

## Engineering Education in the Changing World

By Leah Jamieson, Purdue University

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The world is changing in many ways. We continually ask ourselves whether our graduates are going to have the attributes and skills they will need for careers over the next 40 years. Some of the drivers for change are new technologies that are emerging at an incredible pace. In particular, the continued importance of multidisciplinary technologies is increasing the need to be able to communicate across disciplines in order to have effective, system-level designs.

The rate of technological change is unprecedented and continues to accelerate. Globalization is on everyone's minds. There are also workforce issues that we are trying to understand. Interest in engineering careers among US high school students is down 18% since 1991. What are the workforce implications of our slow progress on diversity? We are seeing engineering students working in fields other than engineering. Are we preparing them for careers outside of engineering? And last, but certainly far from least, what issues are raised from off-shoring?

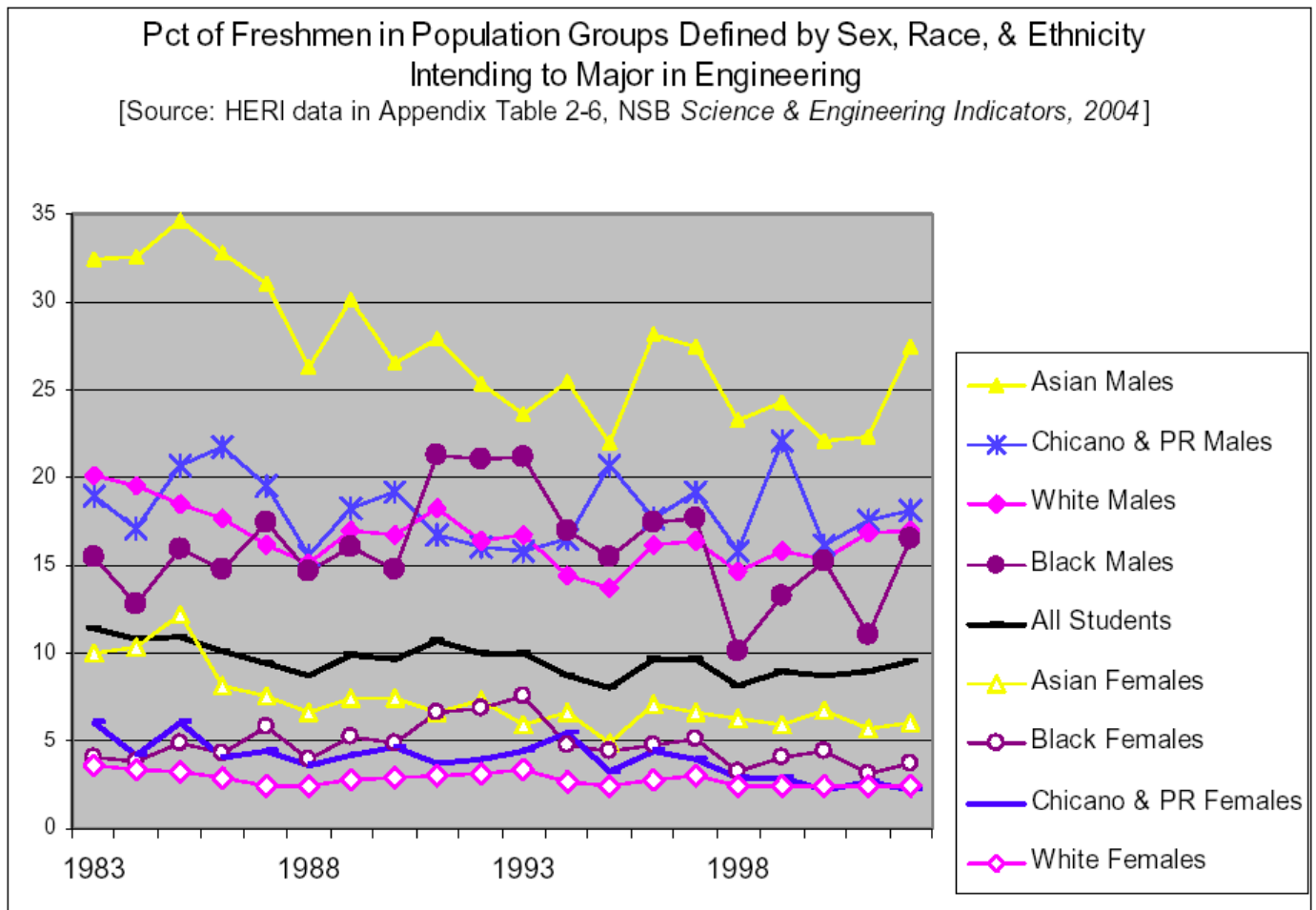


Figure 1. US trends in engineering enrollment.

Figure 1 shows some national trends in enrollment. The black line shows the percentage of US freshman intending to major in engineering between 1983 and 2003; the colored lines are breakdowns by race, ethnicity and sex. We see a gradual decline in interest in engineering majors in the United States. All of the lines below the black line are the patterns for women in engineering and all of them have a downward slope. The only lines with upward slopes are Asian males, and there is a fair amount of jumping around regarding African-American males, with some years high and others low.

