AC 2008-1129: RESPONSIVENESS OF ENGINEERING CURRICULA TO CULTURAL AND SOCIETAL CHANGES

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Responsiveness of Engineering Curricula to Cultural and Societal Changes

Abstract

Throughout history there has been a call for change in engineering education. Since the early 20th century, there has been a national concern for the state of engineering education as can be seen by reports by the Carnegie Foundation for the Advancement of Teaching, National Science Board, National Academy of Engineering, and National Research Council[1]. Much of the focus of these reports has been on graduate outcomes, with less focus on the attributes of the student entering engineering school. Previous research suggests that today's incoming students have a different set of abilities when they arrive at the university than those from previous generations. For example, they do not have experience working on lawn mowers and cars, but do have experiences playing advanced computer games. These different experiences result in different competencies. This change in student's competencies across generations led the authors to investigate the following research question:

> How responsive has the engineering curriculum and accreditation requirements been to cultural and societal changes?

Authors investigate the conditions of three time periods namely: 1800's to pre-world war II (apprentice, vocational focused), World War II to 2000 (engineering Sciences focused), and 2000 to present (outcome focused). The guiding questions that helped answer the main research question are the following:

- What experiences did a typical student have prior to entering an engineering program in each time period?
- What were the accreditation requirements during each of the time periods?
- What was a typical curriculum within each of the time periods?

Findings from this effort will provide recommendations to improve engineering curricula based on the experience and skills of the incoming student population and to eventually provide accreditation recommendations based on the findings.

Introduction

A search for the definition of responsiveness from dictionary.com[2] yielded the following: "the ability of a machine or system to adjust quickly to suddenly altered external conditions, as of speed, load, or temperature, and to resume stable operation without undue delay; and answering or replying". Therefore, to be able to meaningfully study curricula responsiveness to a cultural and societal change, it necessary to search and compare events and conditions surrounding those changes involved and the timeliness of the stimuli. American society has changed over time and changes have brought about unique needs. The responsiveness of engineering curricula and accreditation requirements to cultural and societal changes is critical, as a different set of cultural and societal circumstances result in a different set of experiences and beliefs by the student population. The study is grounded in the constructionist epistemology that specifies that meaning is socially constructed based on previous experiences, beliefs, and values.

A typical American high school student spends more time (44.5 hours per week) in front of computer, television, and game screens than any other activity in their lives except sleeping[3]. Fifty years ago a typical high school student spent a considerable amount of time outdoors playing or working on a farm or in a shop[4]**.** One hundred years ago, a typical high school student spent time on the farm or as an apprentice[5]. Youth engagements at these time periods show major discrepancies, particularly in the amount of outdoor versus indoor activities.

As the experiences of pre-college students change, it would naturally follow that students' learning or meaning making in college would be affected. This paper investigates the experiences of pre-college youth and the responsiveness of the engineering curricula and accreditation requirements in three time periods (1800's to pre-World War II, World War II to 2000, and 2000 to present).

Time period I (1800's – pre world war II)

What experiences did a typical student have prior to entering an engineering program in this time period?

Due to the decentralized educational programs early in this time period, youth education and experiences varied during this time period. Youth from New England states received formal high school education and additional apprenticeship experiences. The middle colonies had migrants of mixed cultures and its youth were educated in reading, counting, writing, and religion. Education in the south was influenced by societal class. The poor participated in apprenticeship training and some were educated in poor pauper schools, while the rich could enjoy education in the home, in private schools, or in schools abroad. According to Barlow (1967), public education in America was slow to develop. The awakening of the educational consciousness in the United States occurred about 1820. It wasn't until the 1870s that people accepted the concept of universal public education. Education at this period was goal oriented, with its goal being to develop skills that would make a livelihood for its graduates (p. 30). The Barre Academy's (1852) Catalogue stated that the practical intent of the academies was to provide youth "… the means of securing a sound, practical education for the business of life."[6]. A difference in opinion arose on whether to offer mechanical and industrial subject matter to all students or not. Horace Mann advocated for a free, public, and popular education to be equally available to all classes in preparation for a democratic life. In 1893, a Report of the Committee of Ten on Secondary School Studies recommended subjects for the high school that are still followed today, the including Foreign Language, mathematics, English, History, and Science[7]. Informal learning experiences were mostly agricultural related.

What were the accreditation requirements during this time period?

