AC 2009-1212: WHEN THE LIGHT GOES ON: ILLUMINATING THE PATHWAY TO ENGINEERING

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Abstract

After teaching first-year students for many years, a number of instructors expressed interest in becoming involved in programs that seek to define and work toward addressing the problem of flat engineering graduation rates in the United States. Can we help illuminate the pathway to engineering for the right students? Given the many excellent recruitment initiatives and opportunities to work with K-12 programs, it was not clear though, which type of program to pursue to this end. We wanted to find the right target point, considering when, what, and how to get involved in attracting young engineers – therefore our research begins it's focus with a question: when does the light go on? In order to have some data from the youngest engineers we know, we administered a survey as the first-year engineering students started classes in order to capture their information before they developed any bias from their current experiences at the university. The research and analysis revealed a distinct profile of factors that attract young people to the engineering field in different stages of their development. This work will provide examples of the survey used and the salient results. The hope is to get other educators involved in order to exploit the students marked interest in engineering as determined by their age group – in the end inspiring students to pursue an engineering career.

Introduction

Recent engineering leaders have disclosed concern that fewer students have shown interest in engineering in the last ten years, and that the pipeline into engineering colleges is not supplying enough students to engineering schools. Consequently, universities cannot graduate enough engineers to meet the needs of companies in the United States. This plateaued graduation rate puts the United States at a severe disadvantage in an ever-expanding global economy where competing nations such as China have seen their rates increase to levels of 10 to 12 times that of the United States. However, there is a different viewpoint taken by others that say more international collaborations through the use of technology is the way to maintain the U.S. edge in the global market place.[1] An argument for the second perspective is the belief that the U.S. leads in creativity and innovation and has the best universities in the world to pilot the way.[2] Regardless of the viewpoint taken, it is apparent that we must transition more high school students into engineering to be competitive; having a clear picture of the current state of the market factors that may influence our youth as they make their career choice is imperative.

According to the U.S. Department of Education[5] it was estimated that in the fall of 2008 nearly 49.8 million students attended public schools in the U.S. with an additional 6.2 million attending private schools. Of those attending public schools, 34.9 million were in prekindergarten through 8th grade and 14.9 million in grades 9 through 12. Graduation rates for high school have remained steady ranging from 72-74% in the reported years between 2002 and 2004. About 70% of those graduating high school will attend post secondary school in the following fall. In the fall of 2008 this translated to 18.3 million students attending 2 and 4 year colleges and universities, which is an increase of over 3 million students from the fall 2000. This trend of increasing college enrollment is expected to continue with estimates set at 20.4 million for the fall of 2016. During the 2008-09 school year, 714,000 Associate's Degrees, 1,585,000 Bachelor's Degrees, 647,000 Master's degrees and 55,800 Doctor's Degrees are expected to be awarded. Figure 1 shows the trends in Bachelor's degrees conferred in selected fields of study as reported by degree-granting institutions. The graduation rates for engineering and engineering technology is relatively flat over the reported period at around 75,000-80,000 degrees conferred. The largest increase in degrees conferred shown for the U.S. occurs in business and the social sciences.

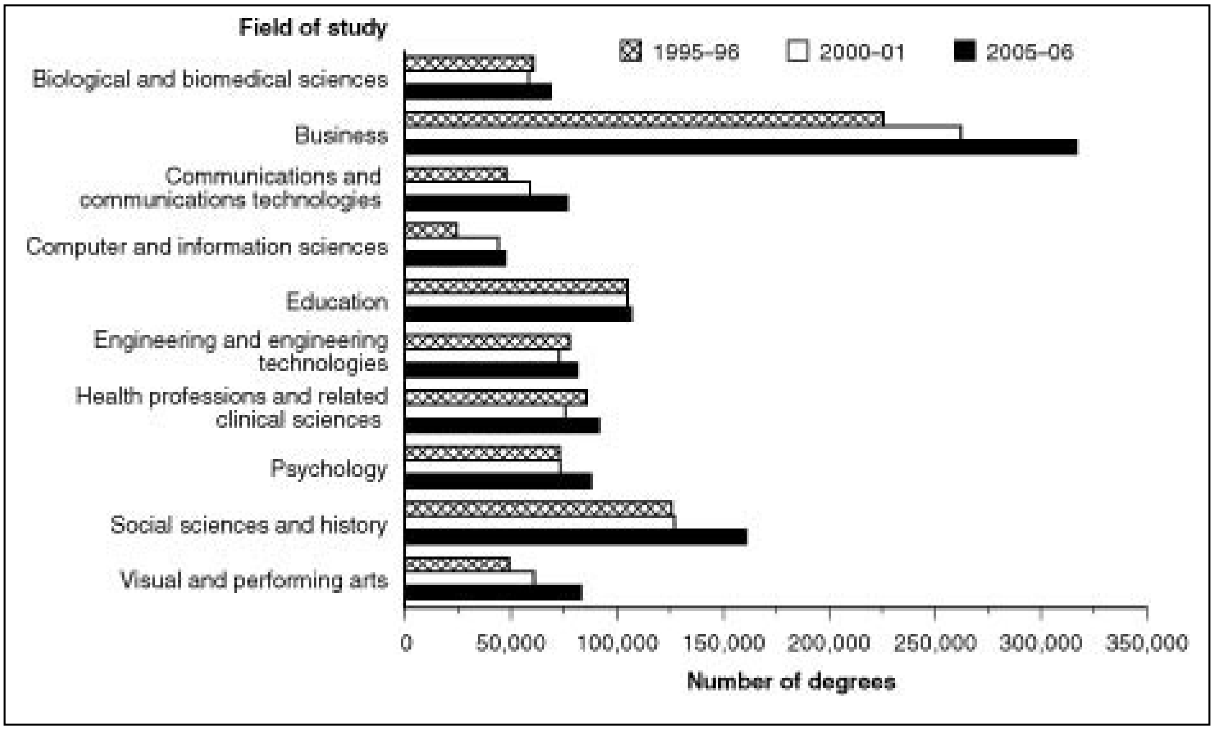

Figure 1. Trends in bachelor's degree conferred by degree-granting institutions for years 1995-96, 2000-01, and 2005-06. SOURCE: U.S. Department of Education, National Center for Education Statistics, 1995-96, 2000-01, and 2005-06 Integrated Postsecondary Education Data System, "Completions Survey" (IPEDS-C:95-96), and Fall 2001 and Fall 2006.

