AC 2011-727: A LARGE SCALE ANALYSIS OF FIRST-YEAR ENGINEERING STUDENT ESSAYS ON ENGINEERING INTERESTS

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Abstract:

There is an increasing demand for qualified engineers in the workforce, and a decreasing interest in engineering educational and professional pathways into the field. This has prompted many studies of engineering programs as well as the motivating factors that lead students there to begin with. What is it about engineering that interests students and motivates their initial pathway into engineering? And were those factors significant in maintaining student engagement through the "valley of despair" to degree completion? These were the research questions asked at the University of Notre Dame beginning in the Fall of 2007. That cohort of students was asked as part of a homework question, in the Introduction to Engineering Systems Course, "Engineering is a very broad field of study. What is it about engineering that interests you?" The essay responses of 163 students were reviewed by two engineering education researchers (initially coded independently and then codes compared for final classification). The types of responses varied, but many recurring themes emerged, including math or science interest or ability, enjoyment of problem solving, a desire to impact the world in a positive way, preparation for another professional field, among others. Frequency counts were tabulated, and compared to retention numbers as these students are now seniors. Response frequencies were also compared by gender and discipline, indicating that women were more likely to cite "better world" and men were more likely to cite "innovative / creative, how things work, or build things" as motivations for studying engineering. Engineering disciplines also had a few interesting differences including Civil engineering students indicating "build things" and Chemical Engineering students indicating "practical or broad" as motivating factors for studying engineering.

Introduction:

Several notable National reports have called attention to concerns for STEM education, specifically decreasing student interest at a time when there is increased demand for well trained scientists and engineers needed to maintain competitiveness in a global market[2,5,10]. This has

prompted many research studies from engineering educators to consider what are student motivations are for pursing engineering degrees.

A survey of Dean's from various engineering programs was conducted and reported their collective perceptions of the factors impacting a student's selection of a profession including (in decreasing order): career advancement opportunities, compensation, image, informal advising, knowledge of the profession, academic advising, social relevance, and finally work conditions[7]. The top 3 factors mentioned by Dean's related to the compensatory factors necessary for certain lifestyle which has been noted as a gender difference. Other studies have indicated that monetary incentives are more important for male students than female students while genuine interest in the field is critical, especially for women[4,12].

The Center for Advancement in Engineering Education (CAEE) found that students who do not persist in engineering were more likely motivated by family to consider it in the first place[6]. Seymour and Hewitt also indicate that the influence of family and others was a commonly cited factor for pursuing a STEM major, especially among women who did not persist in engineering[12]. Parents and teachers have reportedly had higher influences on students that chose to study engineering than on non-engineering counterparts[4], and having a parent that is an engineer is often associated with pursuing a career in that field[1].

Seymour and Hewitt's extensive interviews of students has contributed significantly to the engineering educational community's understanding of student motivations because they interviewed both students that were retained in engineering as well as those that switched out. They reported student's desire to feel passionate about what they do, feel a social purpose, and healthy work life balance in the future. And male students in particular were twice as likely as women to cite "good at math and science in high school." Finally, the initial motivations indicated by students that left engineering include: influence of others, material/pragmatic

considerations, seemed an appropriate next step since they are good at math and science, or they chose initially with little understanding as to what the major would involve[12].

The insights gained from the prior literature related to student motivation and retention were formative for the current study. In particular, the motivational factors that have previously been identified were found to be quite relevant to the current study. Prior work has primarily focused on individual student interviews at a certain time in their academic career but has never linked motivations to persistence directly. The current study took a differing approach to prior work by reviewing individual student reflections from students entering an engineering program in the fall of 2007, as the class prepares to graduate this year (2011) their initial motivations were linked to their educational persistence (or non-persistence).

Methods:

The primary source of data in the current study was student essays written for a class assignment. These qualitative reflections were reviewed by two engineering education researchers, coded independently. The researchers met regularly to form a consensus for classifying student responses into a form of tabulations, frequencies, and simple statistical breakdowns that help to tell a story of the commonalities and distinctions represented by the students and are represented in this paper through excerpts that come directly from students. Finally, a link between motivations expressed as a first-year student and educational retention through undergraduate engineering studies are presented. These methods, both qualitative and quantitative, were used in conjunction with one another to support and strengthen the findings of the other through triangulation[9,11].

