First Year Engineering Students Perceptions of Engineering

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Abstract

Engineering at the University of Illinois has steadily drawn increasingly larger incoming classes of students. With a significant population and a diverse number of programs, these freshmen will be entering a unique engineering culture. This study sought to understand the perspectives and experiences of the students in regards to their engineering identity as they entered the university in the Fall of 2017. Differences in perceptions among demographics such as gender, ethnicity, and the different engineering majors were also examined.

A survey was administered to 1986 freshman engineers within their first month of school. The survey contained questions pertaining to the students' perceived understanding of and confidence in engineering, as well as their reasons for pursuing engineering. Common perceptions of engineering qualities and responsibilities were also assessed. Based on survey results with a 23.3% response rate, students across all majors were confident in their ability to succeed, but female students reported lower levels of confidence than male students. The most common reasons students selected for pursuing engineering were their abilities in math and science, followed by having prior experience with engineering. However, female participants selected prior experiences as a reason at a significantly lower level than their male counterparts. Within the various engineering majors and programs themselves, there were differences in satisfaction levels. Students who were not in their first choice major were less likely to agree with being happy in their field or intending to stay in their major. However, overall the participants rated themselves as having a good understanding of engineering and planning to stay within engineering as a realm. Descriptors for engineers that were most commonly selected included 'Practical' and 'Analytical' while less commonly selected were 'Artistic' and 'Kind'. A brief description of a follow up study is provided.

Introduction and Background

Engineering education has grown in significance as the focus on engineering development and diversity grows. One of the key concerns within the realm of engineering education is that of the students' perceptions of engineering in regard to their own engineering identity and abilities.

In a study by M. Besterfield-Sacre in 1997, incoming engineering students were surveyed on their perceptions of engineering as a field, their own abilities as engineers, and their confidence in their success [1]. The performance and retention of the students were then tracked for the following three years and related back to their initial attitudes. Students who left engineering in good academic standing had significantly different attitudes about themselves and engineering compared to students who stayed in engineering, or who left in poor academic standing. The initial attitudes of students who left in good standing reflected significantly lower general opinions of engineering courses and work, and lower confidence in their own knowledge and skills. This suggests that identifying initial attitudes such as low confidence and negative views of engineering and finding ways to improve them may lead to increased retention of students.

Another factor towards retention that is often considered alongside initial confidence levels and view of engineering is self-efficacy. Self-efficacy can be differentiated from self confidence in that it pertains to the belief in one's ability to attain a certain specified level of accomplishment. In a study by Dr. M. Hutchison-Green in 2006, first year engineering students were surveyed regarding their self-efficacy beliefs and what factors were related to them [2]. It was found that self-efficacy was largely shaped by mastery and vicarious experiences, in which either the subjects themselves mastered a task or encountered someone else mastering a task. The beliefs were also shaped by social persuasions, where interactions with teammates, professors, and teaching assistants could all influence how a student viewed their abilities [3].

Historically, engineering has been a field predominantly filled with men. This has shaped a lot of public perception of engineering as a male space and field, and can lead to women in engineering having very different perceptions than their male counterparts. Research has consistently shown that female engineering students entering college often have lower confidence in their background knowledge of engineering and ability to succeed than their male peers [4][5][6]. The lower confidence levels in female engineering students has been a concern for many educators and researchers looking to increase retention rates in science and engineering fields. In a longitudinal study tracking women engineering students over 6 years, it was found that in the first year of engineering there was often a significant drop in academic self-confidence [5]. This implies that women in engineering not only start off with lower confidence, but can decrease further over the course of the crucial first year depending on experiences. Factors that helped combat this noted confidence decrease were experiences in programs specifically meant for women in STEM, and membership in student groups within the university. Interestingly, when students were interviewed about their experiences during their first year and asked to rate their own confidence in their success, male students rated themselves much higher than female students, and cited feeling more accomplished than their peers as a reason for the confidence [3][4]. Female students, instead, felt inferior to their peers and thus gave lower ratings for themselves. Both groups of students were in fact similarly performing, showing that the difference in perceptions may be based more on social conditioning than factual evidence.

Other differences in perceptions have been noted in studies assessing attitudes of students in different specialties, and of different nationalities. In a 2003 study on engineering perceptions of students in 11 different engineering majors, it was found that students held higher regard for their own major, and that students in smaller, more selective programs saw engineering as a more competitive and male oriented field [7]. A similar study examining perceptions of domestic versus international students found that domestic students were more confident in their understanding and ability to succeed in engineering [8]. These differences show that the effects of experiences on perceptions of first year students cannot be considered monolithic.

Aims and Methodology

The University of Illinois has been a center for engineering innovation and academic success for over 150 years. At the time of this study, there are over 15 different engineering majors and several engineering programs available. While the overall enrollment of women and minority engineering students has increased over time, there are still significant differences in the

demographic statistics between genders and ethnicities. The size of engineering departments varies as well, with the larger ones such as Computer Science or Mechanical Engineering having a greater breadth of concentrations and application areas. Smaller departments often have more concentrated areas of interest, such as the Nuclear Engineering and Chemical Engineering departments. The variety between majors and differences in student demographics creates a unique culture of engineering at the university.

Given the importance of the first year students' attitudes in determining a student's success, this study primarily aimed to understand the perspectives of incoming engineering students. The goal was to examine what perceptions students have when they arrive to the university and to engineering as a major. A secondary aim was to further assess what significant differences in perceptions and attitudes exist in between student demographics such as ethnicity, gender, and major.

