CHAPTER

Declining Interest in Engineering Studies at a Time of Increased Business Need

Wayne C. Johnson and Russel C. Jones

INTRODUCTION

The numbers of students studying engineering have declined in recent years, both in the United States and in Western European countries. Many factors have contributed to this decline — including the difficulty of the curriculum, the attractiveness of alternate paths to good technical jobs, and the lack of attractiveness of projected employment paths for engineering graduates. This decline has occurred at a time when the employers of engineers face new challenges due to globalization, offshore outsourcing and the need to "move up the food chain" in innovation and technical expertise in order to remain competitive — thus creating a demand for more highly qualified engineering graduates. Much of what needs to be done to make engineering more attractive to bright students is well known — but educational institutions, employers of engineers, and government policy-makers have been slow to move aggressively to address the issues effectively. The authors attempt to describe "what can be done" in a comprehensive way.

PIPELINE ISSUES

The number of engineering graduates at the bachelor's level in the U.S. peaked at around 80,000 per year in the mid-1980s, then declined to about 65,000 per year until the end of the century (Engineering Workforce Commission, 2004). The number of graduates is increasing again, but not yet keeping pace with employers' needs. To put these numbers in global perspective, it is of interest to note that China currently has 3.7 million engineering students in its pipeline.

There are many reasons for the decline of student interest in engineering:

- *The curriculum is difficult* — Much difficult study and hard work are included in the current undergraduate curriculum in engineering, and that is built on top of strenuous prior preparation requirements in the secondary education years. Engineering curricula typically start with two years of intense mathematics and science — including calculus, probability and statistics, modern physics, chemistry and biology — often taught by service department faculty members who do not put this preparatory work in the context of engineering applications. This is typically followed by challenging engineering science courses, taught by engineering faculty members — but often research-oriented doctoral graduates with little applied engineering experience to bring into the classroom for motivation.
- *The curriculum is densely packed and inflexible* — Even though the number of credit hours required for graduation in engineering has drifted downward as other parts of the university head for only 120 credit hours for graduation, the actual time required for engineering students to complete degree requirements remains much higher than for other fields. The four-year bachelor's degree programmes in engineering schools are typically highly lock-stepped, with prerequisites offering little flexibility for individualized programmes or broadening experiences — such as a semester abroad. Engineering students who miss a required step in the proper order often must take an additional semester or year to complete their studies — at considerable extra expense and loss due to postponed employment.
- *Other paths to good jobs are easier* — High school students looking at various options for university level study often compare engineering to alternate paths — such as computer science — where the curriculum is less formidable, and where jobs at compensation levels similar to engineering jobs are readily available.
- *Engineers treated as commodities by employers* — In the current employment environment, engineers are often treated as commodities by employers. They are likely to be laid off when the quarterly balance sheet is not positive, or when new graduates with sharper technical skills are available at lower cost, or when their function can be off-shored at lower cost to the company. This leads to employment patterns that include multiple positions with different employers, but often involving lateral moves at best. Previous patterns of upward

mobility throughout a progressing career are often lacking (Jones & Oberst, 2003).

- *Traditional entry level jobs are being offshored* — The types of jobs that fresh engineering graduates have filled until recently — support positions in technical operations of large employers of engineers — are now often being outsourced to offshore locations where good technical talent is available at much lower cost. This can result in fewer job opportunities for bachelor level engineering graduates, and lower salary offers (Oberst & Jones, 2004).
- *Media reports indicate instability* — The offshoring of technical jobs, as reported often in the media, transmits an aura of instability in the engineering profession — including the spectre of unemployment. Potential engineering students and their families see such reports, and are often influenced away from engineering study and employment.

Another area of concern in the engineering education pipeline is the lack of diversity in the student population — both women and minority students (National Science Foundation, 2003a, 2003b & 2004). Women students typically make up less than 20% of engineering classes, and minority engineering student populations typically fall well below the percentage of Black or Hispanic people in the community from which students are drawn. These populations often leave the potential engineering student pipeline even before high school — often opting not to take the math and science courses that would be needed to make them eligible to enter an engineering programme at the college level. In addition to the factors listed above, women are often turned off by engineering due to stereotyped images of engineers as nerdy white males.

A very major concern in the U.S. today is the size and composition of the doctoral pipeline in engineering (National Science Foundation, 2003c). In the dot-com boom years, jobs were so lucrative for engineering bachelor's graduates that few went on to graduate study — particularly through a doctoral degree. Universities responded by attracting increased numbers of foreign graduate students to fill research and teaching assistant positions — and eventually faculty ranks. In some fields today, well over half of the engineering faculty are foreign born. In the post 9/11 era, the flow of foreign graduate students to U.S. engineering graduate schools has slowed substantially — due to visa and security problems. In addition, developing countries such as China and India have developed their own good-quality graduate engineering programmes, allowing students from those countries to stay at home for study — and countries such as Australia are aggressively seeking students who would previously have sought U.S. graduate educations.