Figure 2 reports the international comparison by field for degrees conferred. For the United States, the percentage of engineering degrees conferred is relatively low at 6.4% of all degrees in comparison to competing nations such as Korea at 27.1%, Japan 20.2% and Germany 16.5%. This is a striking figure at first glance –requiring a careful review of the labor profile to gauge its relevancy

The U.S. Department of Labor collects employment information and makes it available on the Bureau of Labor Statistics (BLS) website. The following information is taken from the 2007 National Occupational Employment and Wage Estimates where data is taken from all employers in all industry sectors in every state and the District of Columbia. Each major category provides several pre-prepared charts summarizing national employment and wage estimations.

The 2007 labor numbers under the category for Architecture and Engineering Occupations is 2,486,020 jobs with a mean annual wage of $68,880. This is reported out of 134,354,250 total jobs in the U.S. with a mean annual wage of $40,690. The BLS reports total number of jobs for the major engineering disciplines of chemical, civil, computer, electrical, industrial and mechanical engineering as 28,780; 247,370; 79,330; 148,800; 204,210 and 222,330, with mean annual wages of $84.2K, $75.2K, $94.2K, $82K, 73.5K and $75K, respectively. While the annual mean wage of the engineering disciplines is nearly twice that of the national average, the total number of jobs comprises less than 2% of the total U.S. workforce. The next question is whether there is a link between current trends in engineering enrollment and technology jobs accounting for such a low percentage of the work force. The BLS outlook for available employment does look promising for engineering majors with the demand for new technology and innovation, and a labor pool that is aging as many workers approach retirement. Is there another mitigating factor that is limiting the number of new students to engineering?

					Sciences, mathematics, computer science, and engineering					
Country	Total number of degrees conferred	Education	Arts and humanities	Health	Total	Physical and biological sciences	Mathematics	Computer science	Engineering	Business, social sciences, law, and other[1]
OECD country mean[2]	6,230,006	13.5	11.7	11.7	23.1	5.7	1.3	4.1	12.2	40.0
OECD weighted mean[3]	6,230,006	12.0	13.4	8.6	21.1	5.2	1.0	3.4	11.5	44.9
Australia	209,115	11.7	11.1	13.2	21.8	5.4	0.5	8.9	7.0	42.2
Austria	23,071	9.8	10.6	8.5	26.8	5.7	0.7	4.9	15.6	44.3
Belgium	38,304	7.8	14.1	12.9	23.0	7.9	1.0	2.7	11.5	42.1
Canada	177,433	13.9	13.9	9.6	19.4	6.8	1.2	3.6	7.8	43.2
Czech Republic	46,097	23.7	8.4	6.3	24.5	4.3	0.8	2.8	16.6	37.1
Denmark	39,236	9.7	15.4	28.6	18.3	3.9	1.7	3.2	9.6	27.9
Finland	38,819	7.4	12.5	19.2	29.9	3.8	0.8	4.4	20.8	30.9
France	412,346	9.3	16.9	2.7	28.6	10.6	2.5	3.0	12.4	42.6
Germany	219,746	7.6	14.6	14.2	30.8	7.7	1.7	4.9	16.5	32.9
Greece	35,779	17.7	17.1	1.7	27.6	13.6	4.4	4.4	5.2	35.8
Hungary	72,652	23.9	9.9	7.3	9.5	1.3	0.1	1.9	6.3	49.3
Iceland	2,600	24.5	11.2	10.7	16.9	5.0	0.6	5.8	5.6	36.7
Ireland	37,069	9.2	13.9	12.4	23.4	6.7	0.9	7.0	8.7	41.1
Italy	321,284	8.5	12.2	15.5	22.9	4.8	1.5	1.2	15.5	40.9
Japan	646,983	5.6	17.8	6.3	25.0	4.8	([4])	([4])	20.2	45.3
Korea	303,559	5.3	20.5	8.2	38.6	6.4	1.8	3.3	27.1	27.4
Luxembourg	—	—	—	—	—	—	—	—	—	—
Mexico	324,013	16.1	3.7	8.5	25.4	2.7	0.5	7.7	14.6	46.3
Netherlands	96,890	17.4	6.9	18.9	16.1	3.1	0.4	3.7	9.0	40.7
New Zealand	38,730	12.5	15.9	14.1	18.6	6.6	1.1	6.0	4.9	39.0
Norway	30,476	19.1	6.5	25.9	16.2	1.9	0.3	5.7	8.3	32.3
Poland	479,458	12.3	6.4	2.3	12.1	1.8	0.6	2.7	7.1	66.8
Portugal	4,649	12.2	12.3	5.5	34.7	12.9	4.8	4.5	12.5	35.3
Slovak Republic	32,537	16.8	5.4	10.3	26.0	5.4	0.7	4.0	15.9	41.4
Spain	210,603	13.6	9.9	13.0	24.9	5.1	1.0	3.9	14.9	38.6
Sweden	54,504	16.7	5.4	25.8	28.6	4.5	0.7	3.2	20.3	23.5
Switzerland	28,549	8.3	12.5	10.0	25.1	7.9	0.9	3.4	13.0	44.1
Turkey	215,603	25.1	7.1	7.4	17.3	5.1	2.0	1.0	9.3	43.1
United Kingdom	—	—	—	—	—	—	—	—	—	—
United States	**2,089,901**	**13.2**	**15.5**	**7.6**	**16.0**	**4.9**	**0.9**	**3.9**	**6.4**	**47.7**

—Not available.
[1] Includes journalism, agriculture, and services.
[2] Each country contributes equally to the OECD mean.
[3] Each country contributes to the OECD mean in proportion to the number of degrees awarded by that country.
[4] Included under science.
NOTE: Includes academic degrees conferred at International Standard Classification of Education (ISCED), levels 5A and 6. Data include all degrees awarded by institutions located in the country, even when the degree awards were made to foreign students. These levels correspond to bachelor's, master's, first-professional, and doctoral degrees in the United States. See *supplemental note 6* for more information about the International Standard Classification of Education. Detail may not sum to totals because of rounding.
SOURCE: Organization for Economic Cooperation and Development (OECD), Center for Educational Research and Innovation. Retrieved December 23, 2006, from http://stats.oecd.org/wbos/default.aspx.

