A Perspective of the Forces Driving Change in Engineering Education

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Abstract – The authors describe a number of forces that have been steadily gaining momentum over the last few decades and have the potential to significantly impact the engineering education landscape well into the future. Recognition of these forces and their characteristics is an essential foundational step in developing well-conceived strategies to face challenges posed by the individual and collective effects of these forces. Technology is an example of a force that has demanded continuous and creative implementation at a high cost to meet the needs of today's students. Other forces include knowledge of how people learn, accreditation, the economy, student populations, and global challenges. The paper discusses these forces and the impacts that they have had on the direction of engineering education.

Keywords: Technology, accreditation, economy, global challenges

INTRODUCTION

This is a great time to be an engineering educator as well as a challenging one. Over the last several decades, a number of forces have dictated a shift in the thinking of educators with regard to teaching. However, the educator's challenge has remained the same and that is: we are educating engineering professionals to use tools and knowledge that may not even be currently known, using ever more limited resources.

The total time that the two authors have been in engineering education is well over 50 years. During this period they have seen and experienced change in the delivery of education primarily to civil engineering students. Both would argue that they teach and think about teaching quite differently than they did when they entered the teaching profession. In addition, both authors have held administrative positions where they have had leadership roles in directing change at the department level, and one of the authors has served at the School level as well.

Within the last decade, several forces have been driving change at a rapid pace. This paper will summarize these forces and project the ramification of these changes to engineering education. Changes that will be discussed include the use of technology, increased knowledge on how people learn, outcome based accreditation through ABET, the impact that the recession has had at institutions of higher learning, the ever-changing demographics of the student population, and global challenges that countries such as China and India have on the direction of engineering education. These changes are shown in Figure 1.

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TECHNOLOGY

Many important developments in engineering education in the last three to four decades have been associated with technology. When the authors began their study of engineering, slide rules and computer cards were among the available technologies. The advent of the calculator (the first author bought a four function one for $400) signaled a rapid advancement in computing technology. Within a relatively short period of time, personal computers and floppy disks were widely available for student use. Over the years, 8" floppy disks gave way to 5-1/4" to 3-1/2" disks; later, other portable storage devices such as Zip drives, CDs, and thumb drives became available. Memory as well as CPU speeds have also been increasing at a dizzying speed of innovation and production. Of all the forces driving change in engineering education, improvements in technology demonstrate clearly to the authors of this paper that "we are educating engineering professionals to use tools and knowledge that may not even be known" since none of this existed when they were first introduced to engineering.

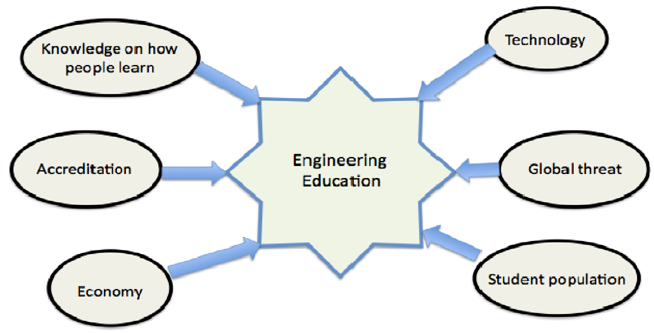

Figure 1: Forces of Change

Engineering education can be significantly impacted by multiple decisions that are made concerning technology. These decisions include which technologies are incorporated into the engineering classroom, how engineering educators respond to pressures from industry, how issues related to distance learning are addressed, how information will be delivered to students, and how social networking is used in teaching students. These decisions are discussed briefly below.

Now that almost everyone has a computer, engineering educators must address the question of how to effectively use computers in the education of our students. For example the first author of this paper is a structural engineer who was taught a number of different ways to compute the deflection of a beam (double integration, moment area, virtual work, conjugate beam etc). This was because computations at that time were limited by the capability of the slide rule and each of the above methods had their advantages in promoting the ease of the mathematical operations. However, with the software Mathcad, the method of preference on all the deflection problems has become the virtual work method. From the perspective of the engineering educator, the question has now become "What should be taught in the engineering classroom?" especially when considering shrinking the curriculum or adding additional topics to an already packed curriculum. These are tough decisions and not easy to make.

