Skills Gap: Understanding the Transition from Secondary School to the University

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Abstract

Record numbers of students are flocking to engineering with the promise of high salaries and plentiful jobs. Unfortunately, these students are entering engineering programs across the country with a wide range of skills, many of which are lacking. The level of preparation a student brings to the university from the secondary schools directly affects their probability of success in an engineering program. According to observations and research, students' math skills are weak, they have too much confidence in their own abilities, they lack discipline and study skills to be successful, and do not have experience with teamwork to name a few areas of deficiency. While there are more "Skills Gap" topics, many of these areas are targeted under the ABET assessment and must be addressed in university engineering programs. The question arises as to what can be done to better prepare these incoming students for their college experience. This paper highlights some of the programs that are being accomplished in high schools across the country to address these gaps. Programs such as the FIRST Robotics Competition and Project Lead the Way are highly successful. The paper also highlights three innovative high schools in the Waco area that are addressing these issues with limited success. Lastly, the paper outlines several new activities at Baylor university to encourage students to become engineers. One such program is the mentor program that is being undertaken by Baylor University student organizations in engineering to address some of these secondary schools' needs.

Introduction

There is a shortage of engineers, or so we are led to believe by recent headlines in the media. The bottom line is that engineers are in short supply and the demand is increasing. Current headlines point to the fact that the world is headed for certain doom because of the perceived shortage. "Airbus Seeks 500 Engineers: Company having trouble finding applicants in Europe,"[1] "U. S. Aerospace Industry Facing Labor Shortage,"[2] and "Brain Drain Could Ground Aerospace Production: Industry Task Force Offers Dire Warning if Workforce Challenges Aren't Met"[3] are but a few of the headlines that reflect this need. However, other headlines just a few years earlier indicated otherwise or that the cause of the lack of engineers was unclear. In 2005, Bill Schweber wrote that there is "No Shortage of 'Engineering Shortage' Talk"[4]. At this point in time, the media was saying there were too few students in math and science and that the perception of engineering discourages students from pursuing the profession. Schweber points out that most people were caught in a circular reasoning: an insufficient number of people were entering the engineering field which leads to companies recruiting overseas which leads to a poor job outlook for U. S. engineers which leads to an insufficient number of people entering

the engineering profession. Shortly after Schweber's article, Katrina Arabe, in an article titled "Newsflash: There is NO Engineering Shortage,"[5] pointed out that at the time, no one knew how many engineers would be needed in the future so how can there be a shortage? The Ronaoke Times published an article that was titled "Shortage or Surplus?"[6] in 2006 which highlighted that times were getting tougher and finding qualified engineers was difficult, however, the article also highlighted that engineering programs were increasing in enrollment so time will tell if this is enough. All of this added to the confusion. The debate still rages today. Whether or not you believe in an engineering shortage, today is an outstanding market for graduating engineering students however, the situation does not ask the obvious questions of how did the country and world get in this position and, more importantly, how are we going to insure a supply of engineers for the future?

The study published by Duke University's Pratt School of Engineering titled "Where the Engineers Are" compared aspects of engineering education in the U. S. with that of India and China[7]. According to the study, the U. S. graduates approximately 70,000 engineers a year while China graduates 600,000 and India, approximately 350,000. The study goes on to discuss that data from China and India are not very reliable. The definition of "engineer" also varies. When one compares qualities that engineers from each of these countries possess, several are common, such as strong educational background. Engineering graduates from different countries, though, possess other skills that are unique to their particular educational system. In China, cost savings and willingness to work long hours are qualities instilled in engineers. For India, cost savings, English language skills, ability to learn quickly, technical knowledge and work ethic are strong characteristics. Lastly U. S. students possess a very different set of skills such as strong communication skills, an understanding of U. S. industry, a desire to challenge the status quo, strong technical skills, superior business acumen, and a sense of creativity. Obviously these are the skills valued by the U. S. educational system. How are students exposed to these skills and where should exposure to these skills occur?