An anonymous online survey, administered during the first month of term, was determined to be the most effective way to reach participants and achieve the study goals. The surveyed population included all students entering the University of Illinois in either the Engineering College or engineering programs such as Preengineering, which in the Fall of 2017 was a total of 1986 students. These students were sent a recruitment email for the study within the first month of each semester, including information on the purpose of the research and a link to the survey. A reminder email containing the same information was sent to the same list of freshmen one week after the initial email, in order to encourage higher participation. Additionally, Engineering Learning Assistants (ELAs) who are upperclassmen assigned to first years within their major were asked to instruct their groups of freshmen to check their email and take the survey.

The survey was designed to take an average of 5 minutes to finish, in order to have a significant number of participants fully complete all questions. Subjects were first asked to self-identify their ethnicities, genders, and majors. Each demographic question included both a "Prefer not to answer" and an "Other" option, with "Other" allowing participants to expand upon their answer if they chose. In questions which asked students to rate their responses, the scale included "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" which corresponded to numerical ranks of 1-5. All questions (except for the first three assessing demographics) are included in Table 1.

Table 1: Survey Questionnaire

Question 4	My major was my ____ choice ❏ First ❏ Second ❏ Third ❏ Other

Question 5	Please rate the extent to which you agree with the following statements: ❏ I have a good understanding of my engineering major ❏ I have a good understanding of engineering as a profession ❏ I have a good understanding of the role engineers play in society ❏ I'm not sure what engineers in my field do professionally
Question 6	Please rate the extent to which you agree with the following statements: ❏ I feel confident in approaching coursework in my major ❏ I can get good grades in my classes ❏ I will be successful in my field ❏ I am just not good at engineering ❏ Engineering is too difficult for me ❏ I am good at math ❏ I am good at science ❏ Engineering is for students who are good at math and science
Question 7	Please rate the extent to which you agree with the following statements: ❏ I knew what major I wanted before I applied to college ❏ I am going to stay in my major ❏ I am happy with my major ❏ I am passionate about my major ❏ I am going to stay in the Engineering College ❏ I don't enjoy engineering ❏ I don't enjoy engineering coursework
Question 8	I chose Engineering because.... (please select all that apply) ❏ I have prior experience with engineering ❏ I am good at math and science ❏ My Guidance Counselor advised me to ❏ My parents advised me to ❏ Other (please specify)
Question 9	I chose my major because I wanted work that.... (select all that apply) ❏ Challenges me ❏ Will let me make lots of money ❏ Allows me to use computer, math, technical skills and/or science ❏ Makes me think highly of me ❏ Allows me to help my community and society ❏ Is satisfying to me ❏ Other (please specify)
Question 10	Please rate the extent to which the following statements agree with your idea of what engineers do ❏ Mainly work on machines and computers ❏ Mainly work with other people to solve problems ❏ Work on things that help the world ❏ Work on designing and improving things ❏ I don't know what engineers do ❏ Other (please specify)

Question 11	Which of the following words agree with your idea of an engineer? Select all that apply. ❏ Confident ❏ Competitive ❏ Independent ❏ Big Picture Oriented ❏ Helpful ❏ Practical ❏ Kind ❏ Unimaginative ❏ Thrive under pressure ❏ Analytical ❏ Understanding ❏ Disorganized ❏ Loner ❏ Artistic ❏ Arrogant

In determining significant differences in responses between demographics, two different regression methods were used for the different types of questions. For questions of the form "Select all that apply" a simple logistic regression model was fit to the data, treating the response of each option as a binary (either Yes or No). For questions requesting a rating of agreement, an ordinal logistic model was fit, evaluating the different ratings as responses. Each of these methods evaluated significance of ethnicity, gender, and/or major at a 95% confidence level.

Results

Of the 1986 surveys sent out to Engineering and Pre-Engineering freshmen, 462 were completed and included in the results, giving a response rate of 23.3%. The demographic statistics of the responses are shown in Figures 1, 2 and 3a.

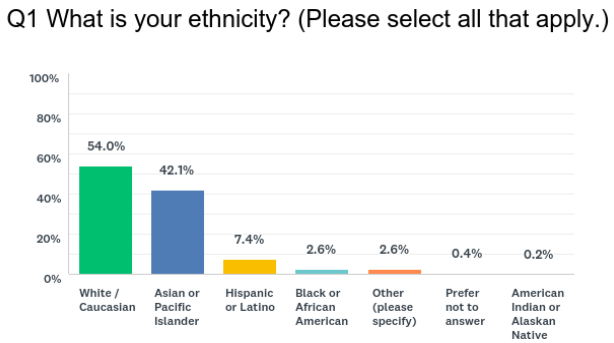

Figure 1: Ethnicity Statistics of Sample

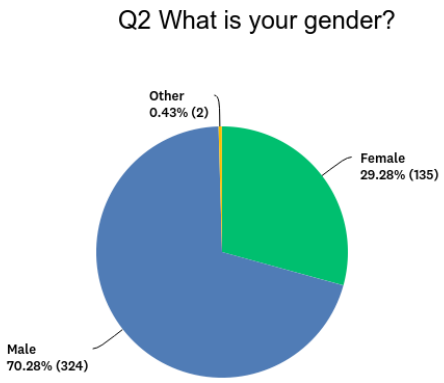

Figure 2: Gender Statistics of Sample

It can be seen that the majority of participants were either White or Asian/Pacific Islander, and 70.3% of participants were male. This does reflect the known demographics of the engineering population at the University, and follows trends noticed in engineering populations overall.