Some observers in the U.S. do not believe that there is a problem with declining engineering enrolments. They argue that market forces will keep the supply and demand in balance. While that dynamic may have been at least somewhat true in the past, it is drastically altered in the rapidly globalizing workforce environment — where offshoring and mechanisms such as H-1B visas give employers options other than increasing salaries to attract U.S. engineering graduates to their jobs. The authors of this paper believe that the flow of engineering graduates should be kept at a high level — both to meet the needs of employers who traditionally hire engineering graduates, but also to supply the growing number of fields where the quantitative skills and problem-solving abilities of engineering graduates are increasingly valued.

BUSINESS NEEDS

In an increasingly global environment for businesses and for professional practice, engineers who will be employed by industry need to be much broader than graduates of previous generations. And they will need to be credentialed in ways that are recognized across national borders, and available in sufficient quality and quantity to meet the expanding need of employers seeking graduates with superior quantitative and problem solving skills (National Academy of Engineering, 2004).

Globalization impacts

The globalization of business requires university graduates with an international perspective and with at least some international experience (Jones & Oberst, 1999). While that is typical of engineering graduates in Western Europe, it is not typical of engineering graduates in the United States. Just over 5,000 U.S. engineering students studied abroad in 2002-03, just 2.9% of all U.S. students studying abroad that year (Institute of International Education, 2004). Well less than 10% of all engineering graduates in the U.S. have *any* international experience when they graduate from their university programmes. Several universities do require international experience for their engineering graduates, and many others are instituting programmes to provide such experience — but the total activity in this area remains well behind the power curve.

In addition to well qualified graduates from U.S. engineering programmes, U.S.-based companies need qualified engineering graduates in developing countries in sufficient numbers to allow direct foreign investment in such countries (Jones & Oberst, 2000). The days of being able to send business and technical personnel from the North to staff operations in the South are over; an indigenous pool of technical personnel must be available to staff the operations of multinational companies, in order to be politically acceptable to developing nations (InterAcademy Council, 2004). To address this issue, many companies — in their enlightened self-interest — are involved in stimulating and supporting capacity building efforts in developing countries. Hewlett-Packard, for example, is heavily involved in an "Engineering for the Americas" capacity-building effort being mounted through the Organization of American States and the World Federation of Engineering Organizations.

Graduates of engineering programmes today need significant "soft skills" in addition to technical expertise, if they are to be effective for their business employers. With strong input from industry advisors, the U.S. Accreditation Board for Engineering and Technology (ABET, 2000) since 2000 has required the following outcomes of engineering education programmes:

"Engineering programs must demonstrate that their graduates have:

a) an ability to apply knowledge of mathematics, science and engineering;

b) an ability to design and conduct experiments, as well as to analyze and interpret data;

c) an ability to design a system, component, or process to meet desired needs;

d) an ability to function on multi-disciplinary teams;

e) an ability to identify, formulate and solve engineering problems;

f) an understanding of professional and ethical responsibility;

g) an ability to communicate effectively;

h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;

i) a recognition of the need for, and an ability to engage in lifelong learning;

j) a knowledge of contemporary issues;

k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."

Engineering schools must show, through outcomes assessment, that these attributes have been acquired by their graduates.

Offshoring impacts

Business needs native engineers who can help to lead their organizations up the food chain as routine activities and jobs are outsourced offshore. These native engineers need to be able to work effectively with international colleagues, having appropriate sensitivity to cultural differences. They also must be able to work in teams that are geographically separated, utilizing high-tech tools that make such distributed teamwork effective.

Quantitative needs

Business requires a sufficient quantity of engineering graduates to meet its employment needs — with appropriate high quality and appropriate diversity in gender and ethnicity. Broadly educated bachelor's level graduates continue to be needed, but increasingly master's level graduates are needed to lead engineering practice up the food chain. Doctoral level graduates are needed — particularly in U.S. domestic operations — to provide innovation and to utilize research and development in applications in order to keep competitive new products and services coming.

Additional qualitative needs

Beyond the basic quality needs cited above, industry needs engineers who are lifelong learners, able to keep up with technological advances in this rapidly developing world. And engineering graduates for companies must increasingly be interdisciplinary in education and approach, to keep abreast of and take advantage of the convergences in this bio-, nano-, info-technology world.