ABET has given a list of outcomes that point to qualities necessary for successful engineering students[8]. Those outcomes are listed below:

> Outcome a: "an ability to apply knowledge of mathematics, science, and engineering"
> Outcome b: "an ability to design and conduct experiments, as well as to analyze and interpret data"
> Outcome c: "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"
> Outcome d: "an ability to function on multi-disciplinary teams"
> Outcome e: "an ability to identify, formulate, and solve engineering problems"
> Outcome f: "an understanding of professional and ethical responsibility"
> Outcome g: "an ability to communicate effectively"
> Outcome h: "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context"
> Outcome i: "a recognition of the need for, and an ability to engage in life-long learning"
> Outcome j: "a knowledge of contemporary issues"

> Outcome k: "an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

Since these skills are important in the university setting, these are the skills or qualities that should be also pursued in the high school setting to encourage the students to be successful at the university level.

Today, in spite of all the technology and educational emphasis surrounding secondary school students, freshmen entering into the university to study engineering are not prepared for what they face. High school student believe they are technology literate because they have a cell phone but few have ever pondered how the cell phone works or how they are able to talk, or should one say, text their friends. Most students know how to use a computer but few have taken the time to "look under the hood" and see how it works. Students are very proficient at computer games such as Guitar Hero and Rock Band but few have ever thought about the computer programming and hardware interface required to achieve this graphic display. After teaching freshman engineering for a number of years and observing the skills of recently entering freshmen, the question becomes are the secondary or high schools doing all they can to interest students in a university engineering degree? What skills are necessary to help high school students develop the skills and make the transition to a successful university academic career?

Defining the Skills Gap

Faculty teaching introductory freshman engineering courses indicate that there exists what some would call a "Skills Gap" referring to the lack of skills that graduating high school students are bringing to their engineering college experience. Skills Gap in an organization can be defined as:

> "…a significant gap between an organization's skill needs and the current capabilities of its workforce. It is the point at which an organization can no longer grow and/or remain competitive in its industry because its employees do not have the right skills to help drive business results and support the organization's strategies and goals"[9].

For those students seeking to attend an engineering program at the university, the following might be a definition for an entering engineering skills gap:

> "The lack skills and abilities present in students who are transitioning from secondary or high school to the university setting that would be needed to be competitive in an engineering program and insure their successful completion of an engineering degree."

One could argue that it is the purpose of an engineering program to impart the skills and abilities over the four year academic program. How much more could a program accomplish should the students enter with some skills already in place? A survey of incoming freshman at Baylor University was taken over several incoming classes consisting of 70 to 150 students each year. The classes are typically 80% male and 20% female, over 80 % of the students come from Texas, and approximately 45% of the students who enter the program graduate with an engineering degree. The survey indicates that over 45% of incoming engineering freshmen

were unable to clearly define engineering[10]. Most students state they want to be engineers because they perceive they are good at math and science. Over 85% come in with calculus, pre-calculus, and physics experience. Students are not being adequately exposed to the concept of engineering and its role in society today while they are in secondary school. This state of secondary school students again raises the question of what skills are required to help students be more successful in their engineering programs at the university? How can secondary schools better prepare students for engineering in the university?

Discussions with professors who currently teach introductory engineering to freshmen reveals some of the challenges facing high school students and schools[11]. In the freshman classroom students are either too confident in their abilities or lack confidence. Some students were not challenged in secondary school experience and have not had to work very hard to receive excellent grades. They quickly find out that this will not work at the university. Professors actually describe the students as having little experience with teams, and are lacking in math and study skills. Students are not very disciplined as is evidences by the efforts on homework. They are not prepared to work hard nor do they possess time management skills. As far as communication, students' written and oral skills are lacking as is evidenced by e-mails, meetings with professors, and just their interactions in general. Entering students usually write like they speak in everyday language. Another observation is that students do not read enough and, as a result, their vocabulary is lacking, especially technical vocabulary. In all, students are not very knowledgeable about engineering and the skills needed for success when they arrive at the university.

Secondary school Principals point to some reasons why these gaps exist, especially in schools with high populations of minority students[12]. Because of the lack of resources (funding), there are not enough qualified teachers for math or science. Teachers qualified to teach engineering are almost non-existent. Administrators point to the lack of parental involvement in the education process sends the message to students that education is not important and that homework is not essential. An unusually large emphasis on sports in most secondary schools also helps to mask the importance of engineering topics. Most educators indicate that math and science education needs to be started much earlier, in the elementary schools, in order for students to be more prepared.

