Educating Engineers in the US for a Global Workforce

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Abstract
Academic institutions throughout the world are called upon to prepare engineers to meet challenges as defined by industry, a nation, or the world. They shoulder a significant portion of the responsibility for defining the content, designing the delivery, and providing pathways to experiential learning. Each institution develops curricula to educate its students using the resources and talents at its disposal, and within the culture in which it is situated. The blend of diverse approaches is a strength. There are, however, some elements that are becoming increasingly important for all programs. Preparing students for a global workforce is one such component. Similar to other aspects of engineering education, the manner in which individual institutions address global preparedness is not, nor should it be, uniform. This paper summarizes current engineering enrollment trends in the United States, and discusses some viable strategies to prepare students in the US to enter a global workforce.

Keywords: engineering demographics, internationalizing curricula

1. Engineering education in the United States
In the United States engineering programs are offered at approximately 350 universities and colleges, which can be categorized as public or private, and further characterized by the highest level of study (doctoral, masters, baccalaureate, or associate) offered. Influenced by the engineering professional organizations, accreditation processes, and a higher education system in the US that is structured such that most engineering programs are part of comprehensive universities, (i.e., universities with a range of programs from the arts, humanities, and sciences, to those identified as the professions such as business and nursing), the study of engineering is comprised of foundational sciences and mathematics, engineering sciences and design, professional skill development, and a liberal education program composed of courses in the arts, humanities and social sciences.
Throughout its history, engineering, as a course of study, has reflected the shifts in interest among the college-age population. Engineering programs compete with other advanced fields for the best students, even though historically engineering has been viewed as a stable profession—routinely having one of the lowest unemployment rates (1.9% for recent engineering bachelor-level graduates [1]) along with competitive and desirable starting salaries. In spite of those attractive features, colleges, federal agencies, and industries recognize that investing resources to educate the pre-college population and the general public about the importance of engineering and the exciting career opportunities is a worthwhile endeavor and of national interest. Additionally because women and racial/ethnic minorities are underrepresented in the engineering profession, there has been considerable interest in increasing their representation in engineering—both for the value diversity brings when addressing problems requiring technical input and engineering solutions, and to ensure that the number of engineering graduates are able to meet the needs of an aging industrial workforce.
An overview of the engineering enrollment trends generally shows a positive trajectory for the future in terms of overall numbers; however, a mixed review emerges regarding the projections relevant to diversity. Briefly, undergraduate engineering enrollment declined in the 1980s and 1990s but began rebounding in 2000. Throughout the same time period, graduate enrollment was increasing, with the exception of a small decline from 1993-2000. More recently, the enrollment history of full-time engineering students illustrates an increasing trend as shown in Figure 1. Not included in the figure is the enrollment history in engineering technology. Somewhat smaller (less than 10% of the bachelor’s level engineering enrollments), engineering technology enrollments have also experienced an increase over the past five years—nearly 20% relative to 2005. Consistent with enrollment, the number of engineering degrees has been increasing over the past 10 years. Specifically, engineering degrees awarded have increased 25% with the gains greater for graduate degrees, which increased 40% from 2000 to 2009 as shown in Figure 2.
Figure 1 Full-time engineering and computer science enrollment in the United States (Source: American Society for Engineering Education [2])

Figure 2 Engineering and computer science doctoral and master's degrees awarded in the United States. (Source: American Society for Engineering Education [2])

The most recent report compiled by the American Society for Engineering Education [2] provides a picture of the demographics of the engineering and engineering technology student population both in terms of enrollment and the degrees awarded. For example, graduate degrees awarded to women are on the rise having increased from 16% in 2000 to 21% in 2008 for doctoral degrees, and from 22% in 2000 to 23% in 2008 for master's degrees. The percentage of bachelor's degrees awarded to women decreased over the same period (from 21% to 18%), although recent enrollment trends for women indicate that there is a slight rebound, so the percentage of women receiving degrees is expected to increase soon. The enrollment of underrepresented racial/ethnic minorities has remained steady or increased slightly for several years although the share of degrees awarded is not as consistent—the share of degrees awarded to African Americans decreased slightly and the share of degrees awarded to Hispanic Americans has increased.