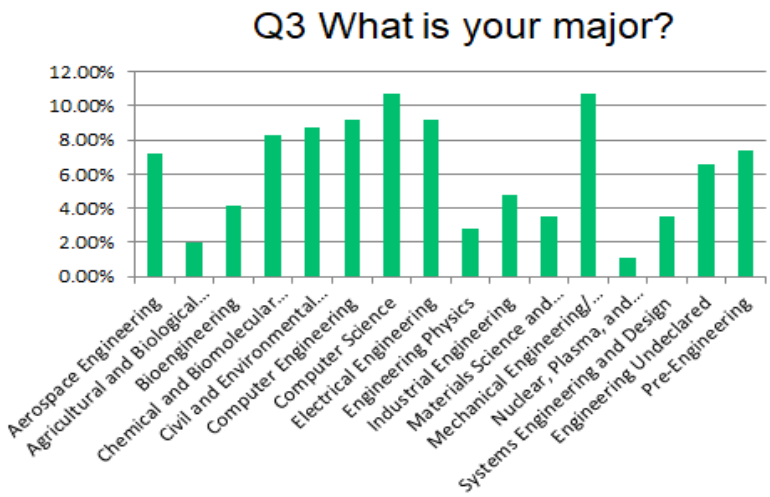

Figure 3a: Major Statistics of Sample

There were responses from every engineering major and engineering program available at the university, with the larger response groups corresponding to the larger programs (Electrical and Computer Engineering, Computer Science, Mechanical Engineering). This accurately reflects the distribution of students among these programs for the engineering population at the university, which can be seen in Figure 3b. These statistics for Figure 3b were drawn directly from the Fall 2017 official enrollment reports from the university [9]. The only difference in population percentages can be seen in the response rates from students in Engineering Undeclared and Pre-Engineering. There is a larger percentage of participants who enrolled in those programs, compared to the overall number of engineering freshmen at the university in those areas. This larger response rate can perhaps be attributed to those students not yet being in their set engineering major, and thus being more interested in giving feedback to the Engineering College and/or having stronger opinions about their perceptions and experiences thus far.

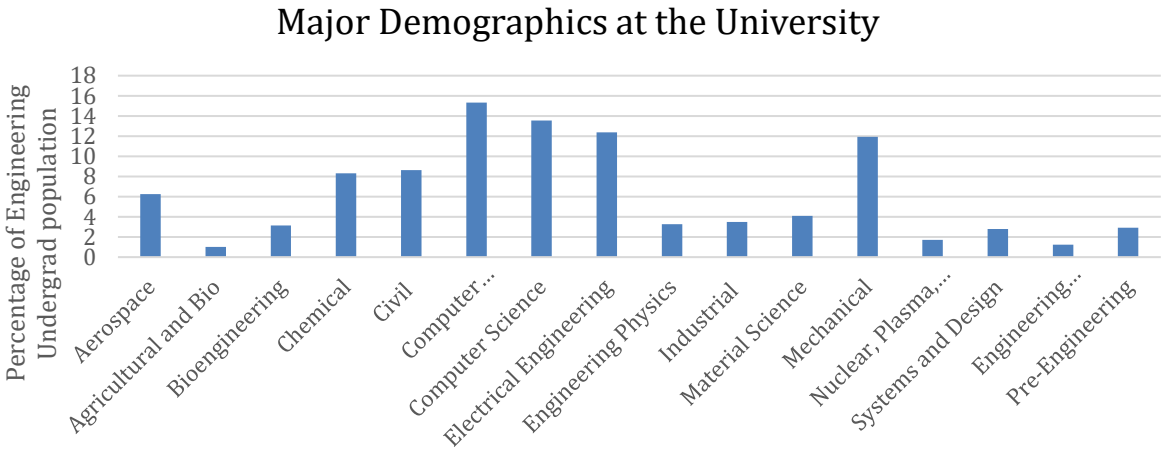

Figure 3b: Percentages of the Engineering Undergraduate Population which are in each Engineering Major.

In examining the students' choices of major, it was determined that gender and the major itself both made for differences in whether a student was in their first choice major or not. Table 2 below shows how female students were over 11% more likely to be in their first choice major. The gender difference may be explained by the Engineering College initiative to include more women in engineering, as mentioned previously. By working to allow women into their first choice of major, the college can support more women in their engineering area of interest and avoid having them leave engineering as a field.

Table 2: Gender Differences in Choice of Major

My major was my....		
	First Choice	Second Choice
Q2: Female	88.89%	5.93%
Q2: Male	77.09%	13.00%

Table 3 displays the difference in choice selection between the engineering majors. This difference is likely due to the acceptance rates and natures of the majors themselves, with the smaller and more selective majors (Materials Science, Nuclear, Agricultural) taking only students who would by nature have the major as their first choice. Larger majors also tend to have high amounts of students who selected them as their first choice, due to having the capacity to take many students. These majors also tend to be more highly ranked nationally and have more diverse job opportunities. It is the medium-sized majors whose placement process often takes students who didn't place into other majors (Systems and Engineering Design, Physics, Engineering Undeclared) who have the lowest number of students who chose the major as their first choice. Systems Engineering and Design in particular has equal number of students who selected it as their first and their second choice, likely due to the program's past as a General Engineering major.