What are people doing?

Across the country many programs are looking to improve their educational standings and to improve the K-12 experience concerning math and science/engineering. Many ideas are being explored as funding becomes available. The following headlines, taken from the ASEE Daily E-mail[13], shows the involvement of some programs in a pioneering role. These examples show funding sources, educational emphasis, innovative teaching, and competitions:

- Funding
  - "Tech gets $2.7 Million Science Grant to Help Children"
    - NSF – Help children see the connection between science and math
  - "UTSA Lands Grant to Support Statewide Summer Pre-engineering Program"
    - $164K to work with pre-engineering students in the summer

  - "Bayless Grant Focuses on Math, Science Instruction"
    - $1.5 Million for teacher training in science and math
  - "Gustavus Awarded $1 Million Grant"
    - For outreach to high school science teachers
- Education
  - 'IBM Forum Seeks to Boost Number of Hispanics Pursuing Technology Careers"
    - Embrace/use Technology But not curious Interested in How it works
  - "Tigard Students go Hands-on with Physics"
    - Phun with Physics outreach
  - "Conference exposes Girls to Math and Science Careers"
    - Celebrating Women in Mathematics and Science Conference
- Innovative Teaching
  - "School in Arnold's Cove Teaches Meaning in Creation"
    - Fabrication rooms
  - "Experts see the Impact of Museums in Science Education Efforts"
    - Use as a resource for teaching
  - "Science Classes Soar with Imagination and Productivity"
    - Small classes and challenging modules
  - "Local Students Blast Ahead of Competition"
    - Rocket building contest
- Competitions
  - "Its not about Speed, It's About Gas Mileage"
    - Competition for fuel efficient vehicle
  - "Can Competitions Raise "Cool" Factor of Math, Science?"
    - Yes – NSF funded $600 million since 2002

National Programs Addressing This Gap

Several programs are being developed on the national level which will promote engineering. One of the most successful programs to expose students to engineering is the FIRST Robotic Competitions (FRC). The mission of the competitions is:

> "… to inspire young people to be science and technology leaders, by engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and that foster well-rounded life capabilities including self-confidence, communication, and leadership"[14].

FIRST Robotics Competition helps high-school-aged students "discover how interesting and rewarding the life of engineers and researchers can be." The students and mentors "solve a common problem in a six-week timeframe using a standard "kit of parts" and a common set of rules."
This program has been studied and the conclusions follow. Students who participate in the competition are:

- Three times (3X) as likely to major in engineering
- Twice (2X) as likely to pursue a career in science and technology

- Four times (4X) as likely to pursue a career in engineering
- Twice (2X) as likely to volunteer in their community

Project Lead the Way (PLTW) is a program growing in popularity throughout the United States. It promotes pre-engineering courses on the middle and high school levels[15]. It partners with public schools, colleges and universities, and the private sector to "increase the quantity and quality of engineers in the educational system". PLTW encourages math and science and applying these topic in every day situations. When a student enters the program they are exposed to the following:

- working as a contributing member of a team
- leading a team
- using appropriate written and/or visual mediums to communicate with a wide variety of audiences
- public speaking
- listening to the needs and ideas of others
- understanding the potential impact their ideas and products may have on society
- thinking
- problem solving
- managing time, resources and projects
- researching
- going beyond the classroom for answers
- data collection and analysis
- preparing for two- and four-year college programs

While PLTW does take time and resources, the benefits are tremendous.

Another often overlooked resource is the Professional Societies. For example, ASME has part of their organizational website dedicated to the K-12 initiatives[16]. It has information for engineer, teacher, and student resources and encourages its members to get involved with K-12 students.