Figure 2. International Comparison by Field for Degrees Conferred. Reproduced from the U.S. DOE report The Condition of Education 2007.

A significant influence on a student's choice of major is the perceived potential for employment. In recent years, the process of moving jobs overseas or "offshoring" or "outsourcing" has received much attention, particularly in the United States. What started in the early 1980s with the movement of many low-skilled manufacturing jobs overseas has expanded to include many service and information technology (IT) jobs. The current impact on IT is manifested in the number of software engineers left unemployed after many of their positions were moved to India. Most would agree that the trend will likely continue and we are already seeing more high-skilled jobs including engineering positions moving abroad. In fact, many U.S. companies have found it more cost effective not to own all stages of production and as a result are outsourcing not only manufacturing jobs but innovation also.[4]

The result of reviewing this background information is that the pipeline of engineers is still a concern, and not surprisingly, there are excellent people and programs working to change these trends. Therefore, an understanding and review of some of these approaches sets the stage for this research and continued interest of the researchers in joining in the work to inspire our young students to consider engineering as a path for their future.

Current Recruitment Approaches

As evidenced by the search mechanism found on the ASEE web site, there are countless engineering-focused programs, activities, and media campaigns targeting youngsters from kindergarten through their senior year in high school[13]. Furthermore, there is a clear basis of support from the National Science Foundation (NSF) for both the recruitment of engineers from our youth and the training and development of those who teach and guide them at the elementary, middle, and high school levels.[15] Collectively, these organized approaches are referred to as *K-12 Initiatives*.

As such, most of the NSF and similar related initiatives are categorized loosely into two efforts: (1) outreach programs focused on prospective young recruits in science, technology, engineering, and mathematics (STEM) and (2) support programs designed for the educators and counselors who teach and/or mentor our prospective scientists and engineers.

Outreach Programs

Connecting to –and with– potential STEM recruits takes many forms: mentoring, activity-focused, and exposure-based. *Mentoring* involves either an existing role model such as a family member, teacher, coach, or friend or an imparted role model such as those put forth to speak, present, and be available as examples of engineering success. In mentoring-based outreach, we have currently limited control or influence over the existing role models, the examples they provide, or the messages they send about engineering, yet they have a strong influence on the decisions made by prospective engineering students.. On the other hand, imparted role models are individuals typically chosen for success in their field, their willingness to serve as a mentor and/or some other appeal to a younger population.[14] To this end, it may be possible to help equip existing role models in the same way imparted role models are promoted: by helping demonstrate their passion, interests, contributions, and pathways into STEM-related careers.

Activity-Based outreach opportunities are seen in camps, on college campuses, and in programs which tend to share 3 common elements: (1) activities based on a STEM knowledge domain, (2) an element of socializing, and (3) a guided structure. These programs develop, capitalize on, or provide a knowledge base as the fundamental ingredient. They also may create a discovery path through hands-on, building, and problem-solving activities. These educational programs are very deliberate in generating a great deal of interaction, which in turn promotes the notion of teamwork along with enjoyment and a sense of collective pride in engineering project work. Finally, the fun and accomplishments are directed and overseen by individuals seeking to ensure the safety, education, and enjoyment of the participants. Dozens of camps, colleges and universities participate by either conducting or hosting the programs designed to inspire interest in science and engineering. [8, 12, 16, 19]

Further evidence of activity-based programs are seen in examples such as FIRST initiatives, with the Lego® competitions for the younger level, and the robotics competitions at the high school and collegiate level, all of which attempt to reach the target populations in an age-appropriate manner.[18] Another example is the STEM Pipeline Grants for programs such as the Invention Convention.[9] Different from compartmentalized camps, these programs are ongoing through the year with teams that are likely to be more consistent in membership. Such programs provide for a deeper level of innovation and team-building and embody the engineering design process to a greater degree than the shorter-term activity-based outreach programs. Pre-college Research Programs, typically sponsored by universities, accomplish this as well by fostering teamwork and a sense of accomplishment on a more enduring level.

Finally, the last type of activity-focused program is more short-lived and less team-based. Examples are science fairs and outings such as going to the Museum of Science or Computer Museum or other educational events. These influences engage the students, but the activity tends to be compartmentalized in time and less memorable. These can be positive influences if the youngsters have the opportunity to participate and relate to the material on a personal basis..

With *exposure-based methods,* outreach tends to be more passive and occurs through a diversity of contact media. Books, magazines, movies, posters, and the internet also serve as recruitment mechanisms which expose potential recruits to the STEM fields. However, they have limited ability to guide the interest *path* of the potential engineer.[11] Slightly more directed are television programs, seminars, or presentations which typically have role models and demonstrations as embedded elements. Often they carry a message related to how something scientific or technical is accomplished. Some examples are Discovery Channel's Extreme Engineering series, Mythbusters, and American Inventor[10]. Without question, these generate interest, but there is no invitation or follow-up mechanism in place.

Educator Effects

This other method of 'recruitment' takes the combined form of education, discovery, and role modeling. Teachers and counselors at the precollege level become prepared to teach and equipped to provide encouragement, guidance, and direction for potential recruits, and also serve as a positive examples for engineering and science in many cases.[3] They can further promote one of the reported foundational elements of engineering interest by helping young students develop and discover their aptitude in math and science as a potential springboard to further STEM interest.[6, 7] The effect of these personal influences can be varied, depending on the level of involvement the educators have with their students.