There is a general sense that engineering is not as attractive in the US as it used to be. We are trying to understand not only our role as educators in that perception, but also the role of industry. There are some global trends in the engineering market. There is an explosion in the engineering workforce in China, a potentially growing workforce in India, and a stable or shrinking workforce in the United States.

All of these factors—globalization, the workforce and the pace of change in technology—have spurred conversations in sectors that consider engineering education. Probably the voices that have been the most coherent, and certainly the most reputable, are coming from the US National Academy of Engineering (NAE) in a companion pair of reports: *The Engineer of 2020* and *Educating the Engineer of 2020*. The first volume sets out visions of what engineering will be for this century and the second talks specifically about the implications for engineering education.

The first phase of the NAE study, completed between 2002 and 2004, looked at the contexts—in particular the technological, societal, global and professional contexts—in which engineering will be practiced. The technological contexts are pulling in two directions due to different population demographics throughout the world: technology for an aging population in the developed world, and technology for a young population in the developing world. Solutions will be interdisciplinary, and complex systems perspectives are going to be essential for successful products in the future.

The discussions on the societal and professional contexts are more wide ranging. With an accelerating global economy, market opportunities will continue to grow in many parts of the world. There needs to be more interaction between engineering and public policy. We know this is true in telecommunications, but it will also be the case in energy, healthcare and security. How issues such as safety and reliability are funded, and which regulations are adopted and which are not are the concerns of public policy.

There is a need for a global perspective of social contexts, perhaps even thinking about where engineering fits into the notion of liberal education. In the 19<sup>th</sup> and 20<sup>th</sup> centuries, liberal education meant liberal arts. Where does engineering fit into the liberal education for the 21<sup>st</sup> century?

From these contexts, the NAE report went on to identify a relatively small set of attributes, some of which are very familiar—communication, teamwork, business management skills and ethical standards. The report also adds things like practical ingenuity, creativity, dynamism, agility, resilience and flexibility. No one I know in engineering education is ready to give up on the notions of technical depth and technical breadth. And so we are faced with the question of how we do all this. We have increasing lists of things that apparently are going to be critical for our success, but where is the time to do it?

The second volume of the NAE report, *Educating the Engineer of 2020*, makes two very specific recommendations. The first is that the bachelor's degree should be considered a pre-engineering or engineering training degree, that is, a four-year bachelor's degree is in some ways analogous to a pre-law or a pre-med degree. The second recommendation is that accreditation should extend to include the master's degree so that the master's degree becomes a professional degree in engineering.

An alternative proposal is to turn the curriculum inside out. The challenge is that we still need to teach engineering, but now we need to teach this other stuff and I contend that most of that "other stuff" is hard to teach in a traditional classroom. The 20<sup>th</sup> century curricula had engineering science at the core, and it probably included a design course—perhaps the best place to learn all of these other attributes. A possibility for the 21<sup>st</sup> century is to put the engineering experience at the core and wrap the engineering

science around that core in support of learning how to design, how to solve problems, how to do more open-ended engineering, even as an undergraduate.

Experiential education includes things such as co-op and internship experiences and service learning. It includes the notion of creating design teams that work in partnership with not-for-profits. Undergraduate research and study abroad are essentially ways of learning by doing rather than learning by listening.

Finally, I'd like to come back to the diversity issue. Will different approaches to engineering education affect who becomes an engineer? For example, in some of the experiential programs, such as international experiences and study abroad engineering programs, the participation of women is more than twice as high as the participation of men. In some cases, the participation of women is three or four times the participation of men in fields where ten percent of the students are women.

International experiences are incredibly attractive to women. In service learning—projects that tie engineering to the community—two to three times as many women participate as compared to the base populations in their fields. So this notion of engineering in context—a very design-centered, experiential-centered curriculum—may give us different stories to tell elementary and high school students about what engineering and engineering curricula is like. There may be some implications between how we are teaching engineering and the question of who wants to be an engineer.

I think the last unanswered question is whether or not we have the courage to make such sweeping changes in education. It's a large system; we have talked about curriculum and thinking about it differently. Do we have the courage to change? Do you want us to change?

## **ABOUT THE AUTHOR**

### ***Leah Jamieson***

John A. Edwardson Dean of Engineering, Purdue University  
IEEE 2007 President and CEO

Dr. Jamieson received her S.B. degree in mathematics from MIT and her Ph.D. degree from the Department of Electrical Engineering and Computer Science from Princeton University. She joined Purdue in 1976, and currently serves as Ransburg Distinguished Professor of Electrical and Computer Engineering. She is co-founder and past director of Engineering Projects in Community Service (EPICS), an engineering design program that operates in a service-learning context. She is a Fellow of both the IEEE and the IEC, and a member of the U.S. National Academy of Engineering.