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ENGINEERS SHOULD HAVE A COLLEGE EDUCATION[†]

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C. Judson King[*]
Center for Studies in Higher Education
University of California, Berkeley

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ABSTRACT

Many societal trends and needs call for engineers to broaden their outlooks, have more flexible career options, and work closely and effectively with persons of quite different backgrounds. Yet the education and general orientation of engineers have been directed inward toward the profession, rather than outward toward the rest of society and the world. Engineering education should change to create a broader outlook and understanding in graduates and thereby engender capabilities for linkages and more likelihood of advancement into management and/or movement into other areas. The appropriate steps include moving the accredited professional engineering degree to the master's level and building upon a liberal education bachelor's degree that is analogous to pre-medical education.

Drivers for Change

The environment for engineers and the nature of engineering careers in the United States are both changing in fundamental ways. The issues with which engineers engage have become more and more multi-dimensional, interacting with public policy and public perceptions, business and legal complexities, and government policies and regulations, among other arenas. This is the natural result of technology becoming more and more pervasive in society and politics. Examples abound in areas such as energy, the environment, communications, national security, transportation, biotechnology, and food and water resources. The engineer must now look outward and interact directly with non-engineers of many different sorts in many different ways.

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[*] The author is Director of the Center for Studies in Higher Education at the University of California, Berkeley. He is also Provost and Senior Vice President – Academic Affairs, Emeritus for the University of California system and Professor Emeritus of Chemical Engineering at Berkeley.

Industry is increasingly global, with the result that the engineer must understand and deal with other countries and other cultures. Globalization and rapid advances in information technology are also rearranging the world employment market and functions for engineers. Many jobs that have traditionally been typical entry-level jobs for US engineers are irrevocably going overseas, as we are reminded when we call help lines for assistance with computer software. US salary levels cannot compete effectively for those jobs in a world that is so thoroughly connected by high bandwidth communications. This situation will only become accentuated, given that China and India now have many times more engineering undergraduates than the US, and the US graduates only about 7% of engineers worldwide.[1] Yet the basis of the US economy is highly technological, and its needs for engineering input will only increase.

Another change that has occurred, more or less contemporaneously, is that the American professional workforce changes employers and even job functions much more frequently than in the past. This trend results from amalgamation, restructuring and downsizing of corporations, lower incentives for employees to remain with an employer for career-long employment, and less job security, as well as the attractiveness of start-up companies. Engineering is affected more by this situation than are most other professions.

As a result of these changes the interests of individual engineers and those of their employers are diverging. The individual engineer should have the wherewithal for flexibility and movement, whereas employers seek those analytical and synthetic skills needed in the current job function, with less concern for possible future functions or job mobility.

There is also a shift towards higher education being perceived as more of a private benefit than a public benefit. Put another way, it is being seen more as a benefit to the individual, as opposed to a general benefit to society. This is reflected in higher tuition and fees for public higher education, diminished state support for public universities, and pressures for academic merit being the sole criterion for admission. Whether this trend is good or bad is a subject for another forum, but the trend is real. To the extent that the individual has to pay the cost, the academic program should benefit the individual.

Traditionally, engineers have not been educated in ways that engender the flexibility to move into non-engineering areas or even into management. The standard route to management is to obtain the MBA after the BS or BE. Engineers are rare in Congress and other positions of public leadership. There have been relatively few among CEOs and other high-level decision makers.

The abilities of engineers to move into other areas and to work effectively with non-engineers are limited by the narrowness and inward-looking nature of their education. Engineering is typically the one undergraduate area that is not subject, or is much less subject, to the general education requirements that are common for other undergraduates. The rationale for this has been that the engineer needs to know the requisite science as well as engineering, and there is just not much room left for anything else in an accredited undergraduate curriculum.

[1] W. A. Wulf, "A Disturbing Mosaic," *The Bridge* (Washington, DC: National Academy of Engineering, Fall 2005).

When I received my undergraduate degree from Yale fifty years ago, I received a BE rather than the AB received by classmates in other majors. Whereas other diplomas were written in Latin, mine was written in English. I was in the School of Engineering rather than Yale College, the home of other undergraduates.[2] This reflected the ongoing controversy at institutions like Yale and Harvard over whether engineering belongs within a university or undergraduate college predicated upon a liberal education and, if so, in what form.[3] A related issue is how much liberal education, if any, should be in the curriculum for engineering students.[4]

The image of engineering as a chock-full and narrow curriculum has made it difficult to attract students with wider outlooks, interests, and learning styles. Interestingly, engineers are among the primary partakers of the relatively new Master of Liberal Arts continuing-education degree programs, suggesting that they perceive the narrowness of their own education in hindsight while mid-career. This image may well be a primary obstacle to increasing the number of women and minorities who become engineers. Yet the involvement of persons of all sorts is certainly needed for the future of the engineering profession.

What Changes Are Needed?

The best approach is simple in concept. The undergraduate degree should be a liberal "college" degree, and the master's degree should become the professional and accredited degree.