The question remains, how effective are each of these methods in inspiring our youth to the STEM disciplines? A primary consideration involves looking at the cost of programs vs. efficacy? What is really inviting, informing, changing minds, and providing opportunities to our prospective engineers?

Population and Logistics

In order to capture students' perspectives on what they perceive as the strongest influences on their choice to begin in engineering, we surveyed our first-year engineering students at Northeastern University on the first day of class in the fall semester. These students come from all majors, or more accurately, are undeclared engineering majors, as they do not declare majors until the following spring semester. The students were told that we are interested in knowing why and how they selected engineering. The survey was administered in September 2006 and again in September 2007 to about 250 students each year. A series of questions focused on who or what influenced them, at what age they recall being interested in engineering, and to what degree each factor contributed to that influence -represented by a percent of the decision. The survey document is seen in Appendix A.

The influences our young engineers were selecting from were as follows: parents/relatives, teachers/counselors, camp/programs, activities/events, seminars/workshops, TV/movies, reading/books, job shadowing, or 'other'. They could choose as many as applied. They were also asked if they had taken things apart, and if they had a strong affinity for math and science. The survey appeared to capture most of the methods of influence; there were only a handful of other influences reported. The survey also asked the students to rate "I am sure I want to be an Engineer" on a 5-point Likert scale, and describe "What is engineering?". At the end there is an open-ended section for comments or any other relevant information they chose to provide.

Survey Results

Percentages and Means

What do the results tell us? As seen in Figure 3, the results have supplied some key information about the paths and influences of our prospective engineers in making their career decisions. Parents and relatives have the strongest influence, with 69% of the students reporting them as having a key impact, at an average age of 12.4. For parents and relatives, the percent influence is 29%, the largest percent reported. The next largest reported contributor is that of teachers and counselors at 43.7%, and that happens at a significantly later age, at 15.8. Many, but not all of the students reported both parents and teachers (35%); approximately 25% reported teachers only, but not parents or relatives. Activities/events (28.3% of the responses) at the age of 12.8, is a strong influence (20.5% influence contributed), with job shadowing at 22.1% but at a later age (15.4). Viewing media and books are at 16.5% and 15% respectively at around 15 years old.

Camps/programs and seminars/workshops have less influence at 10.9% and 4.7% respectively, but the ages at which they are influenced by these are older, at 14.8 and 15.4, respectively. Also very significant in the results are that 60% of the students said Yes, they took things apart, starting around the young age of 9, and 87.9% of the students reported that they recognized that they were good at math and science, at the age of 13.5. Both of these factors have a high influence percentage (24% and 32%).

The next sections review each of these areas in some more detail, with comments from the surveys, to bring more resolution to the distribution of responses and the students' thoughts on engineering as they are just beginning in the field. As noted above, Figure 3 shows the clustering of the data by the average age with both the percent that responded, and the percent of influence of that category. This shows the dominance of Parents/Relatives influence, and the characteristic of having demonstrated Ability in Math and Science, and Like to Take Things Apart. These major influences show that high numbers of students selected these and the relatively high influence on their decision. In terms of influence, Camps/Programs and Activities/Events have strong influence, but with a much smaller percent of students filling in those as responses. It is likely that if the students participated in a Pre-Engineering program, activity or event, they would have selected that item. This survey does not track what students participated in; rather it has them identify which influenced them and when. But given the results show that large numbers of students selected multiple influences, it is likely that if they attended a program or event, they then mentioned that influence. This foundational information now provides focus to explore the nature of the individual programs and the most compelling factors in them.

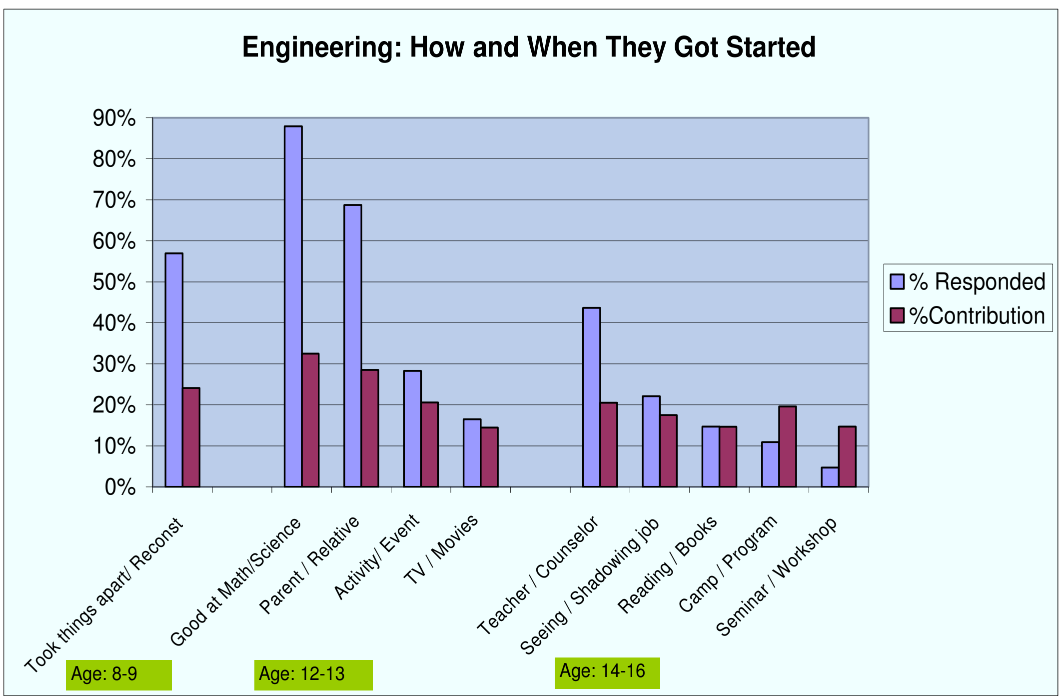

Figure 3. Clustered Survey Responses on Influences for Engineering

Patterns and Results from the Data

From these findings, a distinct profile emerges as seen in Figure 3 above. Three age breaks are identified, one at 8-9 years old for taking things apart/reconstructing, then another at 12-14 years of age with a variety of influences, especially parents along with camps, TV, and that students identified a proficiency in math/science. Finally at 14-16 years of age, teachers/counselors exert influence, along with seminars/workshops and job shadowing. Both the percent of response to the category and the contribution percent of that category are shown. The top three in both are the first three shown on the chart.