Table 3: Major Differences in Choice of Major

My major was my....		
	First Choice	Second Choice
Q3: Aerospace Engineering	87.88%	12.12%
Q3: Agricultural and Biological Engineering	100.00%	0.00%
Q3: Chemical and Biomolecular Engineering	86.84%	13.16%
Q3: Civil and Environmental Engineering	92.50%	7.50%
Q3: Computer Engineering	95.24%	4.76%
Q3: Computer Science	97.96%	0.00%
Q3: Electrical Engineering	78.57%	21.43%
Q3: Engineering Physics	61.54%	38.46%
Q3: Industrial Engineering	81.82%	13.64%
Q3: Materials Science and Engineering	100.00%	0.00%
Q3: Mechanical Engineering/ Engineering Mechanics	93.88%	2.04%
Q3: Nuclear, Plasma, and Radiological Engineering	100.00%	0.00%
Q3: Systems Engineering and Design	43.75%	43.75%
Q3: Engineering Undeclared	62.96%	14.81%
Total	86.28%	10.72%

The next section of the survey asked questions assessing how students would rate their own understanding of engineering in various contexts. There was no significant difference in responses among the various demographics, and thus the average responses from the entire sample population are shown in Figure 4.

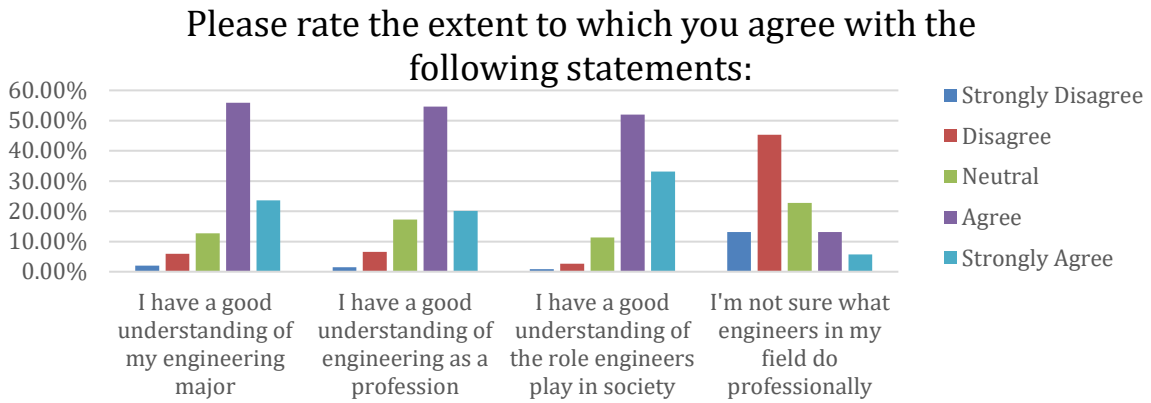

Figure 4: Participants Overall Rated Understanding of Engineering

Overall, incoming students rated themselves as having a good understanding of engineering both at the academic and professional level. However, the majority favored merely agreeing with their understanding being good, rather than strongly agreeing. In response to the question assessing whether they were unsure about the role of engineers in their field, the subjects primarily disagreed or chose to be neutral.

The next series of questions sought to further assess the confidence of the first-year students with regards to their own performance and success within engineering. Within the responses given by the subjects, significant differences were found between the male and female averages. These averages are given in Table 4, along with the calculated p-values denoting the strength of the statistical difference between the answers given by the two groups.

Table 4: Female vs Male Rated Confidence Responses, with P-Values

	Weighted Average		P-Value (< 0.05 highlighted)
	Female	Male	
I feel confident in approaching coursework in my major	3.41	3.82	8.68 e-05
I can get good grades in my classes	3.41	3.86	1.38 e-05
I will be successful in my field	3.71	4.00	3.41 e-03
I am just not good at engineering	2.34	2.19	0.099
Engineering is too difficult for me	2.36	2.07	0.013
I am good at math	3.71	4.02	6.70 e-05
I am good at science	3.67	4.16	2.37 e-09
Engineering is for students who are good at math and science	3.7	3.84	0.211

The entire group of participants on average rated themselves confident in their own abilities and had very similar agreement that engineering as a field is for students who are strong in math and science. Within each question however, males consistently rated themselves as agreeing more strongly with their own abilities and disagreeing more strongly with engineering being too difficult or not for them. Female participants tended to rate themselves closer to simply "Agreeing" or being "Neutral" when it came to their confidence in their success and abilities.

Satisfaction with their major was the next quality assessed in the survey, with a series of questions asking how much the subjects liked their current major and intended to stay with it. Figure 5a shows the overall average response to each question.

