

Engineering: The Basic Degree of the Future

Sukhvarsh Jerath, Member ASEE
Professor in Civil Engineering
University of North Dakota, Grand Forks, ND 58202

Introduction

In the past the cathedral church schools engaged in the training of priests and clergy for their respective denominations. These schools evolved into universities upon the rise of scholasticism and the development of theology as a systematic discipline. The course of studies included theology, law, medicine, and what came to be known as liberal arts. The liberal arts included philosophy, logic, languages, natural philosophy and science, music, etc. There was a strong desire to found institutions of higher learning among the first European settlers of America to advance learning. In October of 1636 the general court of Massachusetts established Harvard College, the first institution of higher learning in America. Harvard's charter of 1650 referred to its purpose as "the advancement of all good literature, arts and sciences" and to "the education of the English and Indian Youth of this Country in knowledge: and godliness¹." Other colleges founded prior to the American Revolution shared the same broad sense of dual purpose as that enunciated by Harvard, namely, educating civic leaders and preparing a learned clergy. From 1636 forward, nearly 200 years, the major purpose of education in the American colleges and universities was to train the elite citizenry and to train ministers. The Morrill Act of 1862 signed by President Lincoln was responsible for the establishment of the Land Grant Institutions for the benefit of agriculture and the mechanical arts in the U.S. This act established the great state universities and the system of public higher education expanded in the U.S. After World War II, the college student population grew further and college was essentially open to anyone.

The traditional liberal arts degree with majors in arts, humanities, and sciences, has been the basic undergraduate degree in the 19th and 20th centuries. This degree has opened doors for the graduates for careers in business, education, government and industry. By 1940, a bachelor's degree had become the common level of education for most white-collar jobs and professions. As we look to the future, there is no question that we live in a technology dependent world. People working in every job, from multi-media classrooms to fully automated factories, will need some basic knowledge of modern technology. As it was necessary to promote literacy and basic education commonly known as liberal education for achieving success in the past, it will be necessary to have technological component in education to be successful in life in the future. In addition, engineering education imparts analytical, problem solving, and logical thinking skills that are very useful in many careers.

Today, the engineering colleges must not only provide their graduates with intellectual development and superb technical capabilities, but must educate their students to work as part of teams; to communicate well; and to understand the economic, social, environmental, and

international context of their professional activities. These changes are vital to the national industrial strength and to the ability of engineers to serve as technology and policy-decision makers. And just as important as their specific technical skills, engineers receive valuable preparation that is useful in other careers. A 1995 NSF survey found that only 38 percent of engineering graduates work as engineers. Most of the rest say that their work is related to engineering. Following the demands of the job market, engineers are choosing to enter into other fields where their skills are highly valued and rewarded. As technology's role increases in society, engineers, who possess a strong understanding of technology, are becoming assets in almost every field. Thus, engineering is an ideal undergraduate education for living and working in the technologically dependent society of the 21st century.

Engineers in Non-engineering Careers

Many engineering educators tout that “**engineering is the liberal arts degree of the 21st century**” because it provides students with the strong technical and problem solving skills that are needed in many fields². Many of our graduates may go on to do things other than technical work, but that is all right, and in fact should even be encouraged, because we need lawyers, economists, doctors, financiers, and others with engineering background - Marshall Lih, Director of the National Science Foundation's Division of Engineering Education and Centers³. In the U.S. liberal studies in the form of courses in the humanities, social sciences and sciences have been an integral part of engineering education. This is because engineering educators tend to stress the desirability of providing students with opportunities to broaden their understanding of humanity and society, and deepen their sensitivity. Because of this many non-technical fields are hotly pursuing applicants with technical skills and experience. To some extent engineering has always provided a foundation upon which to build other careers. Engineering education can be a very valuable training for non-engineering careers of law, medicine, entertainment industry, public policy, and finance, etc. Some people think engineering school is a great preparation for the non-engineering careers because of the analytical problem solving skills learned in engineering.

Patent lawyers, for instance, have long recognized the benefit of having a technical grounding. Patent law is a common choice for engineers as a career because it allows them to apply their technical skills to the law. Some people think engineering school is a great preparation for law school because engineering is so rigorous. Engineers turned into lawyers can understand the intricacies of the technical products better than others that give them an edge to fight the patent and copyright infringement cases. So much of modern medicine, such as laser surgery, MRI, CAT scans use so much of technical innovations that engineering education could be very helpful in health professions. Engineering background can be very helpful even for jobs in the entertainment industry where it can be used for designing state of the art theme parks containing different kinds of rides and amusement activities. In the music and recording industry engineering knowledge especially in electronics is very useful in creating different kinds of visual and audio effects. Engineers now work in the theatre industry designing high-tech theatre sets. In many engineering schools a systems approach is emphasized in which engineers examine social, political, and economic factors in addition to technical ones, and develop a range of

solutions. Such open mindedness is important in public policy work, because the optimal technical solution may not be very popular politically. For example engineers can quickly assume responsibility in the areas of Nuclear Waste and Environmental policies. They can work as staff members helping members of legislative or executive branch to enact legislation or implementation of policies in these fields. Engineers can be very helpful in translating complex technical information from the Department of Energy, Nuclear Regulatory Agency, NASA, and other federal government agencies for Congressional representatives, members of the President's cabinet and other Whitehouse staff. If successful the jobs will have very many rewards in terms of public service, opportunity to work in key public policy positions, and ability to influence the public policy of the nation.

