A Survey of Engineering Education Outside the United States: Implications for the Ideal Engineering Program

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Abstract

Undergraduate engineering programs in twelve countries are surveyed to determine the status of engineering education outside the United States and to analyze the implications for the ideal engineering program of the future here in the United States. The items surveyed include the number of years required to obtain an engineering degree, title of the engineering degree, high school preparation for engineering programs, cost of education, completion rates for engineering degrees, entrance requirements, mathematical requirements, and support for laboratory work. The most notable aspects of engineering education outside the United States are:

- Stronger high school preparation and requirements in mathematics and science
- Longer period of time required for an engineering degree
- Advanced level of mathematics required in engineering programs
- Low cost of education

It appears that in most countries engineering education is more intense and rigorous than in the United States. In formulating the ideal engineering program of the future we must be sensitive to competing programs in the rest of the world.

Introduction

The purpose of this informal survey is to obtain a picture of engineering education outside the United States at the present time. This information can give us an idea of what other countries are doing with respect to engineering education , and may provide us with some clues as to how we should develop engineering education here in the United States. This survey is limited in scope (only twelve countries surveyed), with only one department and university sampled in each country. However since most other countries have centralized educational systems, the results should be fairly representative. The departments/universities sampled are:

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- **Argentina**-Electronic Engineering/University of Buenes Aires
- **Brazil** -Electrical Engineering/State University of Campinas
- **China** -Applied Mathematics and Physics/Beijing University
- **Germany** -Electrical Engineering/University of Hamburg
- **Israel** -Mechanical Engineering/Technion
- **Italy** -Automatic Control and Computer Science/Turin Polytechnic
- **Japan** -Control Engineering/Tokyo Institute of Technology
- **Korea** -Electronics/Kyungpook University
- **South Africa**- Chemical Engineering/University of Natal
- **Spain** -Signals, Systems, and Radio Comm./Polytechnic University of Madrid
- **Sweden** -Automatic Control/Lund Institute of Technology
- **Switzerland** -Electrical Engineering/Swiss Federal Institute of Technology, ETH, Zurich

The following eleven questions were included in the survey

1. Your name/department/country
2. How many years of study are required for an engineering degree in your country ? how many for a medical doctor? How many for a lawyer?
3. Do you limit enrollments by grades from high school ? By entrance exams?
4. What high school subjects do you require for engineering studies ? Circle appropriate items: advanced algebra(up to complex numbers), linear algebra, introductory calculus(analysis), geometry, trigonometry, physics, chemistry, other

5. Approximately what percentage of students who start engineering programs complete them ?

6. What are the annual costs (tuition or fees only) for engineering education

7. Are engineering students required to take social science/humanities courses ?

8. What mathematics courses are required of your engineering students ? Circle appropriate items: Integral and differential calculus, ordinary differential equations, partial differential equations, linear algebra, modern algebra(groups, rings, fields), complex variables, advanced calculus(real analysis), other.

9. What is the exact title of your engineering degree ?

10. Approximately what percentage of your engineering students are female ?

11. In general are your engineering(teaching) laboratories well supported ? Comment separately on technician support, new equipment support, equipment maintenance support, space, and faculty support.

Summary of Survey Results and Comments

- **Years of Study for Engineering, Medicine, and Law**. About 58% of the respondents indicated that **more than 4 years** were required for an engineering degree, with an average of **5 years** and a maximum of 6 years. Only China, Israel, Japan, Korea, and South Africa listed 4 years for an engineering degree. The average number of years required for medicine was **6 years** and for law **4 years**. It is interesting to note that medical education outside the United States requires only a slightly longer period of education than engineering education (one year more on the average) and legal education requires a shorter period of time(one year less , on the average). This can be explained , in part, by the fact that most countries do not require 4 years of pre-professional education as we do for medicine and law. However professional education outside the United States tends to be much more intensive, with few non-technical requirements.

- **Enrollment Limits**. Contrary to popular belief in the United States that all tuition-free schools in other parts of the world have very exclusive entrance requirements, over 41% of the respondents indicated that enrollments were open to **all their high school graduates**. However some countries, especially in Asia (for example, China, Japan, and Korea) require very high grades in high school and/or very difficult entrance exams.

- **High School Subjects Required for Engineering Studies**. As an indication of the high level of rigor required at the high school level for engineering studies, 92% of the respondents indicated that both physics and chemistry were required, 83% indicated that introductory calculus was required, and 67% indicated that linear algebra was required. Of course, all of these subjects are in addition to the usual algebra, geometry, and trigonometry.

- **Percentage of Students Who Complete Engineering Studies**. The average completion rate was 65% with highs from Korea(98%), Brazil(95%), Japan(90%), and Israel(85%), and lows from Argentina(15%), China(40%), and Italy(40%) .