Innovative Schools in Waco, Texas

In fact, Texas in general has recently adopted a higher requirement for math and science, requiring four years of math and four years of science in secondary schools. Waco is fortunate to have looked at the problem of encouraging math and science courses. There are three schools in Waco that stress math and science in their curriculum. The first is A. J. Moore Academy, which is a magnet school, attracting students from across McLennan County[17]. It houses the Academy of Engineering, is a T-STEM school, and is a teaching center for Project Lead the Way. Project Lead the Way introduces students to the scope and rigor of engineering. The second school is Rapoport Academy which is a charter school. Students from across the school district can apply for the school and are selected by lottery[18]. It is a T-STEM school and is an Early College High School which means that students can attend the local community college for specified courses with all expenses paid. Rapport Academy also has both Spanish and Chinese languages available for study. The last school is the Harmony Science Academy which is also a Charter school with an open enrollment lottery system. It is a T-STEM school and uses the Project Lead

the Way curriculum[19]. This school model has nine other locations around Texas. All the schools have free tuition with the charter schools being funded at the 85% of state level. The schools have high expectations for their students with rigorous academics, requirement for discipline and projects with teamwork. Required is parental involvement. The schools boast highly motivated and qualified teachers and keep a class size on average from 10-15 students. These schools offer some of the fine arts and limited sports but, with budget constraints, these are not necessarily the priorities. Between AP and College Credit, students can earn between 27 and 60 hours toward their college degrees while in high school. What is even more amazing is the fact that these schools are mostly minority enrollment and have a 95% graduation rate with approximately 85% entering college.

Important to these schools and to the engineering profession is the attraction of women to the engineering career field. This is still a difficult topic however it is improving. With the importance of engineering to the future of the planet, including solving the challenging topics of clean water, energy and disease, people are finding that women are attracted to engineering because of these challenges. Women have a strong desire to humanitarianly help people and to give back to the community. The topics of energy and biotech are two of the most promising. These topics need to be presented in as early as elementary school to expose young ladies to the possibilities for involvement. In talking with all three schools, what is needed is more resources, especially funding, and engineering mentors to help advise the students.