The Master's as the Professional Degree. There is no comparable profession for which the baccalaureate is the recognized principal professional degree or for which accreditation is primarily at the bachelor's level. The recognized professional degree, and hence the primary level of accreditation, is either the professional doctorate (e. g., medicine, dentistry, law, pharmacy) or the master's (e. g., business, public health, architecture).

Reflecting that fact, current engineering bachelor's curricula are the most crowded of all, despite their narrowness. It is no longer realistic to expect to be able to build a sufficient base of mathematics and science, provide minimal general education, and create a practicing engineer within the confines of a four-year bachelor's degree, yet that is still what we ostensibly do. We should instead establish the master's as the recognized and accredited professional degree and design a path of education that results in that degree in order for a graduate to be prepared to practice in the profession.

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[2] This organization has since changed at Yale such that the engineering departments are now within Yale College.

[3] See, for example, W. J. Cunningham, *Engineering at Yale: School, Department, Council, 1932-1982* (New Haven: Connecticut Academy of Arts & Sciences, 1992), written from the perspective of a long-term Yale engineering faculty member; Wikipedia, "Harvard Division of Engineering and Applied Sciences," http://en.wikipedia.org/wiki/Harvard_Division_of_Engineering_and_Appled_Sciences.

[4] The controversy regarding the interface between, and integration among, the professions and liberal education has much history and many dimensions. See E. F. Cheit, *The Useful Arts and the Liberal Education* (New York: McGraw-Hill, 1976).

For those institutions that choose to provide a professional program that provides more depth than the MS, the Doctor of Engineering remains an alternative. The PhD should continue to be a research-oriented degree and could build upon the master's or be an independent degree with its own path.

The Role and Nature of the Baccalaureate. The bachelor's curriculum should be a liberal, undergraduate "college" degree, allowing a wide choice of majors. All the other professional degrees mentioned above are built upon the base of liberal education at the bachelor's level. As much as anyone else, engineers need to understand society and the human condition in order to function well in working with others and to enjoy an enriched life. This would, in fact, be a return to the breadth aspects of engineering education in the late 1800s, when there was a full component of humanities and liberal-education subjects.[5] The change would recognize that the technical material to be learned has greatly increased since then, but that the need to start with a liberal undergraduate education has, if anything, increased rather than diminished.

One result of the changed structure would be that aspiring engineering students follow the general education requirements of the undergraduate college. Another benefit would be that students develop thinking and writing skills in a variety of contexts, not just engineering. During the undergraduate years the student should also be able to participate in an education abroad program, if the institution has one, and thereby gain direct involvement in the culture, tradition, and values of one or more other countries. All of these experiences, in addition to taking courses in a number of different departments together with students with a variety of backgrounds and educational aims, would serve to expose the potential engineer to a variety of outlooks and ways of thinking.

A recent NAE report recognizes the desirability of additional education and recommends a pre-engineering degree or BA in Engineering, followed by an MS that produces a professional or "master engineer."[6] The report states that, "industry and professional societies should recognize and reward the distinction between an entry-level engineer and an engineer who masters an engineering discipline's 'body of knowledge' through further formal education or self-study followed by examination." Accreditation would exist at both levels. Lengthening of the educational span is surely a step in the right direction. However, the report implies an undergraduate engineering degree as the path toward, or even a prerequisite for, the graduate, professional degree. The goals of breadth, flexibility, and ability to understand of a variety of modes of thought are better served by removing the constraint that the undergraduate degree be a degree in engineering.

No other profession expects a bachelor's degree in the same subject as a prerequisite or even the preferred path to the graduate, professional degree. However, in some cases graduate-level professional education does rely upon certain courses or categories of courses being taken at the undergraduate level. An example is medicine, which itself is a close relative of, if not a form of, engineering. Medical schools are in general agreement that an entrant to medical school should have completed courses in certain subjects. They do not encourage a particular major or group of majors at the

[5] Cheit 61-82.
[6] National Academy of Engineering, "Educating the Engineer of 2020" (Washington DC: National Academies Press, 2005).

baccalaureate level. Instead, they encourage diverse majors and often even take into account variety among backgrounds as a desirable criterion in composing an entering class. The same practice would be beneficial for engineering.

The typical required pre-medical array of courses consists of general chemistry, physics, general biology (including vertebrate zoology), and organic chemistry, each with laboratory.[7] Calculus, advanced biological sciences courses, humanities, and English composition are recommended. For the various engineering majors, it should be possible to identify similar sets of courses at the undergraduate level that are sought for entry into the graduate-level, professional major.

The Nature of the Master's Degree. The professional master's degree should logically be a two-year program, emphasizing courses in the particular engineering discipline, but also allowing some possibilities for the student to gain a deeper knowledge of science, or to take some courses, or even a minor, in areas such as economics, public policy, law, or business.

Even with the additional space in the overall curriculum created by the master's degree, it must be recognized for the engineering and science elements of the curriculum that knowledge grows exponentially and consequentially becomes more and more compartmentalized. A graduate cannot know all pertinent methodology and information that will be needed for an engineering career and must instead be able to locate, master, and learn it as needed. That fact must be recognized to a greater extent in the design of courses.

