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Citation
Peter P. Rogers. 2008. Problems with Civil and Environmental Engineering Education in the U.S. Journal of Contemporary Water Research & Education 139(1): 3-5.

Published Version
doi:10.1111/j.1936-704X.2008.00010.x

Permanent link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:4099743

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 139, Pages 3-5, June 2008

Problems with Civil and Environmental Engineering Education in the U.S.

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> …work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance," has been widely attributed to the effects of technological change (National Academies, 2005, Executive Summary, p.1).

One important part of this "residual" has been the vast expansion of engineering and scientific educational efforts. Recently, however, in educational and industrial circles there is concern that we, as a nation, are not producing enough engineering graduates at all levels (undergrads, masters, and Ph.D.s). This is not only reported in the popular press, but also by leading institutions such as the National Academies (2005) in the report quoted above. For example, in 2004 more than 600,000 engineers graduated from institutions of higher education in China, and in India the figure was 350,000. For the U.S. it was about 70,000. Wadhwa (2006) and Freeman (2005) both dispute the accuracy of these numbers and point out that they are so far out of line with the real numbers as to cause mild panic among engineering educators and employers of engineers. Wadhwa's research led him to suggest that the more realistic numbers of graduates from four-year degree programs were for the U.S. 137,000, India 112,000, and China 351,000 (using a broader definition of basic engineering education). While these numbers do not lead to complacency, they make the situation a little less dire.

The conventional question is how to expand engineering enrollment at the undergrad and higher levels? Both Wadhwa and Freeman caution that this may be a naïve question. The more important question is why are so few U.S. students choosing to major in engineering and, even more importantly, why do so many of the graduates accept jobs outside of the engineering profession? The simplest explanation is the lack of financial incentives. In comparison with law and medicine, engineers fare extremely badly in terms of salary. Freeman reports that in 2000, the average pay for engineers was $91,000 compared to $114,000 for lawyers and $156,000 for M.D.s (in 2006 dollars, $106,000, $134,000 and $182,000, respectively). To account for differences in time spent in professional schools and post-doctorate training and whether the student was paid or supported on research grants or fellowships, Freeman showed that Ph.D.s in engineering and science had lifetime earnings deficits on the order of $3 million compared to doctors and $1.8 million less than lawyers over their professional lifetimes.

These financial incentives have some unintended effects as well. Since law and medicine make it extremely difficult for foreign workers to move into their ranks, but the engineering professions do not, the job market is open to a huge pool of foreign engineering graduates who can typically increase their income by a factor of as much as 15 by moving to the U.S. This bids down the wages for engineers. Both Freeman and Wadhwa do not see a great shortage of engineering skills in the U.S. because of the relatively free mobility of foreign engineering graduates. Clearly, wages for engineers would rise if entry were restricted solely to U.S. graduates. It is not obvious, however, that this would be desirable given our current reliance on foreign graduates[1].

There is also the "outsourcing" of both jobs and facilities. According to the National Academies study, during 2004 chemical companies shut down 70 facilities and tagged 40 more for closure in 2005 in the U.S., but of the 120 large chemical plants of $1 billion or more being built in the world only one is to be in the U.S. and 50 will be in China. For the cost of one chemist or engineer in the U.S. a company can hire five in China and 11 in India.

Assuming that the financial incentives could be improved, there remains the issue of support for student education and maintenance of engineering teaching and research at the universities. Unfortunately, two things are at work here – an inadequate expansion of research funding from all sources and the emphasis of government funding agencies on science over engineering in research funding. This has in itself induced an unhealthy bias against teaching engineering, even in engineering schools, because of the scramble for research funding leaning more towards the theoretical, or the hot topic subjects like global warming, at the expense of the more traditional concerns of engineering for the public sector.

Issues in Civil and Environmental Engineering

The issues surrounding civil and environmental engineering (C&EE) include all of the above plus some additional difficult problems. First, the major employer of these graduates is government service or consulting companies designed to serve the civil population. As a result, the salaries are significantly lower than the general engineering salaries mentioned above. In 2006 average salaries of $70,000 are reported[2]; this has to be compared to the average of all engineering salaries in 2006 dollars of $106,000. This is a major deficit far below average engineering salaries.