Overall Distributions of Ages and Influences

Figures 4 and 5 use all of the data, and all of the students in every influence category. The distribution of the percentage of influence, not including blanks or zeroes is shown in Figure 4. The survey tried to have a large variety of options to choose from, and the students then proceeded to choose many different influences. If the survey had been completely open-ended, they may not have reported as many, or may likely have only mentioned recent or distinctive ones. Without that choice on the top of the form, they may not have even remembered that their parents probably had something to do with their choice, or that they liked to take things apart. But given the ease of selection, and that we have covered most of the possibilities, they identify a variety of contributors or influences in deciding on Engineering.

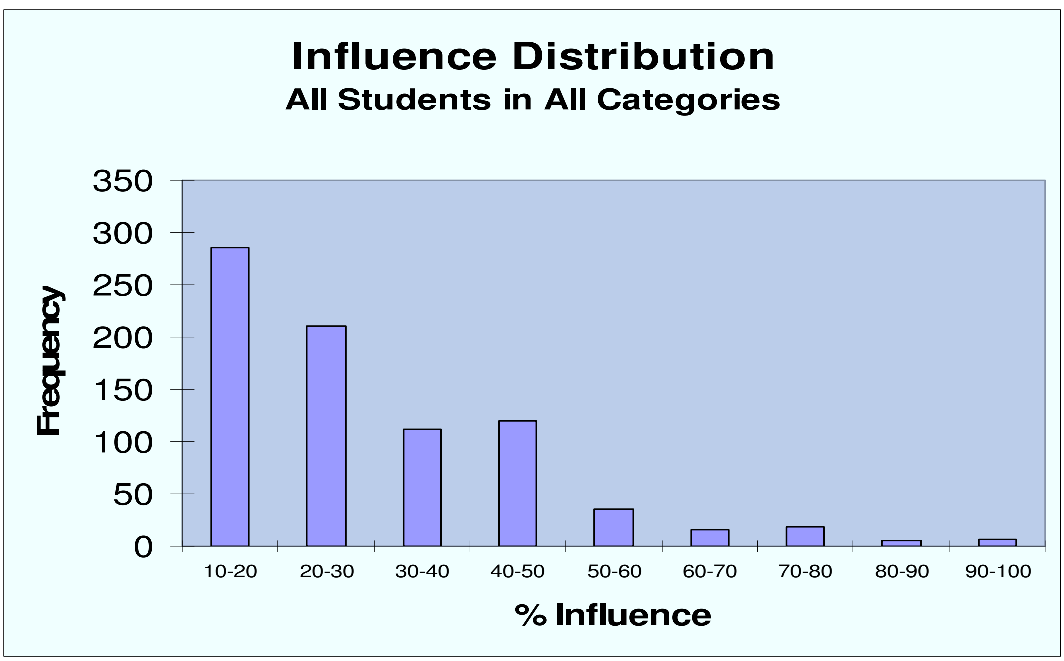

Figure 4. Distribution of influence percentages for all data.

What age is most significant overall? Figure 5 illustrates that the distribution of ages is fairly level from age 4 to 12, but with many reporting events occurring from ages 14-18. This is an interesting result. They are identifying many things that occur from ages 14-18, but the influence of these is not as overwhelming as Parents/Relatives and other categories. Recent history is more prevalent in detail in their surveys, so it also shows in this distribution of reported ages. Being Good at/Liking Math and Science is reported by most students, and the age they list is usually Middle School to High School, with possibly an AP course. If they are good at math and science in High School, they were likely good at it much earlier in life, but are only reporting the recent recollection. This may skew this result due to the large number in that category.

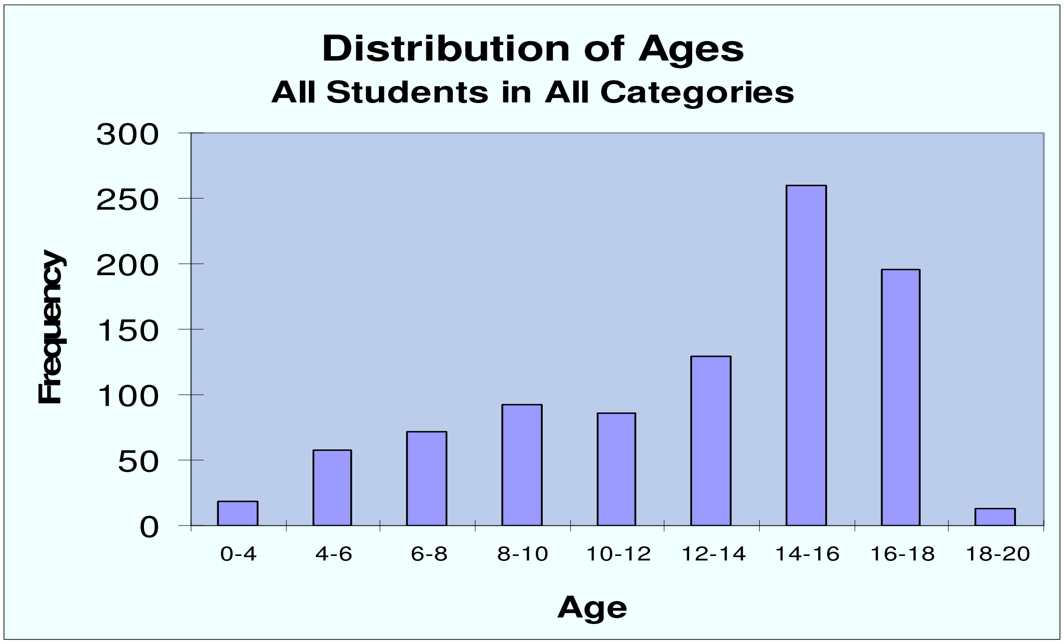

Figure 5. Distribution of ages reported for all data.

