches in the program. Instead, students go into careers such as technical sales, technical writing, project management, construction management, industrial management, information systems management, and environmental management.

The curriculum for the first two years of Lafayette's A.B. in engineering parallels the school's curriculum for its B.S. in engineering. In the third year, however, the programs begin to differ, with A.B. students taking a history of technology course and a seminar on engineering and society. Rather than taking all of the upper-level technical courses required of the B.S. students, A.B. students complete a four-course cluster of engineering courses. These can be from the B.S. offerings or from separate engineering management and policy courses that Lafayette established five years ago.

Why Do Engineers Enter Nonengineering Fields?

Following the demands of the job market, engineers are crossing into other fields where their skills are highly valued and rewarded. As technology's role increases in society, engineers, who possess a strong understanding of technology, are becoming assets in almost every field, say some engineering educators.

"Virtually everyone encounters technology in their everyday life," explains Lester Gerhardt, associate dean of engineering at RPI. Thus an engineering education can lead to a multitude of career opportunities, he says.

Lance Schachterle, assistant provost at Worcester Polytechnic Institute (WPI), says that "technology is opening up new opportunities to practice engineering in fields we hadn't thought of engineers practicing in before." For example, he says, engineers now work in the theater industry designing high-tech theatre sets. Schachterle developed WPI's Interface Programs, which combine engineering with nontechnical subjects such as theater, public policy, and economics.

The list of fields that value engineers and their knowledge of technology goes on. For example, so much of modern medicine—laser surgery, MRIs, CAT scans—uses technological innovations that an engineering education is ideal for doctors, Edward Ernst notes. Likewise, he says, public policymakers with an engineering background have an extra edge because "there is a large technical component" to many societal issues, including global warming, telecommunications, and nuclear energy.

Joseph Morone, dean of RPI's Lally School of Management and Technology, points out that every business, not just Wall Street companies and large consulting firms, needs employees who understand technology. For example, he notes that even companies in the entertainment industry, such as Blockbuster, must be concerned with technological changes. "If they think that 10 years from now we're going to be getting into a car to get our videos, they're wrong," he says. Because engineers understand technology, Morone projects that they will be hot commodities for many companies. "If you want to be prepared for technology," he says, "you need a technical foundation in your education. There's no shortcut to that."

But engineers bring more to the workplace than an understanding of technology. Engineers also offer the problem-solving and logical-thinking skills that come in handy in many careers. After all, what employer can't use someone who can find workable solutions to the company's problems?

Schachterle notes that employers in fields such as finance and law "have indicated that a solid grounding in how engineers think—especially with their familiarity with mathematical modeling, with computer databases, communications, and software; and with

solving problems by deciding among various conflicting solutions—is ideal preparation for employment in their fields."

Gregory Farrington, engineering dean at the University of Pennsylvania, enthusiastically agrees. "An engineering education is a fabulous preparation for a variety of careers. Engineers are educated to think quantitatively, pragmatically, mathematically, and are comfortable in the computer age," he says.

Many employers view engineers as intelligent people who can learn new things, assume more responsibility, and take their careers down different paths.

Ernst recalls asking a Procter & Gamble representative why the company needed electrical engineers. The answer: "They're smart people and they're willing and able to learn and move into management."

Meanwhile the demand for engineers in more traditional engineering industries has declined. With many high-tech and defense companies downsizing in recent years, many engineers have felt compelled to look beyond these companies to get a steady paycheck.

"For a while some of the traditional engineering companies were downsizing and reducing their campus recruiting efforts," says Stephen Director, engineering dean at the University of Michigan. Simultaneously, consulting firms like Arthur Andersen were increasing their efforts. Director notes that "when companies like IBM and AT&T start laying off, it sends a signal to students" to look for other types of employment.

"If you want to be prepared for technology, you need a technical foundation in your education. There's no shortcut to that."

Engineering: The Liberal Arts Degree of the 21st Century?

Many engineering educators tout that "engineering is the liberal arts degree of the 21st century" because it provides students with the strong technical and problem-solving skills that are needed in many fields. But to be truly successful in careers such as finance, public policy, and education, don't students need an education that also provides them with skills and knowledge that are not traditionally part of an engineering education?