Engineering can also serve as the perfect entry to a career in the fast-paced world of finance and Wall Street. Engineers are very proficient in quantitative methods and computer modeling of complex systems. These skills are very useful in analyzing huge databases of stock information and provide clients with useful financial information. Such skills are becoming even more valuable because of the availability of fast computers and ability to store huge amounts of data. Finance is a quantitative field, and is becoming more so, thus it is advantageous to have an engineering background. Engineering or other science and technology degree is great asset in the area of investment banking because it helps in analyzing the profitability, product lines, and other assets and liabilities of various companies. The overall analysis is very important before recommending the merger or divesture of different companies. Investment bankers with a background in science and technology have an edge over others in advising clients to invest in the initial public offering (IPO) of companies that are selling their stocks for the first time on a stock exchange. The most important of all is how engineers think and solve problems, which is very helpful in various professions.

New Expectations

“Restructuring Engineering Education,” a 1995 NSF report⁴, foresees the reform of undergraduate engineering education that will better prepare graduating engineers for entering a variety of professions. It recommends that the curriculum for every major should prepare graduates for two career paths. One that prepares graduates for the practice of engineering, the traditional curriculum; and the other will provide broad base education for non-engineering careers. While engineering education in the United States has served the nation well, there is broad recognition that it must change to meet new challenges. This is fully in keeping with its history of changing to be consistent with national needs. As per the NSF Report: “Engineering curricula should be broad and flexible, preparing students for both leadership and specialist roles in a variety of career paths. Each curriculum should be designed to develop graduates who are lifelong learners and contributors to the profession, fully capable of succeeding in the current and future global, multi-disciplinary marketplace. Further, engineering education should provide an opportunity for non-majors to study engineering topics and concepts and should work to make these studies accessible to non-majors.” The Report further states: “The new paradigm depicts engineering education as broad and forward looking. It describes an engineering education that offers a broad liberal education that provides the diversity and breadth needed for engineering;

and prepares graduates for entry into careers and further study in both the engineering and non-engineering marketplace; and develops the motivation, capability, and knowledge base for lifelong learning. Further engineering education must help develop technologically literate graduates of non-engineering programs.” The Report stipulates that engineering will have a broader service role within the university community with some engineering courses included in the general education requirements for non-engineering students.

In today’s world and in the future, engineering education programs must not only teach the fundamentals of engineering theory, experimentation, and practice but be relevant, attractive, and connected⁵. Relevant to the lives and careers of students by preparing them for a broad range of careers as well as for lifelong learning. Attractive so that the excitement and intellectual content of engineering will draw highly talented students with a wide variety of backgrounds and career interests. Connected through partnerships and integrated activities with K-12 schools; community colleges; the full breadth of the university; local, regional, and national communities; industry; and government.

There is a growing realization among engineering faculty that a new vision for the education of Engineers is evolving, a vision based upon the needs in the 21st century. The philosophy that forms this vision differs from the current more rigid and more uniform basis of today’s curricula. Curricula are usually defined in terms of required and elective courses. One way to prepare students for other fields is to urge them to choose electives that apply to the non-engineering aspects of careers they might wish to enter. The problem however, is that the typical engineering curriculum is packed with so many requirements that it leaves little room for non-technical courses. Some think the number of technical course requirements should be reduced so that students can choose more electives as per their career aspirations.

Development of New Curriculums

Criteria for accrediting engineering programs is governed by the Accreditation Board for Engineering and Technology (ABET), Engineering Accreditation Commission (EAC). The latest criterion is known as Engineering Criteria 2000⁶. As per this criterion an educational institution must meet the student quality and monitoring, program educational objectives, program outcomes and assessment, professional component, faculty competency, adequacy of facilities and institutional support in addition to the program criteria specific for a particular discipline of engineering. The basic traditional engineering curricula include basic sciences, humanities, social sciences, engineering sciences, an engineering specialty, and engineering design. One year (32 semester hours) of mathematics and basic sciences, which should include differential and integral calculus, differential equations, is required. Basic sciences must include both general chemistry and calculus based general physics with at least two- semester sequence in both areas. One-half year (16 semester hours) of humanities and social sciences are required. One and one-half years of engineering sciences and design (48 semester hours) are also required. The curriculum must provide the necessary knowledge base for life-long learning.

The Department of Civil Engineering and Operations Research and the School of Architecture at

Princeton University offer a unique program that integrates engineering and architectural design by combining the curricula of the two professional schools⁷. This certificate-granting program, designated “Architecture and Engineering,” and leading to a bachelor of science degree in civil engineering, is intended primarily for students interested in pursuing a career in architectural design or engineering from a broad base that includes course work and independent studies in building structures, history of architecture, and studio design. The structure of the program includes core engineering courses in math, science, and engineering science, core program courses in structures, core program courses in architecture, a group of four technical requirements picked from one of two lists (structures or architectural design), and seven electives of which one must be in architecture history. There are eight electives and four technical requirements included in the program. Regardless of which side of the program (structures or architectural design) that students choose, they graduate with strong academic experience in both architecture and engineering. They become engineers with an aesthetic sensitivity or architects with technical talent.