The Survey: Categories of Influences and Contributions

1. Parents and Relatives. It is not unexpected that parents and relatives were influential, but how high the percentage turned out to be is surprising. In addition, many students reported taking things apart at a young age, again, this is most likely to be under the influence and tutelage of parents. So up until the age of 14, this group needs to be the focus. Keeping in mind that in recent years there have been numerous reports from our Student advisors on students having strong familial and parental influence, so even at the later ages and in an ongoing way, parents continue to play a role and influence from our experience; this may not be the case for all college and university entering freshman.

Figure 6 shows the distribution of the percent contribution of parents and relatives. A majority of the students responded that parents or relatives had some influence, but note that the largest bin is 10% and under. The distribution is strongly skewed, and not normally distributed. Out of 340 responses, less than 25 had Parents/Relatives providing the *majority* of the influence. So although almost 70% of the students report this influence or contributor to their decision to become engineers, there are many other composite influences on these students. They are indicating that a variety of sources over time contributed to their focus, not one large or singular influence.

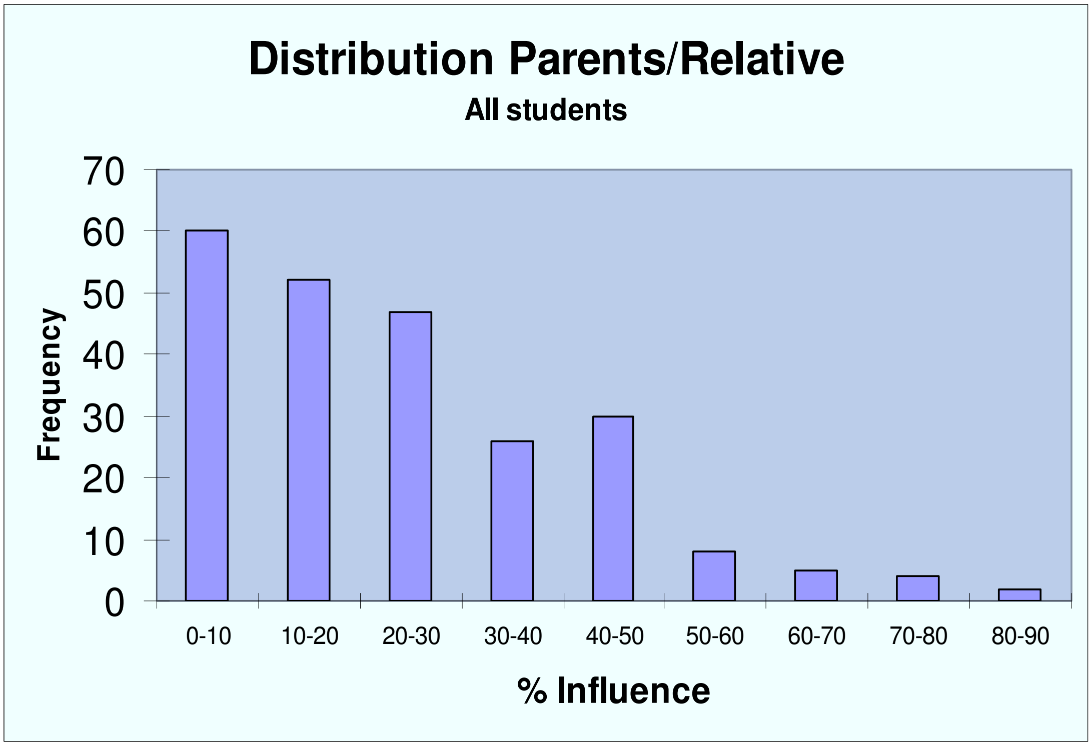

Figure 6. Distribution of the Percent Influence by Parents/Relatives for all Students

In reviewing the surveys themselves, a large number of students mention their parents, most often fathers, with some mothers. There are many uncles and grandfathers, with a few brothers and cousins. About 80% of those mentioned are male, as expected. Many of the students do not specify who, but a few give some interesting details. Here are typical comments:

"My mom is an architect and my grandfather a civil engineer so I've seen their work all my life and always enjoyed it."

"Uncle Eric, Micro-Electronic Engineer for AMD"

"Uncle engineered fighter jets"

"My father used to take me to his work, he is in engineering."

"As young as I can remember, my mother was an electrical engineering student, my father was a mechanic."

"My sister is an engineer here."

"Stepdad showed me what engineering was about."

2. Teachers and Counselors. As students start to think about college, they also start meeting with guidance counselors and working more closely with teachers, especially in Math and Science. Students may have participated in some activities or events before this, and are participating in Science Fairs and Math competitions in High School. Teachers are also starting to focus on students with potential, and trying to encourage and influence these students for higher education. So we see their influence emerging. In the surveys themselves, there are many names mentioned, in a very positive way, we see many "really helped me understand what I wanted to do…" kinds of comments. This being such a recent influence, it seems fresh in their minds. Physics teachers are mentioned most often, occasionally an engineering instructor (!) or a Math teacher. Here are some comments:

"Junior year Math teacher really pushed engineering for us."

"Aptitude tests showed I would be a good doctor or engineer"

"Engineering teacher taught me it could be fun."

"My guidance counselor helped me find my strengths in math and science."

3. The Media. TV/Movies and Reading and Books do not have as strong an influence (~15% responding, and 15% contribution). Not a surprising result as most of the current media focus is not on Science, Math or Engineering. It will be interesting to continue this survey as more and more of our students are starting to mention shows from the Discovery and History channels like Modern Marvels, How It's Made, Deconstructed and Mythbusters, so this influence may be shifting somewhat. In reviewing all of their comments however, we found very few mentioning the internet (<5); in even the most recent surveys the students do not mention an internet experience that influenced them.