International student populations have fluctuated over the past ten years; however the overall trend at the graduate level is that the percentage of international students studying at the doctoral level has increased. The most recent report indicated that 55% of the doctoral degrees were awarded to international students. The percentage of international engineering undergraduate students has held steady over the past several years [2]; however, the distribution of countries and percentage from each country has changed. Currently the largest number of undergraduate engineering students enrolling from countries outside the US is South Korea, followed by China, Japan, Canada, and India [1]. This distribution of international diversity provides a valuable opportunity to educate domestic students about international topics through the diversity that is a growing part of the undergraduate education community at academic institutions in the United States. An additional opportunity exists to enhance and expand the education of the international students, now part of the community, regarding the engineering profession in the US.

2. Opportunities and Approaches to Educate Engineers for a Global Workforce

Engineering in the US has changed over time, not only with regard to demographics but what the graduates are doing upon completion of their degrees. Undoubtedly, the engineering workforce has been influenced by emerging
economies, and shifting national strengths, evolving technologies, and increased technical challenges. The ability of the educational programs to respond to these changes has been dependent on the innovativeness of faculty, efforts of federal agencies and foundations to support those innovations, and the tight linkage with industry. That linkage has been influenced by workforce needs as well as an expectation that the research emerging from academic institutions is making its way to various industry sectors.

Along with the various influences on the engineering profession, several factors are influencing the opportunities to educate students for a global workforce. Some of the factors are based on specific needs while others are the result of the removal of impediments. Consider the following factors.

- Technology has assisted connecting people and social media has lowered communication barriers.
- Multinational companies which have a need to conduct global business have developed practices to effectively work across time zones and parse functions to subgroups, i.e., 24/7 capability.
- International research collaborations have nurtured relationships and formed foundations for expanding partnerships to include educational experiences.
- The intrinsic appeal to assist a humanitarian project has overshadowed student concerns of being in, and challenged by, another culture.
- Grand challenges identified by several leading professional organizations, e.g., the National Academy of Engineering [3], have raised awareness of global issues and the inherent global interconnectedness.

The case then for providing education that prepares students to be global citizens is not centered on the merits of whether a college should provide experiences for its students, but rather how to determine the most effective approaches to meet the individual institutional goals and the need of that institution’s student population. Most universities are moving toward providing an array of international experiences from which students can choose. As such academic programs are being modified to accommodate international experiences—either within the curriculum or as a co-curricular experience. At stake is the level of commitment required by the institution balanced by the breadth of student participation.

A report released in 2008 by Grandin and Hirleman included a summary from a National Science Foundation supported summit of academic leaders who expressed strong interest to enhance the international opportunities at their universities. The report includes a range of approaches that the participants contributed to the discussion at that time [4]. Without replicating here the list or the challenges they identified in implementing programs that support the international education of students, the following examples will be discussed to demonstrate how careful selection of approaches can meet multiple institutional goals and enhance the educational experience of students. Furthermore, these examples bring together two aspects involving the institution’s demographics. The first is how the institution’s international demographics may be leveraged to assist with the global preparation for students. The second is how the promotion of international activities may improve the institution’s demographics with regard to diversity. These examples have the added benefit of being economically viable for both the university and the student because the international experience is embedded in the curriculum or co-curricular activities without the cost of travel for the majority of students.

Example 1: A faculty member responsible for teaching a senior design course develops a partnership with an international (multinational) company which provides a design project to create a product that will be used worldwide. The faculty member also has identified and cultivated a relationship with an international institution which has a similar goal to provide a industry-sponsored project experience. Thus, the team of students is a multinational team comprised of students from two institutions, separated by culture, language and time zone. The student teams work throughout the semester using design tools and communication technology that assist them to complete the design, which they later report to the industry sponsor—perhaps as a bilingual report.