Over time, given the preponderance of foreign to U.S.-born Ph.D.s, the junior faculty in U.S. colleges of engineering is also becoming increasingly staffed with foreign-born teachers. The teachers tend to be more theoretically-oriented (for example, fluid mechanics rather than hydrology) because of the preferences of the major sources of research funding. This leaves the students with little connection to public infrastructure development and its needed research and management tools. The computer science taught in India and China is identical to that taught in the U.S., so is fluid dynamics, but the training for public sector engineering is radically different from what is needed in the U.S. Moreover, many graduate students upon graduation change their fields to more lucrative engineering and business fields.

Funding for academic research, which is essential to keep university programs alive, is either shrinking or not keeping up with inflation. One important difficulty with academic funding for C&EE is that there are no major sources of industrial support as there are for other engineering specialties. The high-tech industries such as information technology are major supporters of their own special areas. Because of the public sector focus of C&EE, there are few well-established private-sector research donors.

Fortunately, it will be difficult to outsource many of the C&EE jobs since there will still be a large demand for actual "hands-on and on-site" work. As mentioned above, importing trained professionals from abroad can readily fill the technical demands for these jobs – at the expense of the social dimensions of public sector engineering. So, the ease of filling the positions with low-paid foreign-born engineers perpetuates the low salary incentives, which in turn affect the recruitment of the best applicants away from undergraduate programs in C&EE at U.S. universities.

Since C&EE engineers often have to work at a detailed level directly with local governments, the foreign-born engineers are at a disadvantage over U.S.-born engineers because of their lack of socialization that must include small-town democracy, working with local governments, and citizen participation in the planning and design of the local environment. It cannot be stressed enough that in C&EE, a cultural and historic viewpoint is essential for training future engineers and also for developing relevant research programs.

Some Modest Suggestions for Change

Much has been written about the need to improve science and mathematics in the U.S. K-12 school system. This would certainly be a desirable improvement in scientific literacy, but it will not necessarily solve the problems that we see with

civil and environmental engineering education. Better industry-university collaboration on research and training has also been widely suggested. This would certainly help with the restructuring of faculty research away from basic sciences and more toward research applications. It could also help improve the engineering content of academic teaching and research.

The issue of incentives for both students and teachers has been of concern for some time. Improvement of the research climate suggested above will make it easier for universities to appoint trained engineers as teachers in engineering schools. A much more difficult problem to solve is how to improve the incentives to encourage students to enroll in engineering as undergrads and stay with it after graduation. As Freeman (2005) suggests, increasing salaries may help somewhat, but given the ease of access to these jobs by foreigners, it is likely to motivate the foreign-born even more. Perhaps a broadening of the management and economic skills of U.S. graduates (in addition to engineering) will give them an advantage in the job market. If this were coupled with scholarship support at the undergrad level, it may be possible to enroll or retain those star students who will fulfill the demands of 21st century engineers.

We also need to entice those government agencies (Corps of Engineers, Dept. of Interior, Dept. of Transportation, EPA, etc.) that are large users of the services of C&EE to help mentor the students. More co-operative arrangements would be an immediate and inexpensive way to improve understanding of civil-sector engineering by students and attract top students to those programs.

Finally, this paper should not be interpreted as an attack on immigrant engineers. There are large numbers of foreign-born C&EE engineers in the U.S. making great contributions to the engineering profession and to society at large. Indeed, without them our public infrastructure and institutions would be in an even worse state than they currently are. The plea here is for upgrading C&EE applied research, professional training, and remuneration for the practitioners.

Notes

1. By 2000, the foreign-born share of science and engineering was 17% of bachelors, 29% of masters, 52% of Ph.D.s less than 45 years of age, and 57% of all Post-Docs. By 2007, these number are expected to be even larger despite a downturn for a short period after 9/11 (Freeman, p.36).
2. http://www.interec.net/salary is one source, and the ASCE reports $73,000 for civil engineers in 2007.

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