An Engineering Component in Liberal Education. A change to the master's as the professional degree need not imply that engineering faculty would largely withdraw from undergraduate education. There will be a continuing need for early courses that exemplify the nature of engineering. Beyond that, engineering courses can themselves be part of the general education program of a university. A notable new initiative along these lines is that of the Center for Innovation in Engineering Education at Princeton, whose goal is to expand their interdisciplinary courses such that over 90% of Princeton undergraduates take at least one engineering course.[8] Such steps would help greatly in creating more technologically literate leaders in the United States.

Going further, there could also be an engineering or technology liberal arts degree that would draw students with much wider interests and career plans. There are already such AB degree programs at Harvard, Yale, Dartmouth, Brown, and Lafayette. These engineering AB degrees are freed of the full math, science, and engineering requirements of the current ABET-accredited degree and are not intended as pre-engineering degrees. Graduates of these AB programs can proceed onward to a different professional degree, e. g., medicine, business, or law, or they can take any of the highly varied career paths pursued by liberal arts majors in general, with the added value of having had substantial direct exposure to engineering. An analogous situation

[7] See, e. g., College of Letters & Science, UC Berkeley, "Pre-Medical Preparation," http://ls-advise.berkeley.edu/pyyac/freshman/premed.html; and UCSF School of Medicine, "Course Requirements," http://www.medschool.ucsf.edu/admissions/apply/gettingstarted.aspx#courserequiremnts.

[8] Steven Schultz, "Rethinking Engineering Education," *Princeton Weekly Bulletin*, v. 95, no. 6 (17 October 2005), http://www.princeton.edu/pr/pwb/05/1017/.

applies to current undergraduate degrees in fields such as biomedical sciences, legal studies, and business.

A substantial number of engineering graduates come by way of the community college transfer route, which is also a promising avenue toward increased ethnic and gender diversity.[9] Conversion to a "college" baccalaureate and the master's as the accredited degree should provide much more leeway within transfer education, and thereby make that route much easier and more attractive to follow.

Accomplishing the Transition

Change will not be easy. The current bachelor's degree is well entrenched as the entry point for the profession. There is a cost for additional education, both to the student and to the institution. Most companies have been more than willing to hire bachelor's graduates in engineering. Some value the lower salary that goes with a BS engineering degree – another example of the interests of individual engineers diverging from those of employers. The restructuring proposed here benefits engineering graduates by giving them more flexibility and the wherewithal for higher salaries and rewarding careers. However, students have tended in the past to resist five-year bachelor's programs and combined BS/MS programs.

Offsetting the extra time and cost for students, to some degree, is the fact that they typically take four and one-half to five years to complete present-day bachelor's programs. With the proposed new structure, they should be able to complete the bachelor's degree reliably in four years. Depending upon the budgeting policies of the institution, much or all of the institutional cost may be offset by engineering departments receiving higher funding per student because of the shift towards graduate-level education.

Other professions provide evidence that change can happen. Medical education steadily lengthened, became more uniform, and made the bachelor's degree and pre-medical education prerequisite during the first half of the twentieth century, largely because of an evolving consensus among medical schools.[10] A similar, but less ordered, transition occurred for law.[11] Pharmacy was originally accredited at the bachelor's level, then added the doctorate as an alternative, and then in the year 2000 converted to the Doctor of Pharmacy as the sole entry-level degree for the profession.[12] Audiology has traditionally been accredited at the master's level,[13] but there is now a

[9] National Academy of Engineering & National Research Council, *Enhancing the Community College Pathway to Engineering Careers* (Washington DC: National Academies Press, 2005).
[10] B. Thorne, "Professional Education in Medicine", in E. C. Hughes, B. Thorne, A. M. DeBaggis, A. Gurin & D. Williams, eds., *Education for the Professions of Medicine, Law, Theology and Social Welfare* (New York: McGraw-Hill, 1973) 23-36.
[11] B. Thorne, "Professional Education in Law", in E. C. Hughes et al., eds., *Education for the Professions*.
[12] Accreditation Council for Pharmacy Education, "History," http://www.acpe-accredit.org/about/history.asp.
[13] American Speech-Language-Hearing Association, "Council of Academic Accreditation in Audiology and Speech-Language Pathology," http://www.asha.org/about/credentialing/accreditation/CAA_overview.htm.

strong movement toward use of the doctorate (AuD) as the professional degree, and a new accrediting organization has been formed for that express purpose.[14]

As for the other professions, a change in the accredited professional degree is ultimately and officially a matter for the accrediting agency, which for engineering is ABET. ABET, however, will consider and respond to the desires of its constituents and to whatever reality is in place. It would be a great help in this direction if leaders of the profession – NAE, leading universities, leading employers – promote the changes, and/or if some well respected universities simply make the change. Engineers are supposed to be the can-do people. This is an opportunity to prove it.

[14] Accreditation Commission for Audiology Education, "Mission & History," http://www.acaeaccred.org/Pages/MisnHis.html.