All students enrolled in the first-year engineering program were required to complete the same homework assignment. Students were no aware this question was going to be used for engineering educational purposes, and actually the researchers obtained IRB approval to use the essays for this study after the homework had already been collected. Thus the only hypothesis was informal – that the motivating factors for students that persist in engineering would be different than those that did not persist in engineering.

Setting

The administration site for the current study was a medium sized, Midwestern, private institution with a traditional student composition, i.e. the vast majority of students completing their undergraduate studies in four years and are in the age range of 18-22. The overall student body is 53% male and 47% female, while the College of Engineering is approximately 75% male and 25% female.

In terms of institutional structure, first-year students are admitted to the separate First-Year of Studies program regardless of their intended future major. Students select their major (whether engineering or something else) near the end of their first-year when they register for classes for the upcoming fall semester. With few exceptions, students that are considering an academic pathway within engineering complete a standard first-year curriculum, including the two-semester course sequence "Introduction to Engineering." They then pass into the college of their selection in their sophomore year. Beginning in their sophomore year until they graduate students are institutionally recognized by their college, which, in the case of this study, is the College of Engineering; and by their specific engineering discipline within. But beyond admission / selection into the university as a whole, there are no admission or selection criteria for entering any of the disciplines of engineering; rather it is based on student interest alone.

Population

The 163 student essays from 2007 serve as a subset of the engineering class that is graduating in the spring of 2011. As the population now stands as seniors, ~70% remained in engineering and ~30% are in other majors at the university. Overall the sample represents all of the disciplines of engineering offered (Aerospace and Mechanical Engineering 27%, Chemical and Biomolecular Engineering 18%, Civil Engineering and Geological Sciences 11%, Computer Science and Engineering 6%, and Electrical Engineering 8%) and is 31% female and 69% male which is roughly representative of the gender distribution at the institution studied. There were 5 essays that were dropped from the analysis because they could no longer be tracked in the system as

they likely transferred to other institutions. Finally, 2 students started in engineering and changed to another major only to return to engineering later – but since they are not currently classified as seniors they were not considered in the current study.

The students' responses were grouped into 14 different categories and tallied. The categories used were “Math/Science,” “Better World,” “Problem Solving,” “Build Things,” “Practicality,” “Specific Field,” “Prepare for Other Career,” “Family,” “Broad,” “Groups,” Innovative/Creative,” “Previous Experience,” “Good Career,” and “How things Work.” The rest of this section is dedicated to defining these groups, shown in Table 1.

Table 1. Coding for Student Motivation Essays

Category	Description	Example
Math/Science	Indicate aptitude or enjoyment of a math or science class (also includes comments about specific math/science class)	“I have always liked math and science classes” or “My best classes were my math and science classes”
Better World	Wishes to study engineering for an altruistic purpose	“I want to make other people's lives easier or better” or “I want to make a mark on the world.”
Problem Solving	Enjoy solving problems	“I have always enjoyed solving problems” or “I like solving puzzles”
Build Things	Indicate enjoyment in creating something new from nothing or fix broken things (we also included coding or computer program development in this category)	"I've always liked to build things" or "I enjoy constructing something useful."
Practicality	Indicate desire to apply skills to real world applications	“I enjoy applying math and science to real world problems”
Specific Field	Indicate a desire to study a particular branch of engineering (only for those responses that indicate certainty of specific type of engineering)	“I have always wanted to study Aerospace Engineering” or “I want to build skyscrapers (Civil Engineering)”
Prepare for Other Career	Studying engineering in preparation for another field upon graduation	“Engineering will prepare me to be a patent lawyer” or “I plan to go into the air force”

Family	Immediate or extended family member is an engineer or in a closely related field	"My father is an electrical engineer"
Broad	Wide range of career paths available	"I can do all kinds of things with an engineering degree"
Groups	Desire to work in groups or collaborate with other people (engineers or not)	"I enjoy working with other people" or "I like being a part of a team"
Innovative/ Creative	Desire to design, create, or study new things	"I want to be on the cutting edge of technology" or "I enjoy designing new things"
Previous Experience	Have had an experience with engineering through a class, extracurricular activity, mentoring relationship, or internship	"I was a part of my high school's Lego robotics team" or "I spent a summer working as an intern"
Good Career	Studying engineering because of career opportunities	"I know engineers make good money" or "engineering is a rewarding career"
How Things Work	Indicate fascination or enjoyment if learning how things work	"I like taking things apart to see how they work" or "I always want to know how things work"