- **Cost of Education**. An average of 42% of the respondents indicated that **tuition was free or less than $100/yr**(Argentina, Brazil, China, Germany, and Sweden). In most of the countries surveyed, private engineering schools are rare, and tuition at public schools, when charged, is relatively low i.e. Japan-$3,000/yr, Israel-$2,000/yr, Italy-$230/yr to $1,000/yr depending on income, Korea-$1,600/yr, Switzerland-$750/yr, and Spain-$600/yr.

- **Social Science/Humanities (SS/H) Requirements for Engineering**. On the average, 50% of the respondents indicated that there were **no SS/H requirements for engineering studies**. In many countries all non-technical subjects are completed at the high school level.

- **Mathematics Required in Engineering Programs**. In addition to the usual calculus and differential equations, most countries require courses in linear algebra (100%),

complex variables (83%), and partial differential equations (75%) of all their engineering students. Few schools in the United States **require** so much advanced mathematics. Indeed in a recent survey of control systems programs in the United States [1], only 50% of the programs reported even requiring linear algebra.

- **Titles of Engineering Degrees**. The titles of engineering degrees vary greatly from country to country. We summarize below the titles reported, together with the number of years required to obtain the degree. **Bachelor of Engineering**- 4 years (China, Korea, Japan); **Bachelor of Science in Engineering**- 4 years (Israel, South Africa); **"Degreed" Engineer** - 4.5 to 6 years (Germany, Switzerland, Argentina, Brazil, Spain, and Sweden); **Doctor of Engineering** - 5 years (Italy). It should be noted that the Doctor of Engineering degree in Italy is the first professional degree awarded and requires the writing of an engineering thesis. A separate degree is available , the Research Doctorate, for those wishing to obtain an advanced degree in engineering in Italy.

- **Percentage of Women in Engineering**. The average percentage of women in engineering for all respondents was **10%**, with a high of 25% for Sweden and lows of 2% or less for Germany, Switzerland, and Japan. It is interesting to note how low the participation rate is for women throughout the world, including the United States. In contrast, the participation rate for women in medicine and law has increased dramatically over the past few years.

- **Laboratory Support**. Since the responses here were difficult to quantify, we summarize only in a general way the responses received. Most respondents complained of poor support for instructional laboratories across the board. University budget problems were cited as the main reason for this poor support. A notable exception was Switzerland , where laboratory support was strong in all areas. Like many universities in the United States, it appears that support for laboratory experiences in engineering programs throughout the world is not what it should be. Many countries are now following the American model of

a very theoretically oriented undergraduate education in engineering.

Conclusions and Implications for Education in the United States

From the responses received in this survey it seems reasonable to make the following conclusions about engineering education outside the United States.

- A longer period of time(five years) is required for an engineering degree outside the United States. This is close to the period of time required for a medical degree(six years) and more than it is required for a law degree outside the United States (three years).
- A substantial number of foreign schools with little or no tuition, have open enrollment for all high school graduates with proper subject preparation. Notable exceptions to open enrollment are the Asian (Japan, China, and Korea) schools, where entrance requirements are very stringent.
- High school subject requirements for engineering programs are more rigorous than in the United States. Most programs require physics, chemistry, and advanced mathematics at the high school level.
- Most foreign countries have little or no tuition at public Universities.
- Engineering education focuses almost entirely on technical subjects , with little or no social science/humanities requirements.
- Engineering programs require much more advanced mathematics than in the United States.
- The most common title for a degree in engineering is not the bachelors degree, but rather the “degreed engineer”.
- The percentage of women in engineering is low , as in the United States.

- Undergraduate laboratory support is generally poor, also as in the United States.

We list next some possible implications of these survey results for engineering education in the United States.

- A need to carefully study the period of time required for an engineering degree, to insure that our degree is competitive with other countries. The norm in other countries appears to be that engineering education requires a period of education close to that of medicine (5 years versus 6), whereas here in the United States engineering education requires only one-half the period of time as medicine (4 years versus 8). See [2] for a detailed comparison of engineering and medical education in the United States. If one accounts for non-technical subjects in most 4 year engineering programs in the United States and the fact the foreign engineering programs are of longer duration and mostly technical, the period for technical subjects outside the United States is substantially greater (3 years in the US versus 5 outside).

- A need to insure that there are no financial barriers to engineering education.

- A need to require better science and mathematics preparation at the high school level.

- A need to require more advanced mathematics and basic science in engineering programs. It is generally recognized that stronger studies in these areas better prepare the engineer for new technological developments.

- A need to improve the undergraduate laboratory experience for engineers. This appears to be a world wide problem.

- A need to increase the number of women in engineering. This also appears to be a world wide problem.

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References

[1] P. Dorato and A. Feliachi, "Control system curricula in the United States: Results of two recent surveys," *Proc. IFAC Symposium on Advances in Control Education*, June 24-25, 1991, Boston, MA.

[2] B. Friedland and P. Dorato, "A case for the Doctor of Engineering as a first professional degree," *Engineering Education*, April/May, 1987, pp. 707-713.