4. Activities/Events/Programs. Activities and Events have more influence than more formal programs, and at an earlier age on average. This effect is much lower than that of parents and teachers. Yet for some students these may be vital, especially if the other influences are not there. More importantly, the percent contribution of Activity/Event is almost as high as Parents. Therefore, students report that their parents and relatives are influences, but the level of contribution of the Activities and Events is almost as strong. Similarly, with Camps and Programs, the percent of students that reported those is small, but the influence is strong. This indicates that if more students could or would attend these, the influence for engineering interest is significant. These types of programs are more expensive and require more resources, therefore have limited participation, but are effectual.

5. Took Things Apart/Reconstructed. The comments on this frequently cited item are the most interesting. There is a lot of mention of Legos, K'Nex, and other mechanically based toys. There are many comments such as "all my life…", "since I can remember…", "still doing this…", "from age 2 until now….". A few mention a family member that was involved, occasionally a school program or teacher, usually when they were fairly young, at which point they got started learning how things work.

6. Other Influences. The survey lists other influences following the given categories, in the event that we had not covered all of them, there is also room in comments. It appears that we covered most of them. Others that they submitted were given once or twice, such as cars, a museum, a person not listed previously, building a fort. Some mentioned 3 to 5 times were Legos or toys, curiosity, programming, internship, non-relative such as a friend's Dad, and high pay. Only once was the web mentioned, we thought maybe we had missed that category given the prolific use of the internet and the amount of time students seem to be on the internet. But in terms of career choices, we saw no mention of the internet as a contributor to their decision.

What is Engineering?

We also asked our students "What is engineering"? This question helps first-year instructors calibrate to the students' preconceptions of their selected major. Content analysis revealed that there were 4 dominant responses –solving problems (39% reflected this in their answer), designing (36%), improving things (18%) and constructing (11%). Of the respondents, 95% answered the question; many mentioned more than one of the responses above. Several things were encouraging about this set of responses: The response was comprised primarily of verbs and actions, not a mere description of the field. Not one respondent said they did not know, or had answers that were unexpected; their responses were fairly commensurate with a reasonable perspective of engineering for their age.

Confidence in Engineering

We also asked our students to provide a measure of agreement for the following statement: "I am sure I want to be an engineer" using a 5-point Likert scale from Strongly disagree (1) to Strongly agree (5). The average response was 4.0, suggesting they are quite confident in their decision at the time of inquiry. We know that first-year engineering students are often undecided about their specific engineering area or major as they arrive, but apparently feel that they are in the right college and have made the correct career choice. Of all our respondents, only 3 students chose 1 (Strongly disagree) and only 17 chose 2 (Disagree). All other responses were 3, 4 or 5 with 85 students selecting 5's. The two extremes (5 and 1) were inspected more closely.

Figure 7 shows the three strongest influences on the students who strongly agree that they are sure about engineering. Parents and relatives are strong influences, along with some others, but two characteristics that are associated with engineering are - Good at/Like Math and Science and Taking Things Apart, and these dominate the responses. These are not included as influences previously, but as identified skills or self-identified traits. What can we draw from this? One consideration, if we initially adopt a negative focus, is that all the efforts of programs, activities and workshops have little influence. But on a more positive spin, many activities and events focus on taking things apart, on building on Math and Science skills and involve parents and relatives. In addition, we are reminded that the students overwhelmingly report that it is a variety of influences that appear to build together toward their decision.

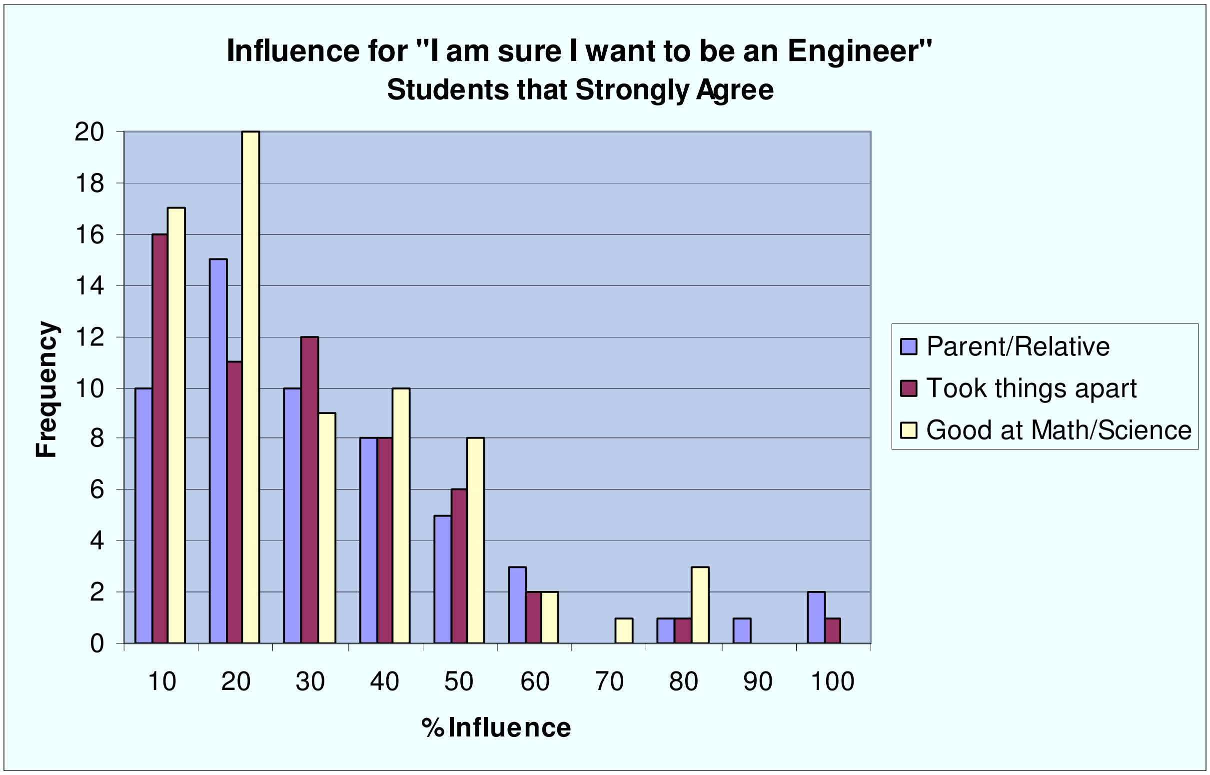

Figure 7. Comparison for top three influences for students that are sure (strongly agree) that they want to be engineers