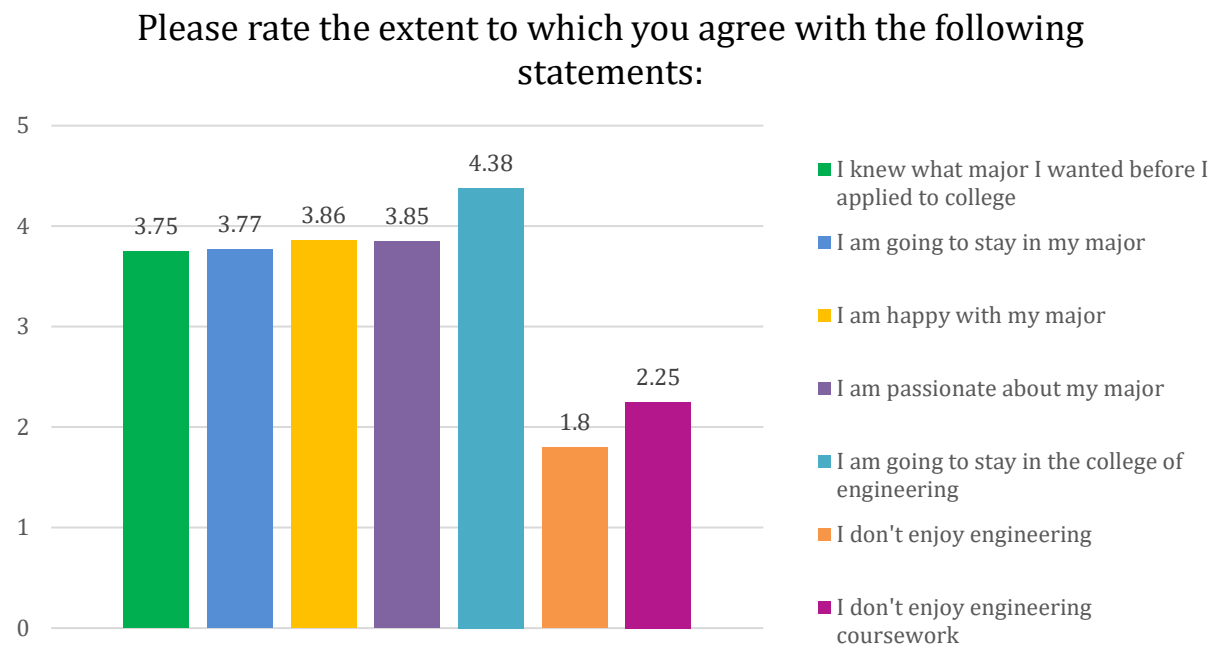

Figure 5a: Participant Responses to Interest in Major

On average, participants agreed that they were happy and passionate about their major and planned to stay with it and in engineering. Most students strongly disagreed (rating of 1.80) with the statement of not enjoying engineering but disagreed less strongly (rating of 2.25) about the statement of not enjoying engineering coursework. Students who expressed neutrality or disagreement about staying in their specific major still expressed strong agreement on the intention to stay within engineering.

Within the majors themselves, certain patterns of responses occurred for the various questions. The most statistically significant differences in responses occurred with the questions of being happy in their major and intending to stay in their major (with p-values of less than 0.0001). The programs with students least happy and least intending to stay were the same ones which had a higher percent of students who were not there as a first choice, such as Engineering Undeclared, Pre-Engineering, Engineering Physics, and Systems Engineering. This suggests that students

who got into their first choice of program are therefore happier with their program and more likely to intend to stay in it. Additionally, the majors Engineering Undeclared and Pre-Engineering are by their nature not meant for students to remain in them for long. Figure 5b shows how the responses varied by major for the two questions.

