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On June 27-28, the National Academy of Engineering held a workshop on Career-Long Education for Engineers. Some 25 representatives from universities, professional societies, and large and small companies met with an 11-member NAE committee to discuss some of the challenges facing engineers and how best to meet them. The workshop participants reached a broad consensus on the need for engineers to become "lifelong learners" as well as on a number of general policies that would further this goal. But instead of releasing yet another policy statement or report that would be read by relatively few people, the members of the NAE committee decided to speak directly to the engineering community. They did this because they believe that changing the attitudes of individual engineers toward continuous education is vitally important, both for the engineers themselves and for the continued economic health of the country. This article explains why.

A decade ago, a group of experts estimated the half-life of an engineer's technical skills--how long it would take for half of everything an engineer knew about his or her field to become obsolete. For mechanical engineers it was 7.5 years. For electrical engineers it was 5. And for software engineers, it was a mere 2.5 years, less time than it takes to get an undergraduate degree. Today, those numbers are surely even smaller.

Technology is rushing headlong into the future at a pace that takes one's breath away. Personal computers, the Internet, genetic engineering, advanced materials, new forms of chemical synthesis--all these things and more are changing our world swiftly, profoundly, and, in most cases, for the better. But the excitement and the progress come at a cost. Rapid change is not always comfortable, and no one knows this better than the people whose job it is to stoke the technological juggernaut.

Think about it. In some specialties, engineers must update half of everything they know every couple of years, all the while working full-time to design products according to the best standards of the moment--which might change next month. In even the slower-paced fields, engineers must reinvent themselves at least once a decade.

There's more. A generation ago, an engineer could expect to carve out a niche in one well-defined area-- automotive steering systems, say, or chemical plant instrumentation--and remain there for a lifetime. No longer. As technological change accelerates and product lines rise and fall in ever-diminishing life cycles, engineers find themselves switching jobs more often, to the point that those starting out today may hold half a dozen jobs over their careers, even if they manage to remain with the same company throughout. So besides staying abreast of developments in their own specialties, engineers must be prepared to switch nimbly to a new field when the old one peters out.

And, to complicate things further, these professional demands come at a time of upheaval in the employment landscape. Global competition has sparked a wave of downsizings in technology firms, destroying much of the job security that engineers used to take for granted and pushing companies to contract out more and more of their design work. Today, service firms such as Andersen Consulting are the largest recruiters of engineering graduates on some college campuses, eclipsing the big manufacturing companies in the number of hires.

The bottom line: A large and growing percentage of engineers now work as contract technical experts, hiring out for a particular job at a particular company, then moving on when it is finished. They may be independent consultants or they may work for consulting firms, but either way they don't have the long-term stability that joining a traditional manufacturing firm used to provide.

In short, engineers are facing a whirlwind of change, and the fact that it is a whirlwind they themselves have sown does not make the buffeting any less.

How well engineers can ride this whirlwind should be of concern not only to the engineers themselves and to their employers but to society as a whole. For to an extent unprecedented in history, a country's economic health and vitality depend not so much on its natural

resources, its military might or its political strength as on its intellectual capital, and engineers are the keepers of the most important part of that intellectual capital--the knowledge needed to create and advance the technology that runs our world.

How, then, can that capital be preserved and increased? The key, the experts say, is having engineers who are constantly learning, constantly upgrading their skills, constantly adapting to new situations. Some refer to this as "technical vitality," others prefer to speak of "career-long education," but the terminology is not important. What is important is that engineers treat their careers as dynamic things which need continuous upkeep and upgrading. And this demands a new way of thinking from engineers and their employers--a culture shift to match the changing technological environment.

Some forward-looking firms are already trying to create such a new engineering culture. These companies recognize that the effort and expense of turning their engineers into perpetual learners will be paid back many times in productivity and quality. Boeing, for example, offers a variety of in-house graduate programs in such areas as technical management and engineering design and analysis. Employees can take the televised courses singly or combine them for an advanced degree. And at Motorola, which has established its own "Motorola University," the company's goal is for each employee to get at least 40 hours of training a year.

But few companies do so much, particularly when it comes to education that will prepare an engineer to move into new areas. Management may talk about the importance of "professional enhancement" or "continuous learning," but too often it's just talk. Unfortunately, many firms offer few or no courses themselves and provide little guidance about which studies an engineer should pursue outside the company. Firms frequently have a limited education budget, which too often shrinks even more with each new wave of streamlining and cost cutting. Supervisors, with looming deadlines and fewer employees to meet them, are reluctant to have their engineers go to even a 3-day mini-course. And when it comes time for deciding on promotions or on who survives the next downsizing, the management often pays little attention to anything past the short-term bottom line of which projects came in on time and under budget. The message that engineers get from such companies is: You're on your own, my friend.

And for now, for most engineers, that's the unfortunate reality. Preparing themselves for the brave new blustery world will be mostly their responsibility. They can expect little help from above.

Fortunately, even without the active support of enlightened employers, there are plenty of ways that engineers can enhance their own intellectual capital. Some of them demand only time and commitment: Read books and journals. Talk to other people at work. Go to professional meetings and listen to the presentations. Seek out the leaders of your field and learn what they're doing.

Past that, there are far more formal courses of study available than most engineers realize, ranging from half-day seminars to full degree programs. Nearly every engineering society, from the Institute of Electrical and Electronics Engineers to the Society for Mining, Metallurgy and Exploration, offers courses tailored for its members. The local university likely has a variety of useful undergraduate and graduate courses, and many schools have developed continuing education programs for engineers, often with some of the classes available off-campus either televised or on videotape. The National Technological University offers a large selection of engineering courses via satellite from top schools around the country and bestows a dozen different advanced degrees, ranging from computer engineering to hazardous waste management. And a number of commercial vendors have appeared in recent years, with classes aimed mostly at developing specific skills.

The value of these programs varies, from the outstanding to the nearly useless, but on the whole the quality and selection are improving each year. With care, most engineers should be able to find something to fit their needs. If they can't, they should lobby their professional organizations, the employers, or the local university to fill the gap.

Some education experts look past such traditional programs and envision a system, perhaps based on the Internet, that will deliver whatever information and instruction an engineer needs, wherever and whenever he or she needs it. It would be the educational equivalent of just-in-time manufacturing, which arranges to have the necessary components of a car or computer delivered just as they are about to be installed.

Ultimately, however, it won't matter so much which of these options an engineer chooses. What will matter will be developing a culture and a set of attitudes suitable for engineering in the 21st century. The precise details of that culture must still be worked out, but one thing is clear: Engineers must stop thinking of education as what they did for 4 years in college and come to see it as a lifetime project.

Endnote:
The NAE Committee on Career-Long Education for Engineers consisted of Ernest T. Smerdon, vice provost and dean, University of Arizona; Dell Allen, director, Wandell Graphics; Daniel Berg, institute professor of science and technology, RPI; John M. Campbell Sr., retired president and CEO, Campbell Companies; Ernest L. Daman, state-federal technology executive, Office of Science and Technology Policy; George E. Dieter, director of continuous quality improvement, University of Maryland; Earl H. Dowell, dean of engineering, Duke University; Robert C. Gooding, chairman, Columbia Research Corporation; George Keller, senior corporate research fellow, Union Carbide Corporation; M. Eugene Merchant, senior consultant, Institute of Advanced Manufacturing Sciences; and Arnold H. Silver, chief scientist of superconductivity, TRW Space and Electronics Group.