In addition there is significant pressure from industry to teach the latest and greatest software. One example of this is the teaching of Computer Assisted Drafting (CAD) using programs such as AutoCAD. In the past, a Civil Engineering curriculum usually had a least one course in drafting. Although these courses were used in the context of engineering education as opposed to training draft-persons, Civil Engineering programs have so far been able to incorporate a certain amount of CAD software into their curricula. However, because CAD software now interacts with other programs used in design (for example subdivisions, structural analysis, and not to mention Building Information Management-BIM software), the pressure from industry is increasing to at least acquaint the student with these programs as well. The challenge faced by the engineering educator is to continue to stress concepts essential to a civil engineering career while integrating engineering tools that industry would like for its employees to have.

One of the technological driving forces that promises to change engineering education is distance learning. As will be discussed in the section on the economy, many administrators are seeing distance learning as a way to increase revenue to their institutions. There are many issues that must be resolved before this becomes a reality. For example, some of these issues are reward systems, intellectual property rights, motivation of student population, marketing, and fee structures. The effectiveness of distance learning and its impact on engineering education depend upon how these issues are addressed.

Another important consideration connected with the use of the computer is how information is delivered to students. Examples include simulation software to replace laboratory experiences, emailing and other tools for communicating to students, and the use of the Internet versus books, periodicals, journals, etc. as a resource for students. Information will be readily available; the challenge of education will be to provide the intellectual skills for the students to critically evaluate this information.

No discussion of modern technology would be complete without at least mentioning the social networks that students are so familiar with today. How can Facebook , Twitter, You Tube, and other similar services effectively be used to enhance education? How well this question is answered by engineering educators may provide benefits in effectively connecting with students and motivating them to progress in their academic and professional careers.

Most of the examples discussed in this section relate to computer technology. There are of course other examples that could be mentioned, but these should suffice to highlight the critical importance to engineering education of evaluating new technology and how it can be incorporated into the curriculum.

How People Learn

The authors recall from their undergraduate experiences a number of courses in which the professor's lectures were the primary mode of delivering educational material. Students were looked upon as empty vessels and the teacher's job was to fill this vessel. This is still the primary mode in the delivery of engineering education, but due to large strides in psychology and educational research there has been significant progress in the learning process [1, 8, 10, 14, 15, 22]. Teaching appears to be moving from a professor-centered model to a student-centered model [22]. In other words, the focus in the student-centered model is on the facilitation of learning instead of the teaching. Part of the engineering educator's tools in this model include such types of learning and teaching styles as cooperative and student team teaching and students teaching students. Two excellent books on this subject are *How Students Learn—History, Mathematics and Science* [14] and *How People Learn* [15], both published by National Research Council.

One area of research in which the authors have an interest is how to transform novice learners to expert learners [15]. This is in fact the goal of education. When one considers education from this framework, it modifies one's view of the student and forces the facilitator of learning to rethink the overall process, placing an emphasis on the learning process and not on the material/content. This is yet another issue with which the engineering educator will have to deal in designing the curriculum.

There is a growing body of educational material on the learning process and the engineering educator needs to keep abreast of this material as well as the material associated with the educator's specific engineering discipline. The authors are excited about the universities that are providing opportunities for graduate students interested in pursuing engineering education careers to obtain a PhD in Engineering Education. Examples of these institutions include Virginia Tech, Purdue, Clemson, and Utah.

Finally, it should be noted that a special application of the student-centered model mentioned above is teaching students that are learning challenged. From a legal standpoint, accommodations must be provided for learning challenged students. However, today's student-centered professor would recognize that not all students learn at the same rate. This, after all, is a major conclusion from all the research in education and psychology. Further, students come to class with their own view of the material a professor wants them to learn [22].

There is a great deal of momentum in engineering education focused on understanding how people learn and how teaching styles can help facilitate the learning process. For the momentum to continue, engineering educators must be willing to invest the time required to adjust teaching styles and institutions must be willing to reward these efforts.

Accreditation

Accreditation at the college/university level (SACS) and at the school level by Accreditation Board of Engineering and Technology (ABET) has been and will continue to be one of the most persistent driving forces for change. The first engineering accreditation document prepared by The Citadel in 1937was just five pages long. Clearly anyone who has gone through the process lately knows that the volumes have increased considerably. Prior to 2000, the accreditation process was basically a "bean counting" exercise. However, in this new century the process has become more of an overall assessment exercise (with some "bean counting"). This has created a considerable shift of responsibility to the faculty to perform assessment of various components of the educational process.

In the very near future (if not already), the engineering educator will be required to provide evidence that the students are really learning. To accomplish this, an engineering educator will need to begin to perform educational research. Although such research is not presently held in high regard especially by Research I and II institutions, it is anticipated that this will change in the future--again driven by accreditation. In other words, the Scholarship of Teaching [7] as described by Boyer and the Scholarship of Assessment [5] as defined by Banta will become more important. Lastly, the ASEE initiative "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education" [4] establishes a framework for the consideration of this type of research in tenure and promotion decisions.