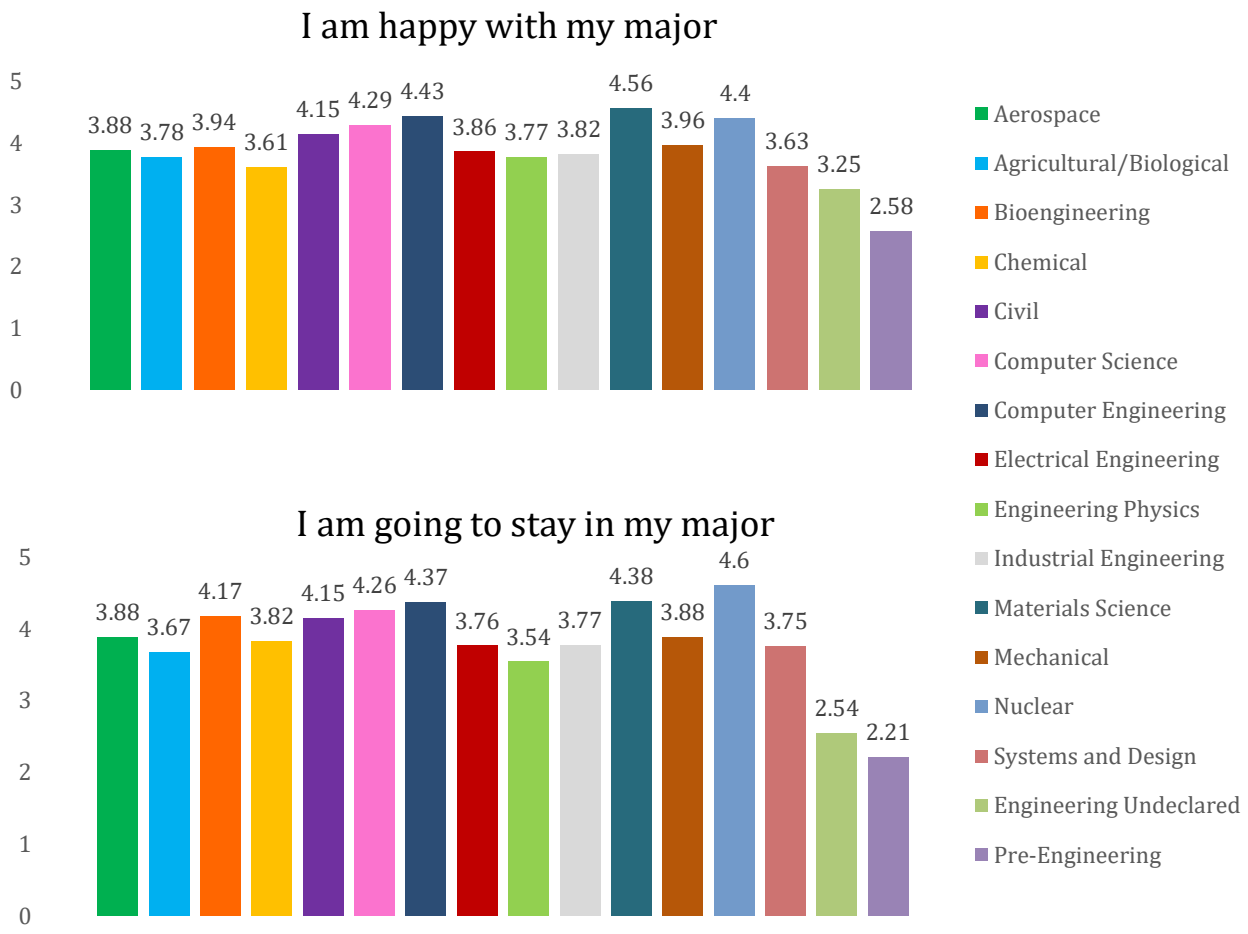

Figure 5b: Satisfaction Responses Separated by Major

One of the goals of the study included understanding why the incoming students chose engineering and their majors specifically. Question 8 on the survey asked which applicable experiences influenced the participants' decisions to apply for engineering at the university. Among the responses given by the participants, the only significant differences found were between male and female students. Due to the structure of the question, it is unknown whether non selection of an experience means it was not influential, or that it did not happen. However, comparing selection responses levels can yield the understanding of which experiences did have an influence when they occurred. Figure 8 on the next page shows the different response levels between genders to the various experiences.

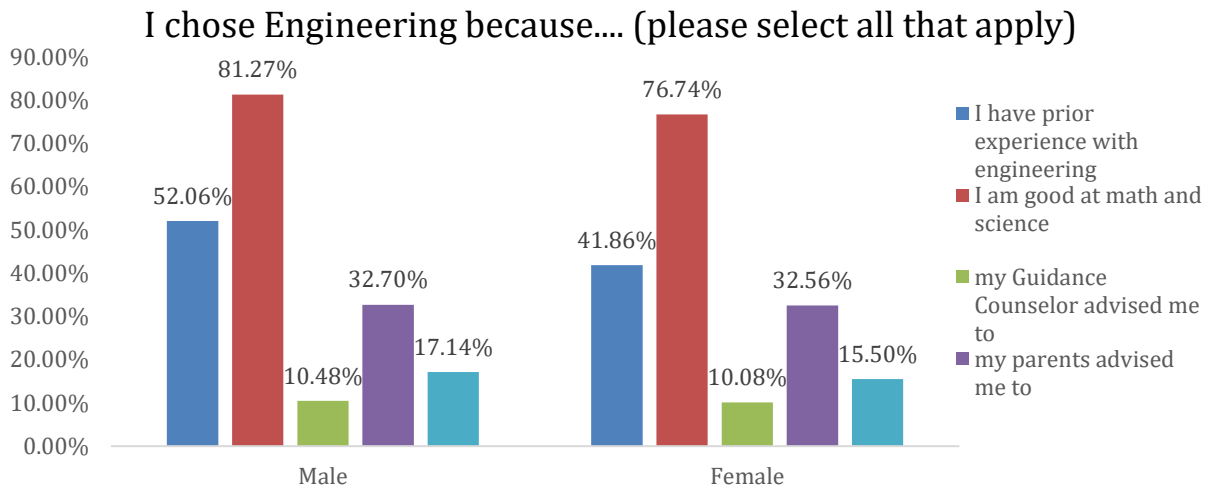

Figure 6: Male Participants and Female Participants Reasons for Choosing Engineering

The significant difference apparent is in having prior experience in engineering, where only 41.9% of female participants attributed that as a factor for their choice of engineering, as compared to 52.1% of males. Being strong in math and science was the most commonly selected reason for choosing engineering, between all participants. Prior experience (at the different levels between genders) was the next most commonly selected, with parental advice being the third most commonly selected. Notably, guidance counselor advice was only chosen by about 10% of participants as a reason for pursuing engineering. This could mean not many incoming students received advice from their guidance counselors in regard to engineering, or if they did it was only influential for about 10% of the participants.

Figure 7a below shows participant responses to a further list of reasons for choosing their major specifically. It is assumed that the participants responded in regards to their first choice major.