Results:

The percentage of students citing each reason for choosing engineering as their intended major are presented in Table 2. The top three reasons cited were Math/Science, Problem Solving, and Better World, while the three least cited responses were Good Career, Prep for Another Career, and Groups. This is in contrast to the perception of college Dean's which claimed monetary compensation was the most important pathway into engineering[7]. These results do agree with the findings of Seymour & Hewitt in which the desire to study engineering is driven by prior interests and abilities as well as altruistic purposes[12].

Table 2. Motivation for Studying Engineering (All Students)

Motivation	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering
Math / Science (interest, aptitude, or ability)	61.3%
Problem Solving	36.8%
Better World	32.5%
Innovative / Creative	25.7%
Practicality	23.9%
Build Things	23.3%
Specific Discipline of Engineering	23.3%
Broad	16.0%
Previous Experience	15.3%
How Things Work	15.3%
Family	14.1%
Good Career	13.5%
Preparation for Another Career Path	4.9%
Groups	2.5%

Table 3 compares the overall response frequencies to the response frequencies by gender. Interestingly, in the present study females reported Math/Science as a reason for choosing engineering more frequently than males, but this category was the most frequently cited reason for both genders. Beyond that, differences between the genders become evident. Better World was the second most cited reason for females to go into engineering while it was the sixth most cited reason for males. While males cited Innovative/Creative, How Things Work, and Build Things much more often than females as reasons they decided to study engineering. The results of t-tests, shown in Table 4 and items of statistical significance are highlighted. (Items that are positive indicate male students are more likely to report, while negative values indicate women are more likely to report.) While not statistically significant in the present study, the results do

show a tendency for males to cite Good Career more often (twice as often) than females, which is consistent with the observations of other researchers[4,12].

Table 3. Motivation for Studying Engineering (by Gender)

Motivation	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Overall**	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Female**	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Male**
Math / Science (interest, aptitude, or ability)	61.3%	68.2%	58.0%
Problem Solving	36.8%	45.1%	33.0%
Better World	32.5%	49.0%	25.0%
Innovative / Creative	25.7%	15.7%	30.3%
Practicality	23.9%	19.6%	25.9%
Build Things	23.3%	7.8%	30.3%
Specific Discipline of Engineering	23.3%	27.5%	21.4%
Broad	16.0%	21.6%	13.4%
Previous Experience	15.3%	19.6%	13.4%
How Things Work	15.3%	3.9%	20.5%
Family	14.1%	17.6%	12.5%
Good Career	13.5%	7.8%	16.1%
Preparation for Another Career Path	4.9%	5.9%	4.5%
Groups	2.5%	3.9%	1.8%

Table 4. T-tests Results by Gender

Motivation	ttests
Math / Science (interest, aptitude, or ability)	-1.29
Problem Solving	-1.48
Better World	**-3.11*** **
Innovative / Creative	**2.00***
Practicality	0.87
Build Things	**3.23*** **
Specific Discipline of Engineering	-0.84
Broad	-1.32
Previous Experience	-1.02
How Things Work	**2.78** **
Family	-0.87
Good Career	1.43
Preparation for Another Career Path	-0.39
Groups	-0.81

*p<0.05, **p<0.01, ***p<.001

The results with respect to the different disciplines are not so clear. Care must be taken in interpretation of the data due to the lack of samples for certain disciplines such as Computer Science and Engineering, which are under-represented in engineering departments nation-wide. However, there are a few interesting observations that can be made by looking at the response frequencies for the different disciplines (tabulated in Table 5). First, students who intended to major in Mechanical and Electrical Engineering were approximately 25 % less likely to cite Math/Science as a reason to study engineering. Second, Civil Engineering intents were much less likely than any of the other majors to cite Innovative/Creative in their responses but had significantly higher response rates for Good Career and Build Things than other majors. Third, Electrical Engineering was the only discipline not to have Math/Science as the top reason for choosing engineering (Problem Solving was 7 % larger). Finally, Chemical Engineering intents

were much more likely to cite Practicality and Broad as reasons to study engineering when compared to the intents of other disciplines. This shows, as expected, that students going into the different disciplines have some significant differences for their reasons for choosing their major. Knowing this information can help in curriculum development to appeal to students and aid in retention. More study is needed to show if this information can really be used to aid in retention.