ECONOMY

The recession has changed the entire economic landscape of the world. Education has not been immune to these pressures. Since education is considered long-term by many stakeholders, it might have borne more than its share of the pain. For example, in about 1997, The Citadel received 44% of its funding from the state of South Carolina. It now receives about 9.5%. This has necessitated increased class sizes and even furloughs of professors and staff. The bottom line is that everyone is expected to do more with less.

For example, to reduce financial stress College administrators and faculty members may be expected to seek additional funding sources. There is a trend for more accountability and justification especially in taxpayer-supported institutions. Although this is not necessarily negative, it nonetheless places an additional burden on already time-strapped faculty members. Paradoxically, tuitions continue to rise (as support from government continues to decrease) while the same government adds pressure not to increase tuitions to keep college affordable for its citizens.

Because economic forces cannot easily be ignored, these forces, when present, will continue to play a significant role in shaping the face of engineering education. While there is often a need to respond quickly to these forces, engineering educators will need to be patient enough to develop long-lasting well-conceived solutions.

STUDENT POPULATIONS

When the authors graduated with their first degree in engineering, there were very few women and minorities in engineering. Regretfully, although the picture has changed somewhat, it is not where it should be. The complex problems that engineers will have to solve in the future require a diverse team that brings to the table various views. Females make up 60% of the college population [12], but make up only 20% of the engineering graduates [12]. Clearly the proportion of women being attracted to the engineering profession is significantly smaller than the women going to college. This disparity must be improved. Similar numbers exist for African-Americans [12].

Following the publishing of "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" [13], an emphasis has been placed at the national and regional levels on STEM (Science, Technology, Engineering and Mathematics) education especially for underrepresented groups. However, much more work needs to be done to attract these groups to the field of engineering.

One other group that has become significantly important is the adult learner. The economy is forcing the workforce to change gears in their career goals. The older student is returning back to college either to retrain for a new direction in their career or to obtain additional education to make themselves more marketable. Engineering programs need to provide these opportunities through short courses, certificates, and evening graduate programs.

The engineering profession needs to change the message [6, 12, 20] of the contribution of engineers to society. Specifically, although employment opportunities are still important [9] to stress (especially in today's economic environment), we need also to stress how engineers improve the quality of life. This is a message that resonates with young people.

This is the bottom line: in this complex society we need to have everyone at the table.

Global Challenges

At present, the United States has the strongest economy in the world. Its GDP is about twice what the second-place economy has (China). However, the U.S. economy is growing at a rate of 2-3% per year whereas the Chinese economy is growing at a rate of 10% per year. At this rate, China will overtake the US in the not so distant future. Further, China (as well as India) is now producing many more engineers than we do each year. Wadhwa [21] reported in 2007 that the United States graduated 137,437 engineers, India produced 139,000 engineers, and China produced 361,270 graduates.

Our institutions of higher learning are still the envy of the world [9]. However, other countries are recognizing the need to have a high quality education. This is going to increase the difficulty of attracting foreign students to come to the U.S. to live and contribute their talents to help our economy grow. Couple this with tougher immigration laws and the problem is magnified.

The authors believe that the country's engineering programs need to stress leadership and team work [2, 3, 16, 17, 18] to maintain a leadership role in the world engineering market. The country is still the hub for innovation and creativity, but without an emphasis on leadership this advantage could easily be lost. The question becomes, "How are we going to adapt our curricula to do this?"

Concluding Remarks

The authors have attempted to present a summary of some of the forces and challenges that they have seen in engineering education. To develop strategies to meet the challenges of the future, one must be able to identify the forces that will change the landscape of education. Knowing these, one can develop short and long-term strategies to prepare their organization for the future.

There is no question that technology will continue to change and develop. If the past is any indication of the future, what technology will look like in the future can only be staggering. The engineering curriculum will have to provide more skills in leadership, creativity and innovation. Perhaps there will be significant emphasis on systems engineering (holistic education) [11].

There will be a stronger emphasis on learning. The scholarship of assessment and the scholarship of teaching will become prominent in the engineering education profession.

There must be a significant effort to recruit underrepresented groups to the engineering profession. The authors are particularly pleased that the National ASEE organization has made this one of its major initiatives. The bottom line is that there has to be more diversity in the profession. To accomplish this it is necessary to change the message concerning careers in engineering.

Finally, there is no question that engineering educators will continue to be asked to do more with less for the foreseeable future.

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