In the early part of this time period, apprenticeship was the major way of learning the engineering profession; hence guilds played a major role on establishing regulations on training[7]. After seven years of working under the guidance of a Craftsman and upon his recommendation, the apprentice would receive a Journeyman title, becoming a new member. After several years of exemplary work the Journeyman could seek the Master title. As a Master, he or she could teach an Apprentice[8]. The later part of this time period, formal engineering education at the university level was initiated. The first known formalized engineering school was opened in Schemnitz, Hungary in 1763[9]. The first American engineering course of study was founded in 1802 at West Point followed by Rensselaer College at Troy, New York, in 1824[9]. In 1862, The Morrill Land Grant provided funds for the promotion of agricultural and mechanical arts in higher education. No American accreditation body existed at the time; however, each state certified their programs. By the 1900's, engineers desired to achieve the recognition, prestige, and professional status that society accorded law, medicine, and other professions. In this move to professional status, engineers distanced themselves from craftsmen and workers using the certification of higher education[10].

What was a typical curriculum within this time period?

Guilds required an Apprentice to work under a Craftsman for a period of time to gain experience and to be proficient and competent in required skills. The formal engineering education approach involved formal courses, with the completion of a series of related courses resulting in expertise. The early engineering courses offered at West Point included arts of military leadership, tactics, and weapons use, mathematics of trajectories, construction of military fortresses, barracks, roads, and bridges, and the practical chemistry of explosives. Rensselaer College, a private college, provided scientific courses of agricultural study for local farmer's children. It also offered engineering degree programs and graduated its first civil engineer in 1835. Civil engineering was dominant through the 1880s, with mining engineers a sizable but much smaller specialization. Mechanical and Electrical engineering first appeared in the 1890s. The mechanical and agricultural courses were becoming increasingly important for the communities and the states as they provided an education for the workforce. These courses were offered to meet and exceed the needs of the emerging industrial revolution and for the preparation of better tooling for war equipment. Chemical engineering appeared in the 1910s in response to chemical needs for household use, medicine, and transportation sectors. Engineering seemed to be responsive to the needs at the time.

How responsive was the engineering curriculum and accreditation requirements to cultural and societal changes during this time period?

The transition from an apprenticeship to engineering education in higher education was a response to cultural and societal changes. The desire to achieve professional status within engineering was grounded in a desire to receive more prestige as other professions, such as law and medicine, receive. This resulted in a division between engineers and craftsmen, which is still apparent in the 21st century. A guiding assumption in this move from a more practical, hands-on education to an education with more science and theory was that students either had the requisite hands-on knowledge from their life experiences prior to college or that the students would gain this practical, hands-on knowledge in the workplace. As the US moves from an agricultural age to an industrial age, engineering education responded with a transition from an Apprenticeship education to a more formal, uniform engineering education higher education program. During this time period, engineering education was very responsive to cultural and societal changes.

Time period II (World War II - 2000)

What experiences did a typical student have prior to entering an engineering program in this time period?

Formal learning at the high school level required students to take Foreign Language, Mathematics, English, History, and Science. Informal learning equipped mostly boys with basic mechanical skills that had been acquired through engaging in the maintenance of simple machines or toys. Motor vehicle, motor bike, and bicycle maintenance provided opportunities to exercise their manipulative skills. Lack of similar informal learning opportunities for girls may have resulted in tendencies to seek non Science, Technology, Engineering, and Mathematics (STEM) degrees. Frehill and Bell (2006) study revealed an increase of women in STEM related work from 8% in 1950 to 26% in 2000[11]. Jacobs[12] and the National Science Board[13] observed that the "gendered" home environment is a factor in the low percentage of women (21%) in engineering today. Informal after school activities included student engagement in work and extracurricular activities. Employment opportunities in various businesses such as lawn mowing, painting, farming, fast food industry, and industrial or factory work provided the youth with skills they could transfer to the classroom's formal learning.

What were the accreditation requirements during this time period?

The Engineers' Council for Professional Development (ECPD) was established in 1932 providing guidance, training, education, and recognition for the engineering community. As an accrediting body, ECPD evaluated engineering technology degree programs in 1936 for the first time and within 15 years ECPD had evaluated 580 undergraduate programs in 133 institutions. ECPD considered that scientific oriented engineering curricula was essential and advocated for strengthening work in basic sciences, including mathematics, chemistry, and physics. ECPD was renamed Accreditation Board for Engineering and Technology (ABET) in 1980[14]. Five years later, ABET established the Computing Sciences Accreditation Board as a response to an anticipated boom in computer science education.

What was a typical curriculum within this time period?

With the accreditation process in place, curriculum was streamlined to provide uniformity of graduates. The breakdown of the curriculum in 1955 is provided in Table 1, showing emphasis in Mathematics, Chemistry, Physics, six engineering sciences, and an integrated study of engineering analysis, design, and engineering systems for professional background[15].