Following the logic that a technical background is useful in many careers, some educators are urging schools to offer a sampling of engineering and technology courses to all students. At the Princeton University⁷, a number of undergraduate courses have been initiated in both Civil Engineering and Architecture, which have helped to strengthen both programs. Some of these courses are: Structural Behavior and Model Analysis, Structures and Urban Environment, and Structure in Architectural History.

Few years ago Carnegie Mellon University changed their Electrical and Computer Engineering curriculum by reducing the number of required technical courses⁸. As per their catalog the Electrical and Computer Engineering (ECE) curriculum revolves around requirements in ten different areas:

<u>Area</u>	<u>Units</u>
1. General Education	72
2. Mathematics, Science, and Computer Programming	105
3. Freshman Engineering	24
4. ECE Core	24
5. ECE Breadth	36
6. ECE Depth	12
7. ECE Coverage	24
8. ECE Capstone Design (This can be a course used to satisfy ECE Depth or ECE Coverage)	
9. Engineering Elective	12
10. Free Electives	51
Total Units required to graduate	360

Note: 9 Units = 3 Semester Credit Hours

Those who want to go into engineering jobs can take more technical courses as electives. They kept the minimum number a faculty committee decided were required to become an engineer, freeing up almost a year for electives. The new curriculum allows students the opportunity to prepare for other careers by providing them the flexibility to decide what courses to take. Students can customize their undergraduate degree curriculum to meet their individual career goals with the help of their advisors. A student can get undergraduate degree in his/her area of interest which include Traditional Electrical Engineering (EE); Traditional Computer Engineering (CE); ECE Generalist; ECE/Engineering and Public Policy; ECE premedical Student, etc. by choosing a particular set of courses. The key to the flexibility in the curriculum is the availability of "Engineering and Free Electives." A student can get an undergraduate degree suitable for his/her career aspirations by including these electives in various combinations. The above mentioned is an example of a B.S. Engineering degree that is ABET accredited.

Universities in cooperation with their engineering schools can go a step further by making the degrees more general for non-engineers who desire to have a substantial component of technology in their education. The undergraduate degrees so obtained may not be ABET accredited because these will not be engineering degrees. These degrees will not be meant to pursue a career in the practice of engineering. But the education received will be sufficient to incorporate some of the engineering traits of analytical thinking, problem solving, mathematical modeling, etc. in the graduates.

Conclusions

The purpose of higher education in the U.S. since its beginning has been to prepare graduates to fulfill the societal need. In the beginning it was to train students to become clergy, and later on to fill positions generated by industrial revolution. During World Wars I and II educational institutions trained people to fight the wars. After World War II higher education has been in the forefront to meet other societal and national priorities such as cold war, environment, information and computer advancements, space exploration, etc. In the 21st century, college graduates will need to have enough technological background because we live in a technology dependent world. Engineering schools may need to change their curricula not only so they can better prepare students for their new roles, but also to expand enrollments in engineering. This will also increase the opportunities for engineering school graduates in the market place. Firms like Anderson Consulting have become hot new work place for engineering grads. According to a 1998 survey by the National Association of Colleges and Employers, 9.7 percent of offers made to students with technical majors came from consulting service firms, more than any other field. These firms are looking for people who combine technological know how with business acumen and communication skills. In the business world, the multi-talented have a clear advantage.

Bibliography

1. Hofstadter, R., and Wilson, S., American Higher Education, A Documentary History, The University of Chicago Press, Chicago, Illinois, 1961.

2. "Restructuring Engineering Education: A Focus on Change," Report of an NSF Workshop on Engineering Education, NSF, Washington DC 1995.
3. Penitz, Beth, "Evolving Paths," *ASEE Prism*, October 1996, pp. 23-28.
4. Penitz, Beth, "Opening New Doors," *ASEE Prism*, November 1998, pp. 20-25.
5. "Engineering Education for a Changing World," ASEE Project Report, *ASEE Prism*, December 1994, pp. 21-27.
6. Engineering Criteria 2000, Criteria for Accrediting Engineering Programs, Accreditation Board for Engineering and Technology (ABET), Inc., Engineering Accreditation Commission, Baltimore, Maryland.
7. Mark, R., and Billington, D.P., "Architecture and Engineering at Princeton University," *Journal of Architectural Engineering*, June 1995, pp. 93-96.
8. <http://www.ece.cmu.edu/undergrad/primer/overview.html> (Depart of Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA.)

SUKHVARSH JERATH is professor of civil engineering at the University of North Dakota, Grand Forks, ND. He is a member of the American Society for Engineering Education. He is a registered professional engineer in the states of Illinois, Indiana, Minnesota, and North Dakota. He worked in industry before joining academia, and his area of expertise is applied mechanics and structural engineering.