Part of the solution, say many educators, is to emphasize to students the necessity of lifelong learning. An engineer working for, say, a financial company must be ready to learn the financial jargon and theories on the job and may eventually need to return to school for an M.B.A. But even assuming that engineers will keep learning information as needed throughout their careers, should the engineering curriculum be modified so that the base students leave college with is targeted to other fields?

Yes, says Ronald Bennett of the University of St. Thomas. He recounts that when he worked as sales director for a high-tech company, he was hard pressed to find sales people who had an understanding of technology and business. "The couple of sales people who had an engineering background weren't any good at selling. And the ones with a business background didn't understand the technical side," he says. Today his university is striving to create an engineering curriculum that will prepare students for a multitude of overlapping careers.

Restructuring Engineering Education, a 1995 National Science Foundation report, recommends that more engineering schools take this approach. It states, "Undergraduate engineering education must support two classes of career aspirations:

1) All students who have a motivation to practice engineering;

2) Those who desire a curricular pathway with significant technical content, but focused on various nonengineering career objectives including careers in K–12 education, public policy, management, financial services, and health care."

While the report's recommendation is not revolutionary, it does raise several questions: How should the curriculum be changed to prepare students for other careers? Is it unrealistic for a program to prepare students for both traditional engineering jobs and other careers? Will preparing students for other careers mean cutting technical courses? If so, will students be as prepared to practice engineering? Will students, perhaps, even lack the very technical and analytical skills so valued in other fields?

Many engineering schools are tackling these questions. Here's a look at some of the answers they're devising.

Making Room for Nontechnical Courses

One obvious way to prepare students for other fields is to urge them to choose electives that apply to the nonengineering aspects of careers they might wish to enter.

The problem, however, is that the typical engineering curriculum is packed with so many requirements that it leaves little room for nontechnical courses. Edward Ernst, rapporteur for NSF's *Restructuring Engineering Education* report, recommends reducing the number of technical requirements, thus allowing students more flexibility in taking electives. That way a student who wants to, say, put his or her engineering skills to work for a financial consulting firm will have time to take courses in finance and economics.

But will cutting technical courses from the curriculum mean that students are not as technically prepared? Ernst contends that cutting two or three technical courses won't make much of a difference. Schools require students to take an abundance of technical courses to prepare them for whatever technical work comes their way, he explains. But what happens, he says, "is that we end up running students through a lot of classes that they never use." He'd prefer an education that provides students with a solid grounding in engineering but doesn't attempt to cover every topic—an impossible feat anyway, he says—and thus leaves room for other subjects.

How will schools determine what courses to cut? Ernst suggests decreasing the number of technical courses required as well as allowing students more freedom to choose their upper-level technical courses. That way, although students won't be enrolled in as many technical courses, they'll be taking the ones that they deem important for their careers.

Five years ago Carnegie Mellon University (CMU) instituted an electrical and computer engineering curriculum similar to what Ernst is suggesting. The school reduced the number of required technical courses to what a faculty committee decided was the absolute minimum needed to become an engineer, freeing up almost a full year of electives. "We recognized that more students were going into nontechnical careers," says Stephen Director, the school's former engineering dean. The new curriculum allows students the opportunity to prepare for other careers by providing them more flexibility to decide what courses to take.

Director says the school could reduce its requirements because "we were requiring just too much. There were unrealistically long sequences and a hodgepodge of requirements. The students felt like they were in boot camp" and were inundated with so much information that they couldn't truly absorb and understand it. Administrators finally recognized that "we don't need to try to cram everything into four years of school." Besides, he says, the half-life of technical information is so short these days that much of what students learn in school will soon be obsolete. Now Carnegie Mellon's approach is to give students a base from which they can build upon with lifelong learning.

Students still receive the necessary minimum training to be engineers, and those who want to be technical specialists can "use their electives to take more technical courses. In fact, a lot of them do," Director says. This increased flexibility in selecting courses, however, also increases the need for thorough advising that guides students toward courses that are helpful for the careers they aspire to, Director adds.

Carnegie Mellon's new electrical and computer engineering curriculum recently underwent the accreditation process and received the seal of approval from the Accreditation Board for Engineering and Technology. Director points out that ABET is considering updating its accreditation criteria. If approved, he says, the new standards will remove the emphasis in accreditation from bean counting and will make innovative curriculum changes even easier.