Table 1: Summary of Time Distribution for Scientifically Oriented Engineering Curricula

Item	Curriculum	Weight
1	Humanistic and Social Studies	One fifth
2	Mathematics and Basic Sciences (about equal weight)	One fourth
3	Engineering Sciences	One fourth
4	Sequence of Engineering Analysis, Design, and Engineering Systems, Including the Necessary Technological Background	One fourth
5	Options or Electives in (a) Humanistic and Social Sciences, (b) Basic Science, (c) Engineering Science, (d) Research or Thesis, (e) Engineering Analysis and Design, (f) Management	One tenth

How responsive was the engineering curriculum and accreditation requirements to cultural and societal changes during this time period?

During this time period there was a transition from the industrial age to the information age, and with this transition came an increase in the number of students attending universities and colleges. The accreditation requirements mirrored the industrial age's focus on mechanization, with strict guideline as to the types and amount of courses required for an engineering program. The accreditation requirements and resulting curricula were rigid which mirrors the industrial age and the post-war era.

Time period III (2000 - Present)

What experiences did a typical student have prior to entering an engineering program in this time period?

In the formal arena, the subjects recommended by the Committee of Ten in 1893 are still followed; these subjects include Foreign Language, Mathematics, English, History, and Science[7]. The use of technology in the classroom has shifted from chalkboards to smart boards and Computer-based instruction. Outside of the classroom, it is increasingly common for students to participate in engagements such as sports and/or math and science clubs where projects and competitions take place to promote learning. Most American children and teenagers have a personal computer in their house and are well versed using the computer at a young age. Additionally, video games have become more popular than movies in America resulting in young people developing a different set of skills than those of 50 years prior.

What were the accreditation requirements during this time period?

In 2001, ABET began holding engineering schools accountable for more than just teaching the required subjects; engineering schools are also now accountable for what students are learning[14]. ABET requires that graduates meet a specific set of outcomes (knowledge, skills, and attitudes) in addition to outcomes that address the individual program's educational objectives. ABET Engineering Criteria requires that graduates of accredited programs possess

> (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as analyze and interpret data; (c) an ability to design a system, component, or process to meet desired needs; (d) an ability to function on multidisciplinary teams; (e) an ability to identify, formulate, and solve engineering problems; (f) an understanding of the broad education necessary to understand the impact of engineering solutions in a global/societal context; (i) a recognition of the need for and an ability to engage in life-long learning; (j) a knowledge of contemporary issues; (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (ABET).

What was (is) a typical curriculum within this time period?

As an example, the mechanical engineering curricula will be used to illustrate a point of a specific engineering program. Ten randomly selected Research I universities were used in the study sample were examined to select a typical mechanical engineering curriculum[16-28]. The mechanical engineering curricula at the University of South Carolina was selected as a typical engineering curricula ("ME Bachelor"; "2001 Curriculum Electives")

A typical American curriculum consists of liberal arts, mathematics, sciences, and engineering sciences courses. Design does not appear in a typical American curriculum until the junior year. In the American curriculum, some basic science courses are required (Chemistry I, Chemistry II, Physics I, and Physics II). The American curriculum consists of 9 electives (21.4% of the total curriculum). While these are called electives, they are actually very prescriptive. The electives consist of a history elective, a freshman elective, an ethics elective, a technical elective, liberal arts elective, fine arts elective, and three mechanical engineering electives.

How responsive was the engineering curriculum and accreditation requirements to cultural and societal changes during this time period?

In America, the industrial age continued to depart as the information age became dominant and globalization became a way of life. Along with this change, a complete overhaul of the accreditation requirements, resulting in ample opportunity for curricular to change as well. The accreditation requirements EC 2000 are much more flexible than previous rigid requirements. While most curricula have not changed substantially, there are multiple examples of engineering curricula changing drastically to meet the needs of today's engineering students. Most universities are predominantly focused on engineering sciences instead of a focus on hands-on practical activities[10].

Conclusion

Responsiveness involves a complex system as an input is processed through an event to provide an output. From the cases above, the input was the student; the event was the curriculum; and the output an engineer. The student brought to the event experiences gained from formal learning and extracurricular activities. The curriculum was based on assumptions of what the student experiences had been and how they would be built upon to develop an engineer, a response to industry or governmental need. The event or link in a response system is crucial for it makes the system complete through its connection. From the literature review and authors experience, it seems curriculum response for time periods I and II was timely. A lag seems to be experienced in time period III where engineering sciences curriculum that was developed for time period II dominates while student experiences have changed from physical oriented to computer based activities. Authors recommend two studies, first, a study to compare to what extent knowledge is acquired using computer based activities versus physical manipulation of apparatus; and second, a study to investigate relationship between student preparedness and student grasp of engineering concepts upon graduation.

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