WHAT CAN BE DONE IN EDUCATION?

Engineering education in the United States is perhaps the most studied and discussed intellectual endeavour in the country. But for all the study, pilot projects, reformation attempts and discussion, it is among the slowest to adopt systemic change.

Many suggestions are relevant to improving engineering education in the United States — and perhaps other portions of the world — to make it more relevant to the needs of business in the increasingly globalized workspace (National Academy of Engineering, 2005):

Undergraduate engineering education

- Make the curriculum more user-friendly (e.g., bring design down into the freshman year in order to motivate students for math and science immersion; concentrate on how to learn rather than trying to cover everything in an intense four-year curriculum; substitute active learning for formal lectures; etc.)
- Focus curricula on its relevance to the solution of society's problems, to provide motivation for the hard work involved (e.g., environmental, health and infrastructure needs; and the needs of developing countries);
- Prepare students for international practice by promoting study abroad and other international exposure opportunities (e.g., engineers without borders experiences);

- Make undergraduate engineering *education* at universities a priority equal to *research* (as the Coalition program of the U.S. National Science Foundation once did);
- Take advantage of the flexibility offered by ABET's Criteria 2000 to offer programmes that produce more broadly educated, internationally oriented, entrepreneurially stimulated engineering graduates;
- Embrace continuous improvement of engineering education programmes, not just periodic change in anticipation of the next accreditation visit;
- Promote systemic change, across the whole of the national engineering education system, based on successful scattered innovations.

Graduate engineering education

- Promote practice-oriented master's degree programmes, in addition to research oriented ones (e.g., the current Body of Knowledge effort by the American Society of Civil Engineers):
- Persuade ABET to drop its prohibition against dual-level accreditation, so that schools can seek accreditation of master's degree programmes in the same fields that they currently have accredited at the bachelor's level, in order to promote innovation in integrated bachelor's-master's programmes;
- Expand relevant continuing education opportunities, to facilitate life-long learning by graduates;
- Teach prospective engineering faculty members how to teach, as a part of their graduate education experience.

One major beneficial thrust for the improvement of engineering education programmes at all levels would be providing more opportunities for engineering faculty to get international experience by going abroad for research, educational and industrial experience.

What can be done in business?

Business leaders must interact with educators and government policy-makers in order to assure that technical employees of appropriate quality and quantity are available for employment. In the current environment, the impacts of globalization and offshoring require particular attention in business-university-government interactions.

Offshoring impacts

- Employers of engineers should be encouraged to develop rational, forward-looking approaches to determining what technical work to outsource offshore and what to retain in-house — considering issues such as innovation management, intellectual property security, strategic manpower deployment, etc., in addition to short-term financial advantages;

- Business leaders and universities should collaborate on revising the educational preparation of engineering students to prepare them to help companies move up the food chain as routine work is offshored;
- Recognizing that a significant number of current engineers will become unemployed, and possibly unemployable, due to offshoring of their jobs, business leaders should work with universities and government officials to develop and fund appropriate retraining programmes.

University-Industry interactions

- Business and university leaders should work together to close gaps between engineering education and the advanced state-of-the-art in practice;
- Where there are gaps between industrial developments and the abilities of universities to appropriately prepare graduates in rapidly moving fields, businesses should offer faculty development programmes (e.g., such as the programmes in quality management offered some years ago);
- Industry should continue to provide funding to universities for relevant research and development efforts;
- Opportunities for faculty members to spend time in industry should be encouraged by both businesses and by universities.

What can be done at the policy level?

Many of the recommendations and suggestions listed above would be facilitated by policy level decisions in the United States (Jones, 2004). Following are several suggestions:

- Encourage relevant legislative action to develop rational visa policies, in collaboration with business and professional society leaders;
- Provide financial aid to attract native students into the Ph.D. pipeline, tied to the national imperative to compete in the global marketplace (like the National Defense Education Act, initiated after Sputnik);
- Make creative use of funds from H-1B and similar visa grants to stimulate native students to fill industry's needs;
- Expand pre-college efforts at attracting women and under-represented minorities into the engineering education pipeline;

- Enhance the public understanding of engineering and its contributions to society.

CONCLUSION

The decline of interest of bright students for the study of engineering is the result of many factors — difficulty and lack of flexibility of the curriculum, their perception of the current employment environment where engineers appear to be treated as commodities, and reports of offshoring of many technical jobs. The need for a steady supply of engineering graduates well prepared to work effectively in the global marketplace is undiminished, however. University, business and government leaders must take coordinated action to assure the flow of well qualified engineering graduates in appropriate numbers in order to assure national competitiveness.

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