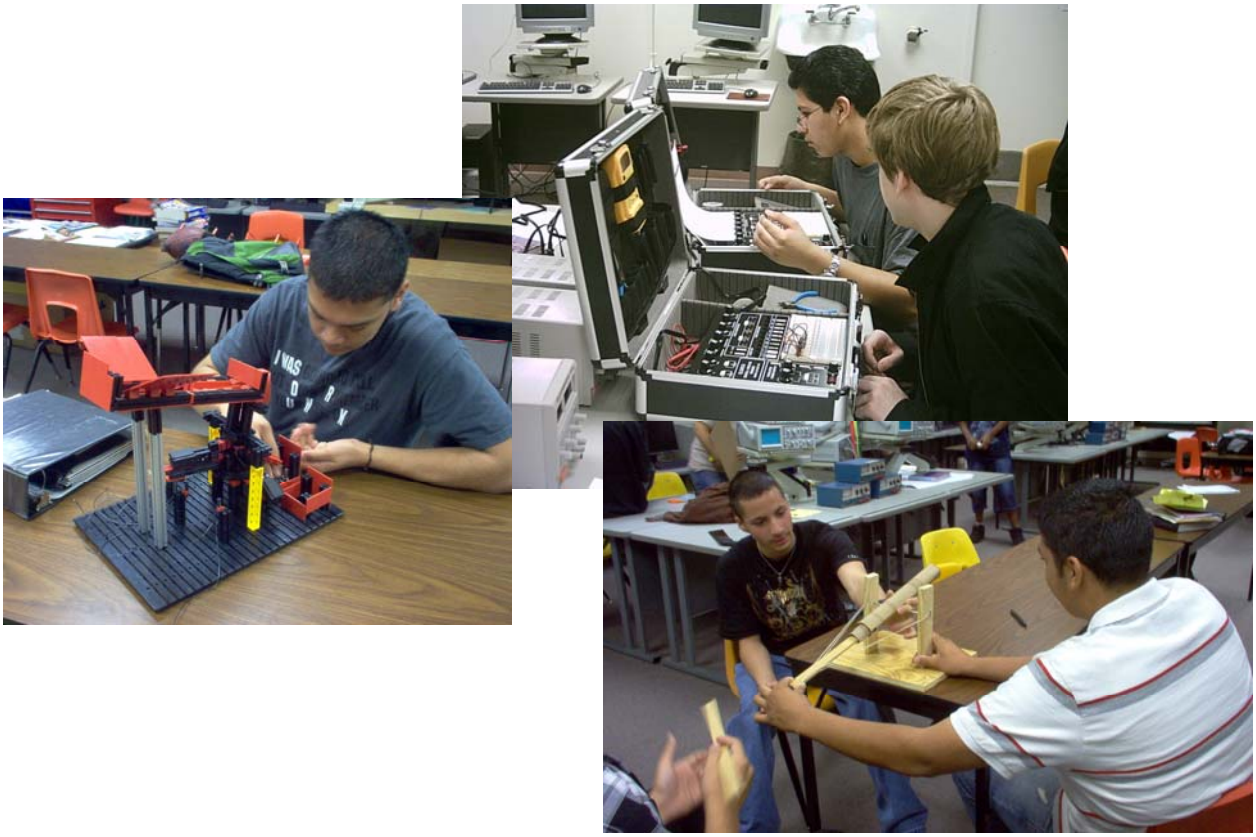

Figure 1 – Students involved in Engineering Projects at A.J. Moore Academy

Baylor University's Involvement

Baylor University has involved their students on several levels, in an attempt to educate high school students on the profession of engineering. Baylor's chapter of the National Society of Black Engineers has partnered with the Rapoport Academy for two initiatives. First, they sponsored a high school chapter of NSBE and had the first induction ceremony hosted by Baylor this past fall. The Baylor NSBE officers have monthly meetings on the Rapoport Academy campus to interact with the students. They are trying to get sponsorships for the students to attend the National NSBE conference. In addition to these meetings, two of the NSBE members have been able to consistently mentor/tutor students at the Rapoport Academy in math. It is a beginning but so much more could be done.

Baylor University's student chapter of the American Society of Mechanical Engineers is also pursuing a partner ship with A. J. Moore Academy. A. J. Moore Academy has had a loose association with the School of Engineering and Computer Science (ECS). A member of the Advisory Board comes from ECS but that has been about it up until now. Several students from ASME had the idea to partner with AJ Moore and talks have been held to determine what role this should be. Several Baylor students recently visited their classes and a regular math tutoring session is being explored. Also, guest lectures by Baylor engineering professors is being coordinated.

Another unique facility on the Baylor campus is the Mayborn Museum. The museum is an exciting place where children of all ages can come and learn in a warm, friendly environment[20]. The Jeanes Discovery Center, a part of the museum, has 16 hands-on discovery rooms for interactive education. Recently, Baylor ECS partnered with the museum to develop an energy room. It is hoped that this exposure will encourage students to pursue a career in the energy area.

Several Baylor professors are involved with the Central Texas Science and Engineering Fair[21], which has been hosted by Baylor on campus in the past. Activities range from being on the planning board to providing judges for the final competition. It would be desired to encourage more participation with the local schools to make the Science/Engineering Fair a meaningful experience for the student.

A relatively new program at Baylor University targets high school students between their junior and senior year. Called the Renaissance Scholar Program, this program gives, "gives high achieving high school juniors the opportunity to engage academically with Baylor faculty, students, and staff while earning college credit in the summer." The students live on campus for one week and actually receive one college credit for their activities[22].

Lastly, Baylor has a student organization called Engineers with a Mission that accomplishes humanitarian projects throughout the developing world. These students often speak in the local community in fund raising efforts. It is hoped that these efforts will also capture the imagination of some of our young student to inspire them to get a technical education so they can help the world.

Summary and Conclusions

It is imperative that more engineers are trained to meet the challenges that lie ahead. The only way that this is possible is if more young men and women are attracted to the profession early in their academic careers. It is not know exactly what the future requirements for engineering are but to solve these problems there must be qualified engineers with all genders and races represented. While the secondary school educators are doing the best with the resources they have, it is evident that more resources are needed. Not just money, but the giving of volunteer time to mentor young students. If the dream of attracting additional students to engineering is realized, then the same problem of resources and lack of qualified faculty will compound what is already being experienced at the university level. For example, in the last five years Baylor's engineering enrollment has increased 300% with little change in faculty and facilities. This increase in student numbers must be addressed if the number of engineers graduating from the university is to grow. In attracting qualified applicants, there is the responsibility of providing the environment to mature and graduate students from the university.

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