Table 5. Motivation for Studying Engineering (by Engineering Discipline)

Motivation	Mechanical	Aerospace	Civil	Chemical	Computer Science /Engr	Electrical
Math / Science	48.1	76.5	77.8	73.3	70.0	46.1
Problem Solving	25.9	41.2	38.9	40.0	30.0	53.8
Better World	40.7	23.5	44.4	36.7	0.0	30.7
Innovative / Creative	44.4	17.6	5.6	30.0	30.0	23.1
Practicality	11.1	23.5	22.2	40.0	20.0	23.1
Build Things	29.6	23.5	38.9	13.3	40.0	23.1
Specific Discipline of Engineering	22.2	29.4	22.2	20.0	10.0	15.4
Broad	18.5	5.9	11.1	30.0	0.0	7.7
Previous Experience	7.4	29.4	27.8	10.0	20.0	30.1
How Things Work	18.5	11.8	22.2	10.0	30.0	23.1
Family	18.5	5.9	16.7	16.7	10.0	0.0
Good Career	14.8	11.8	22.2	6.7	0.0	7.7
Preparation for Another Career Path	3.7	5.9	0	10.0	0.0	0.0
Groups	0	0	0	3.3	0.0	7.7

Table 6 shows the response rates for the different categories for those who stayed in engineering and those who changed majors. Regression models were calculated, however; were found to have little predictive capabilities. T-tests revealed no categories of statistical significance. It is

interesting to note that Math/Science, Build Things, Previous Experience, and How Things Work all showed response rates which were at least 7 % larger for those who stayed in Engineering. Specific Field and Good Career were at least 8 % larger for Non-Engineers. This particularly surprising since it would be expected that those who saw engineering as a good career choice or expressed interest in a specific field would have significant motivation to graduate with an engineering degree. This may be indicative of students choosing engineering with little understanding of what engineering actually involves, which was also mentioned by Seymour & Hewitt as a reason for non-persistence[12].

Table 6. Motivation for Studying Engineering (by Persistence/Non)

Motivation	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Overall**	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Persistence**	Percentage of Respondents that Mentioned this Factor in Reason for Pursuing Engineering **Non-persistence**
Math /Science (ability interest, or aptitude)	61.3%	65.2%	52.1%
Problem Solving	36.8%	37.4%	35.4%
Better World	32.5%	33.0%	31.3%
Innovative / Creative	25.7%	27.0%	22.9%
Practicality	23.9%	24.3%	22.9%
Build Things	23.3%	26.1%	16.7%
Specific Discipline of Engineering	23.3%	20.9%	29.2%
Broad	16.0%	15.7%	16.7%
Previous Experience	15.3%	18.3%	8.3%
How Things Work	15.3%	17.4%	10.4%
Family	14.1%	13.0%	16.7%
Good Career	13.5%	11.3%	18.8%
Preparation for Another Career Path	4.9%	4.3%	6.3%
Groups	2.5%	1.7%	4.2%

Discussion:

Persistence in engineering is difficult to predict. However, it is not surprising that students with a higher commitment to engineering coming into college have higher persistence rates than students who are unsure if they want to study engineering. For the class of students considered in the current study, the retention rate for those students who chose engineering as their major prior to the start of their first year of study was 68.33 % (those that marked on their admissions application) while the retention rate for the students who took the first year engineering class to keep their options open but did not initially intend to study engineering was only 48.57 %. Understanding initial pathways into engineering help us better understand these retention numbers. While the numbers presented in the previous section give some insight into the initial pathways of students entering an engineering program, they are best framed within the context of the responses themselves.