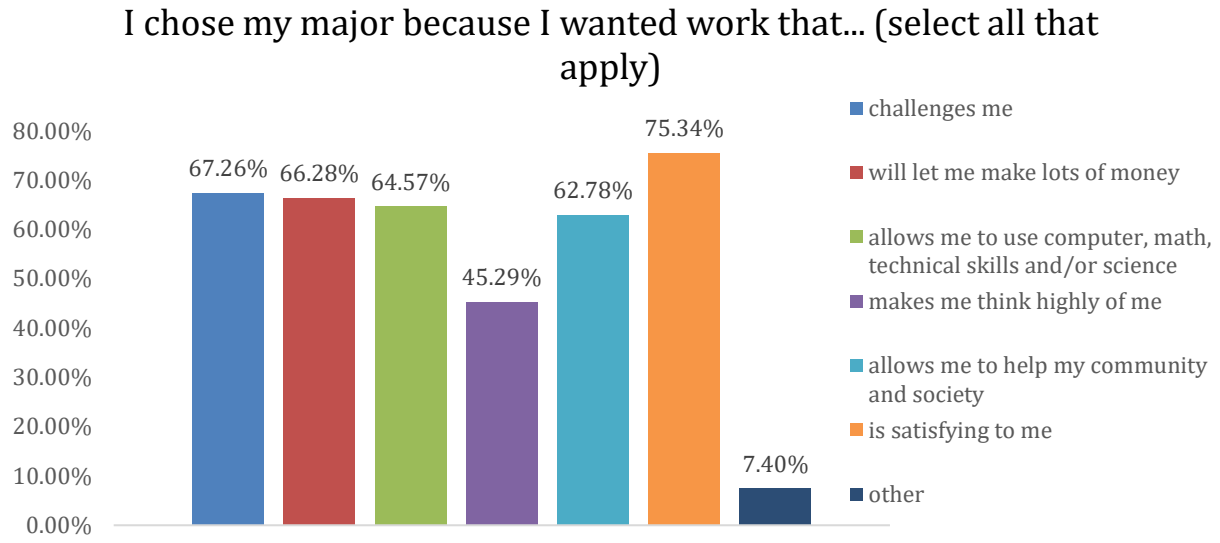

Figure 7a: This figure displays participant responses to a list of reasons for choosing their major

Most of the reasons given were selected by 60-70% of participants, including wanting work that challenges, makes money, allows for use of technical skills, and helps the community. The most selected reason (at 75.3% response) was that participants chose their major because they wanted work that was satisfying to them. The definition of what made work satisfying was not specified in the question, which may explain the slightly higher selection rate of the reasoning. A combination of the other reasons could also be potentially perceived as "satisfying".
Notably, the only reason that was selected by less than half the participants was that of choosing the major in order to have work which made the students think highly of themselves. Overall, this was only selected by 45.3% of subjects, but within the various majors of the subjects there were statistically significant differences (with a p-value of 0.0052). These differences are illustrated below in Figure 7b.

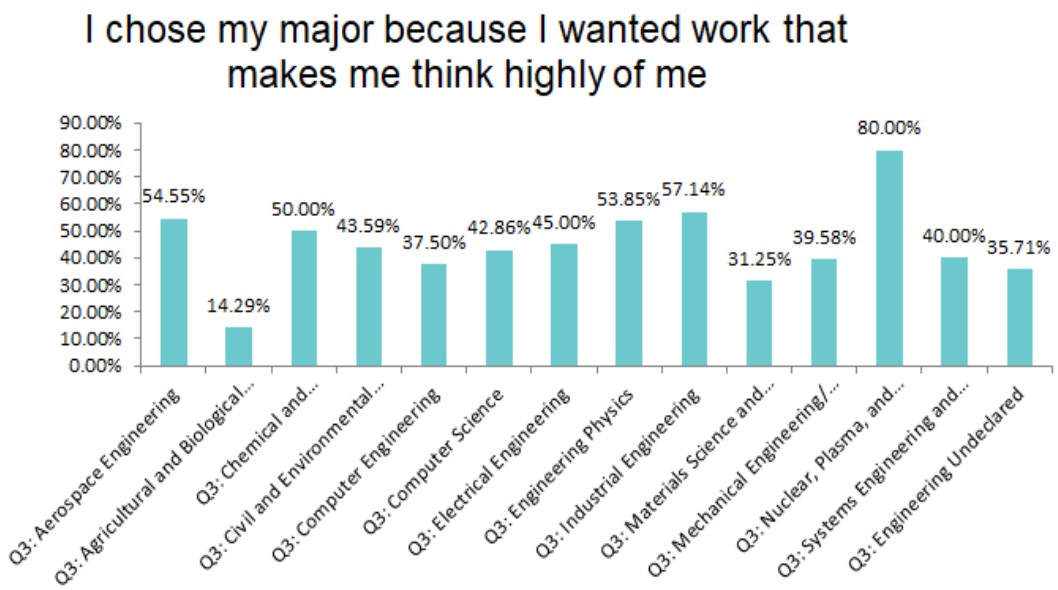

Figure 7b: Percentages of the Different Majors that Agreed with Reason for Choosing

Freshman students in most majors had a selection rate of about 35-50% for the statement about thinking highly of themselves. The two significantly different major groups were Agricultural Engineering and Nuclear Engineering. Of the participants in Agriculture Engineering, only 14.3% chose wanting work that made them think highly of themselves as a reason for pursuing their major. By contrast, 80% of the nuclear engineering participants selected that same reason. This significant difference, along with the other selection percentage differences between the other majors, reflects the diversity in engineering identity between the different majors and corresponding engineering fields.

The survey concluded by asking questions on what specific examples of work or characteristics participants pictured when contemplating engineers. Subjects were asked to rate how much they agreed with the examples of types of work engineers do. Within the ratings received in responses to these questions, the only statistically significant differences were between genders. Table 5 on the next page shows the average weighted responses on the scale from 1 to 5 from both main gender groups, along with the calculated p-values.