Integrating Engineering with Other Subjects and Skills

Some engineering educators argue that there's simply no room for more nontechnical courses in the extensive engineering curriculum because their requirements cannot be cut. An option for these schools may be to integrate other subjects and skills into engineering courses. In fact this method offers the added advantage of more closely relating nontechnical skills to engineering, says Harvey Stenger, engineering dean at Lehigh University.

At Lehigh students can enroll in a new Integrated Product Development program that blends the schools of engineering, business, and arts and sciences. The integrated curriculum gives its students the broad range of skills that industry wants in its employees, "without spoiling our nice, tidy ABET-accredited program," Stenger notes.

The program provides freshmen in all three schools with a laboratory/lecture course in which they take apart electric mixers, Coke cans, and other ordinary products to learn how they are designed. During lectures students learn how engineering meshes with marketing and the arts to produce a successful product. Through this interdisciplinary work, the students begin to "understand each others' [disciplinary] languages," Stenger says. The course, offered last year for the first time, is currently an elective, but may eventually become required for engineering students.

In their senior year, after gaining some expertise in their own fields, engineering and business students take the interdisciplinary work a step further by working in teams to develop real products for industry. Students not only design a product but also devise a market analysis and a business plan. "They're not

just interested in building a better mouse trap but also in marketing and selling it," Stenger says.

The engineering students learn about the business aspects of product development from classmates who have expertise in those areas and from course lectures. "Lectures on marketing and business plans are presented to the whole class, but it's the engineering students who need to listen closer," Stenger explains. Likewise, lectures on design and technical topics are presented to the whole class, "but it's the business students who need to listen closer," he says.

Because the course is a requirement for only the engineering students, these students outnumber the business majors. Consequently about half the teams contain a mixture of engineering and business students while the others consist of only engineers. Initially the teams with a combination of disciplines "have a harder time communicating with each other, picking a leader, and respecting each other's talents," Stenger says. "Often they spend the first two weeks arguing over which is more important, the mechanics of the product or the marketing." However, Stenger says, once the teams pass these hurdles, they devise some of the most successful products—both technically and marketability. This year the projects will be even more interdisciplinary as arts and sciences students join the course for the first time.

While few schools offer programs as integrated as Lehigh's, many are trying to enhance their curriculum by teaching some of the nontechnical skills they may have ignored in the past.

"Historically engineers have been trained as loners," Bennett says. Today, he notes, engineering schools are putting more emphasis on liberal arts courses and on integrating teamwork and communication skills into engineering courses. The new focus on design work—where students work in teams, give presentations to their classmates as well as industry members, and write reports on their progress—helps develop these skills. Not only do these skills come in handy in other careers but educators have come to recognize that this is the way design engineers in industry work.

Extending Time in Undergraduate School

When Nadine Riley entered City College of New York (CCNY) in 1993, she dreamed of putting her strong math and science skills to use as an engineer. However, after working in her freshman year as an elementary school teacher's assistant, she found a second passion—teaching. Through a special program CCNY established last year, she's now studying to earn both a B.S. in mechanical engineering and a high school teacher's certification.

Engineers can bring to the high school classroom a valuable knowledge of how to apply science and mathematics, says Gary Benenson, director of CC-

Engineering Courses for Nonengineering Majors

Following the logic that a technical background is useful in many careers, some educators are urging schools to offer a sampling of engineering and technology courses to all students. "Most of the decisions about science and engineering are not made by scientists and engineers," says Albert Rosa, chair of Denver's engineering department. Nonengineers "need to have some understanding of technology to make smart decisions."

A few pioneering schools have already begun offering their nonengineering students a taste of engineering and technology. Last year, the University of St. Thomas, for example, established an engineering minor in which students gain a technological grounding by taking four engineering courses as well as supporting math and science courses. The minor is geared mostly to science and business majors.

However, Joseph Morone, dean of Rensselaer Polytechnic Institute's management school, says that traditional engineering courses often fall short on offering nonengineering students an understanding of technology. Traditional courses begin with the fundamentals and build up, but nonengineering students need instruction that starts with everyday examples of technology and then explores the underlying principles, he contends. "That takes traditional education and turns it on its head," Morone says.

The University of Denver offers such a series of technology electives. In two lower-level courses, nonengineering students learn about technology and how it impacts society. In an upper-level course, students work in interdisciplinary groups to devise policies relating to major technological concerns such as global warming, nuclear energy, and genetic engineering. As a final project, students write a white paper report advising policymakers on how to handle a specific policy problem.