The first thing these results show is that considerations such as interests, abilities, and a sense of purpose are more important to students entering engineering than simply making a good salary. This was expressed in many ways in the students' responses, for instance "I hope that through engineering, I can explore my love of creating, designing, and tweaking to benefit the world" or "I figured I should go into a field that would use my strengths" (in reference to performing well in Physics and Calculus). This might reflect the desire of the students to not appear too shallow or materialistic in their responses or financial compensation might be a secondary reason for these students to choose engineering as a field of study. Very rarely was only a single category or response mentioned and the "Good Career" category seemed to be one of the last things listed (if it was listed at all). Even within the "Good Career" category, it was more likely to receive comments such as "I would most assuredly get a job upon graduation" or that there are a "huge range of career options open" for engineers than anything related to salary.

Since interests and abilities are, in general, more important pathways into engineering than compensation, it becomes very important for students to understand the nature of engineering to make sure that their interests and abilities do coincide with the demands of the discipline. This has implications for both persistence and recruitment of students.

The results of this study show that the students seem to understand that engineering is "heavily based on mathematics and physics [science]" and that engineers "apply math and science to the real world." These types of quotes appeared very frequently in the responses. However, there are also many misconceptions about engineering that come from extrapolating their high school math and science courses to engineering as a whole. For instance the idea that there is a "true answer to every problem" or that engineering is by nature "black and white," as if the role of an engineer was to solve pre-posed math/science problems. Another student was worried that his "creativity might be stifled" in such a major. It is interesting that the students who made these quoted comments did persist in engineering, however; this perception of engineering could deter others from considering engineering.

For 23% of the student in this study, an interest in a specific engineering discipline was a factor in choosing engineering, yet this reason was cited more frequently by those who did *not* persist in engineering. This result was unexpected, but does support the conclusion that students may be choosing engineering based on incorrect conceptions of the major. It is also important to note that those students who cited "Previous Experience" as a reason for studying engineering, and thus likely had a better understanding of the engineering discipline, were more likely to persist. Having an opportunity to experience engineering before starting college might help students with an interest in a specific engineering discipline or who are told "they would make a good engineer" determine if engineering is "right for them." This could also be done in a First-Year Introduction to Engineering course, such as the one in which these responses were collected, but as stated before, those students who came into their first year intending to be an engineer were nearly 20% more likely to persist than those who came in unsure of their desire to study engineering.

The idea that engineering can be used for the benefit of others is an important factor for many students, especially females, in deciding to study engineering according to this study as well as others[3,8]. However, the response rates for this category were nearly the same for those who persisted and those who did not. In other words, this facet of engineering is an important factor for recruiting students, but does not necessarily mean they will persist. Changes in curriculum

which emphasize the use of engineering practice to better the world or opportunities to use engineering skills to help others during their college tenure could be beneficial to improve these statistics, but further work needs to be done to design and investigate the usefulness such experiences.

Finally, there are a significant number of students that seem to think that engineering is basically "playing with Legos on a larger, more grown-up, scale." The ironic thing is that this fairly simplistic view of engineering may have as much or more of an impact on the recruitment and retention of students as any other factor studied, especially among males. Building with Legos and other construction toys was categorized under the "Build Things" category in this study. Also, many of the experiences categorized as "Previous Experience" were Lego robotics teams. Both of these categories were noticeably higher for those who persisted in engineering. While some of the rigorous analysis used by engineers is often absent in this type understanding of engineering, many of the design, build, test concepts are reinforced. Interest and aptitude in these concepts of engineering might be important considerations for those choosing to study engineering.

There is a great diversity in the types of engineering programs that exist around the country and likewise the navigational path to begin those programs. We cannot suggest a one size fits all approach for persistence or retention, but it is important to recognize that some level of non-persistence is natural and appropriate (despite engineering educational goals for producing more qualified engineers each year) as it is critical to helping students make an informed choice towards their future. This study adds to the body of literature of student motivations and persistence and hopefully initiates meaningful reflection by engineering educational faculty and administrators. The collective responses offer some "trends" related to gender and discipline, but each student is still driven by their individual experiences and we must work to support them as individuals.

Limitations / Future Work:

The primary limitation of the current study is that it was conducted at a single institution; a larger scale study including multiple dissimilar institutions would be required to support generalizability. Also, future work should be focused on expanding the qualitative research beyond essay responses to student interviews to hear from students directly and interactively about their experiences and how they relate to their motivations and educational persistence.

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