Example 2: A course requires the development of a product design for use exclusively in a developing country. Through supplemental instruction, students learn about the culture where the product will be used. They learn about designing a product—the development process and how to be mindful of the users’ needs. And they learn how to incorporate social and economic constraints. It is possible that, like organizations such as, Engineers Without Borders, a subset of the students would plan to visit to implement the design, or to gather additional information. Ultimately, many students would be involved in the project, but few would travel to the country. Whether through an organization or with university support, a subset of the students becomes part of a visiting team.

Example 3: A group of students recognized for their willingness to help other international travelers develop an understanding of the new culture they are going to experience or will experience, are organized to serve as international buddies—both for visitors to the institution or to their student colleagues who will be visiting other countries. When international study abroad or exchange students visit, the buddy program helps to familiarize the visitor to their new surroundings. If another student is planning on studying elsewhere, or implementing a project in another country, the buddy program identifies a student from that country and connects the two students so that the student who intends to travel can learn about the country from someone familiar with the culture and the customs.
These experiences are only a few of the potential approaches that provide opportunities for students to become more intimately familiar with different cultures. Through these programs, students learn from and with others, and the learning is situated in a context which has purpose beyond learning about the culture itself. The examples are not laden with costs, that is, the cost per student involved is low; however, for successful implementation, structure must be provided for the instructional component. Additionally, faculty commitment to the effort and a strong technology support system is necessary. Primarily a faculty member must be dedicated to the relationship with the other institution, the industry sponsor, or the humanitarian aid agency. The technology, in the case of project work, must adequately assist with communication and be sufficiently robust. Even with these matters addressed, the experience will not be as rewarding as if it the student had an immersive experience, but it is often this first experience which lowers (or removes) the barrier that sometimes gets in the way of a student pursuing the more intensive experience later. There is some evidence that the role of non-travel based exposure early in a student’s academic career increases the chance of a student to pursue an immersive experience later.

Finally, the type of project—either connecting to a real life situation through a humanitarian engineering project or product design—provides an experience which tends to appeal to underrepresented populations. These projects are in essence what the National Academy of Engineering was referring to in their publication Changing the Conversation, which stressed the importance of connecting projects that improve lives and make a difference. These projects take the conversation to the next level and connect the students with the projects.

3. Summary
The engineering profession is being shaped by external factors, many of which are increasing the need for engineering programs in the US to be intentional in their efforts to prepare students to be global citizens. The demographics of the engineering enrollments as well as increased mobility of students throughout the world allow greater connections and networks. This interconnectedness can serve to strengthen the international experiences of all students. Additionally, the network and ability to make a difference in the lives of others as an engineer present opportunities to promote the profession and increase the diversity of those studying engineering. Thus academic institutions have the opportunity, given the vast array of interest among partnering institutions, to meet strategic goals to enhance engineering and engineering technology education with international experiences at the same time they improve their ability to attract a diverse student population.

References

Biography
Renata S. Engel is Associate Dean for Academic Programs in the College of Engineering at Penn State. A member of the Penn State faculty since 1990, she is Professor of Engineering Design and Engineering Science and Mechanics, and she has served as Executive Director of the Schreyer Institute for Teaching Excellence. Engel’s discipline specific research includes computational modeling of liquid injection processes, polymer cure kinetics, metal powder compaction and powder compact strengthening via high temperatures. Through various collaborative efforts, she has affected changes in the engineering curriculum to incorporate elements of design in fundamental engineering courses. For her individual and collaborative contributions to engineering education, she has been named Fellow of the American Society for Engineering Education, and has received several teaching awards including the Dow Outstanding Young Faculty Award, the Boeing Outstanding Educator Award and the University's George W. Atherton Award for Excellence in Teaching. Engel currently serves as its President of the American Society for Engineering Education.