Similarly Tufts University has created a series of 40 science and technology courses designed to relate engineering phenomena to everyday life. In "Skyscrapers, Architecture, and Engineering," for example, students learn how architects and engineers plan and design statuesque buildings that withstand the forces of Mother Nature.

Freshman engineering students must take two of these courses—which carry the credit value of half a regular class—while other students can take them as electives. The courses aim not only to spark the interest of nonengineering students but to make engineering more relevant to freshman engineering students, thus retaining more of them, says Tufts' engineering dean, Ionannis Miaoulis.

The courses provide nonengineering students with an opportunity to learn about topics that they couldn't have otherwise, Miaoulis says. For example, Miaoulis teaches a course that relates fluid mechanics to society. To enroll in a regular fluid mechanics course, he says, a student must have four prerequisite courses in math, physics, and mechanics. But Miaoulis' fluid dynamics course has no prerequisites.

"When companies like IBM and AT&T start laying off, it sends a signal to students" to look for other types of employment.

NY's ECSCEL Teacher Certification Program. The hope is that future engineers/teachers, such as Riley, will infuse high schoolers with an interest and an understanding of technology, he says.

To prepare for a second career that is as intensive as teaching, however, usually requires students to tack on an extra semester or two to their undergraduate education. In fact, some educators and employers argue that four years is not enough time to prepare students for traditional engineering jobs alone, not to mention additional careers.

Engineering students in CCNY's teacher certification program spend a semester working part-time as teaching assistants at Brooklyn Technical High School and concurrently take a teaching seminar. Students use their electives for these courses, but most still need to add an extra semester for student teaching, Benenson says.

But even with an extra semester of school, can students really be prepared to be both an engineer and a high school teacher—two very different professions? Lester Rubenfeld, who leads a similar teacher preparation program at RPI, points out that the students complete a standard engineering curriculum and thus are prepared for engineering careers. He admits students could benefit from more instruction in teaching methods, but says the program provides a strong base from which the students can continue to learn.

Combining Engineering with Advanced Degrees in Other Areas

If students can't squeeze all the information they need to start their careers into a four-year or slightly extended program, they may want to continue on for an advanced degree. Some engineering students have always gone on to law school or medical school, but today a popular choice for engineering graduates is to earn an M.B.A.

Recognizing the appeal of business programs, several institutions now offer programs that allow students to earn both a bachelor's in engineering and an M.B.A. in five years.

Alicia Harvey, the Hewlett-Packard sales engineer, graduated from the University of Denver's five-year program. Originally she had planned to complete a traditional four-year electrical engineering program, but says that after her freshman year, "I realized that I still wanted to be an engineer, but I didn't want to be a design engineer." She chose Denver's dual-degree program as a way of tailoring her engineering skills to the business world. Through the program, she started taking graduate business courses in her fourth year of school, while she finished her engineering coursework. "It gave me the opportunity to take all of the classes at once, which I think is better" than having to return to school later for an advanced degree, she says. "I see people struggling because they are going back to school and working at the same time."

Some M.B.A. programs, such as RPI's, even combine management and technology skills. The program, which can be completed through a five-year joint offering with the engineering school, is specifically designed for students with an engineering or science undergraduate degree. It offers a "business curriculum infused with technology," says Joseph Morone. For example, students take a two-semester sequence on new product development that integrates marketing, design, manufacturing, and performance measurement in a team-based project. They also focus on technological entrepreneurship, with many students spending at least one semester working with a start-up company in the school's new business incubator—a program that provides a supportive environment for new technological ventures by connecting entrepreneurs to university and community resources. "The whole M.B.A. program is based on the premise that you can't find a company anywhere in the world that isn't being transformed by technology," Morone says.

Survival in the 21st Century

This fall, as the class of 2000 enters college, many engineering schools are still struggling with the question of how to give engineers a strong technical training that prepares them for a broad range of fields. While there are differing opinions on what solution is best, one thing is clear—as Albert Rosa, University of Denver's engineering chair, says—"The engineers of the future are going to be very different from today's engineers."

And engineering schools may need to change their curricula not only so they can better prepare students for the engineer's new roles, but also for the survival of their engineering programs. Students are no longer flocking to engineering like they used to, Harvey Stenger notes. "One way of revitalizing our programs is to prepare students for a broader range of careers."

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