Table 1 below shows the percent of the responses in each category, at the top is the cluster as mentioned above, note these are lifelong, pre-high school influences and self-identified traits or interests. Then three more seem to group: Teachers/Counselors, Activities and Events and Seeing or Shadowing Jobs. This group is likely to be High School influences. The last 4 do not seem to have a large effect, although when a student has liked a camp, it will receive a high influence rating. Note that the average percent influence for camps is nearly as high as the top three. As seen on individual surveys, students will generally mention a program by name such as “Space Camp – Sophomore year”, or “FIRST Robotics”.

Now, what about the students who are not sure, the 1’s and 2’s? Since there are so few of these, the data is not very informative; however, their comments provide the most insight. Several students stated that they like the courses and even find engineering interesting, but are not sure they love the field. They state that it will get them a good job, with high pay, or that they can transfer or do other careers with an engineering background. One student stated being forced into it by parents; another plans to change majors immediately. Several positive responses say they like what they know so far, hope to find it interesting, but also realize that there are a lot of fields to go into, and it is entirely possible they will change their minds.

Table 1: Influence on or traits of Students that are confident about engineering (strongly agree)

Influence Type	Percent of Responses	Number of Responses	Average % Influence
Good at Math/Science	82%	70	28%
Took Things Apart	74%	63	29%
Parents/Relatives	68%	58	32%
Teachers/Counselors	37%	31	21%
Activities/Events	31%	26	26%
Seeing/Shadowing Jobs	25%	21	16%
Reading Books	15%	13	15%
Camp/Programs	12%	10	28%
TV/Movies	12%	10	16%
Seminars/Workshops	5%	4	18%

Recommendations and Indications

So where can we be most efficacious for helping young students become interested in engineering? Our data suggests a general plan; where to introduce programs, where to start. First at 8 or 9, we can capitalize on that strong drive to take things apart - having schoolchildren with their parents do some simple reverse engineering projects or send devices/objects home through their teachers for children to explore outside of the classroom. We know that many of these types of programs exist; this only reinforces the timing and type of activity.

The next phase of influence suggests that around 12 years old, parents and children might attend events together for exposure because students are heavily influenced by and would still be willing to attend with their parents. The focus may also need to be on the teachers and counselors of 12-14 year olds to help them expose the students to existing programs and camps.

Programs for 15-16 year olds have strong influence, but can only be attended by a limited set of students. These definitely have an effect in the decision process, particularly if the students actively participate and there was a high level of activity. Teachers and Counselors in High School influence in a variety of ways, and are key players in connecting students to activities and programs. Many are mentioned by name. The strong contributors often have a mentoring, one-on-one component or flavor. This seems to be key in the decision making process.

What about being Good at/Like Math and Science? This trait seems to be associated strongly with the engineering decision, and it occurs frequently. It is one thing to have K-12 Programs, and get students interested in engineering only to have them discover that they are not prepared and/or will not have the opportunity to be prepared for engineering school. This seems to warrant further research as there are many programs that work on these core skills, but is there a population we are missing? They would not make it to engineering school to take the survey. Certainly this underlines the importance of the many programs in K-12 that are focused on core skill improvement.

After all of this data, when does the light go on? It is more of a growing illumination, like a fire not a light bulb. And how do we help on that pathway? We plan to continue our surveys to see if these patterns remain steady, but follow that with further looking at where we might contribute, where we might step into the fray. There are many activities, programs, and initiatives already in place around the country to introduce engineering and motivate our prospective engineers to join the field. Our information confirms that they can be effective, but this analysis was designed to help us understand where to more closely focus the invitations and efforts to inspire young engineers, reviewing the different programs that exist at each level as well as being applicable to any future programs that come along. This is but one step in illuminating the path to engineering so that we may better develop the passage from unenlightened to confident, capable and determined engineers.

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APPENDIX A: THE SURVEY TOOL

Gender: M F

~ Engineering: How & when you got started ~

Tell us how and when you became interested in Engineering …

Professor:

1) First, circle any choices along the left that apply to you; 2) Place the best approximation of the age at which *you* were most influenced by the factors on the left; 3) When you are done with the list, go back and fill in percentages on the right in multiples of 5. You only need to place values next to the Contributors you have circled and leave the others blank. Make comments to clarify as necessary.

Contributor(s)	Percentage
Parent / Relative → Age & Who: ________________	______
Teacher / Counselor → Age: ________________	______
Other person you admired: Age & Role: ________________	______
Activity or Event → Age & What: ________________	______
TV / Movies → Age & Which: ________________	______
Camp / Program → Age & Duration: ________________	______
Seminar / Workshop → Age &Topic: ________________	______
Reading / Books → Age(s) & What: ________________	______
Seeing / Shadowing Job(s) → Age & Which: ________________	______
Took things apart / Reconstructed → Age & What: ________________	______
Good at/Liked Math/Science → Age & Course: ________________	______
Other Influence(s) → Age & Who: ________________	______
Other Influence(s) → Age & What: ________________	______
Total:	**100 %**

over → →

4) Indicate how strongly you agree with this statement:

I am sure I want to be an engineer.

Strongly Disagree	*Disagree*	*Neither Disagree/Agree*	*Agree*	*Strongly Agree*
1	**2**	**3**	**4**	**5**

5) Any relevant thoughts, comments or clarifications:

6) In your own words and opinion what does an engineer do?

Thank you