Table 5: Perceptions of What Engineers Do (Female vs Male)

Please rate the extent to which the following statements agree with your idea of what engineers do	Weighted Average		P Value (< 0.05 highlighted)
	Female	**Male**	
Mainly work on machines and computers	3.32	3.45	0.029
Mainly work with other people to solve problems	4.26	4.19	0.298
Work on things that help the world	4.43	4.29	0.031
Work on designing and improving	4.49	4.39	0.092
I don't know what engineers do	1.8	1.84	0.913

On average, all participants strongly agreed that engineers worked with other people, to help the world, and to design and improve things. Also, participants disagreed with the statement that they did not know what engineers did. However, within the responses, female participants agreed significantly less strongly that engineers worked mainly on machines and computers, and agreed more strongly that they work to help the world, when compared to the male participants. This suggests a gendered difference in perception of engineering responsibility.

The final question of the survey asked for participants to select any descriptions that matched with their idea of an engineer. Figure 8 below shows the ranking of the characteristics in terms of how commonly selected they were by participants. There were no significant differences among demographics.

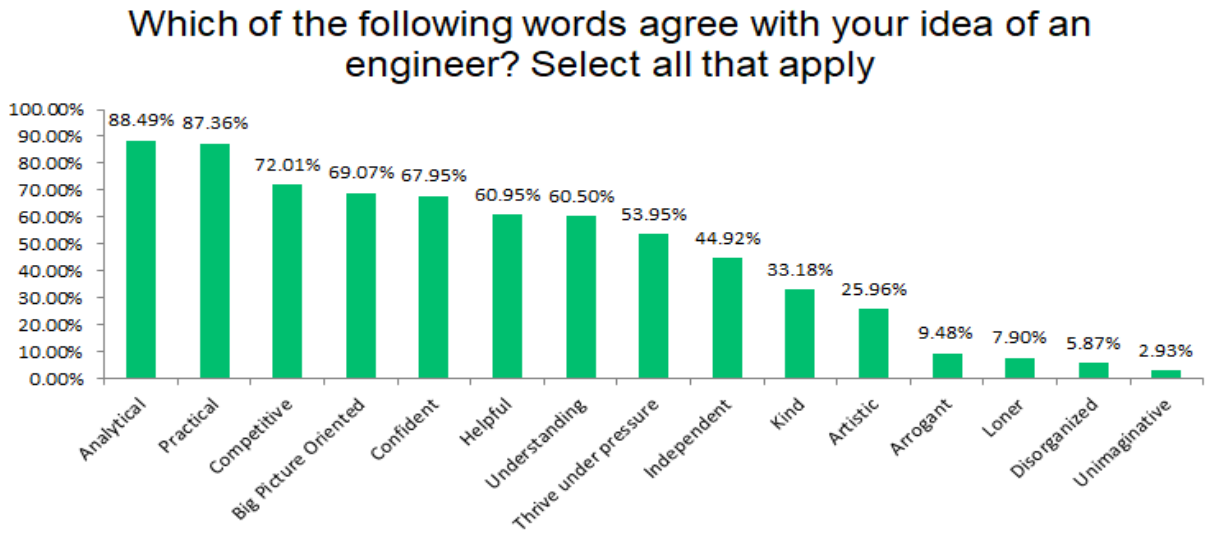

Figure 8: Percentage of Participants Who Selected Various Characteristic for Engineers

Adjectives generally viewed as negative (such as "Loner" or "Unimaginative") were the least selected, with response rates in the range of 3-10%. The next least selected descriptors are "Kind" and "Artistic", which are non-negative but were only chosen by 33% and 25% of participants respectively. The most commonly selected descriptors are "Analytical" and

“Practical”, each chosen by about 88% of participants. The range of descriptors selected by over a majority of participants also include “Competitive”, “Big Picture Oriented”, “Confident”, “Helpful”, “Understanding”, and “Thrive Under Pressure”. This list allows an understanding of the common perception of engineers is by the incoming class of engineers themselves.

Discussion

From the survey responses, several key observations can be made with regards to incoming engineering students perceptions. Mainly, first year students rate themselves as having a good understanding of what engineering is as a major and a field. That understanding itself varies depending on what type of engineering program the first year student is in, and what gender they are. The majority of participants however saw engineering as cross functional, responding that engineers work with people, machines and technology to solve problems and help society. This multifaceted view is a positive sign for the freshmen engineers, as they will often have to work on projects and in areas that can span several engineering and non-engineering fields. Regardless of major, the first year students showed a grasp of the fundamentals of engineering being problem solving and improving.

Incoming engineering students also have largely positive perceptions of engineers as people, viewing them as practical, analytical, and helpful. Interestingly, the descriptors chosen most to describe engineers all pertained to how well they could perform their work as engineers and tended to reflect less on personal traits. While the participants self-identified engineers as competitive and confident, they were less inclined to also include descriptors such as kind or artistic. In this regard, the common perception of the engineer seems less three dimensional than would be suggested by the common understanding of what engineers do. As the first year freshmen encounter more engineering peers, professors, and professionals, these views may change to include more or less descriptors.

As found in several previous studies, female engineering freshmen tended to rate themselves lower in confidence and prior experience in engineering than their male peers. However, given that the confidence rating they had was still positive, this initial attitude towards engineering is not cause for concern. If female students have access to mastery experiences and positive feedback during their first year of engineering, their self-confidence and self-efficacy could stand to increase, and perhaps match that of their counterparts.

This study was an initial part of effort to understand shifts in first year engineering students’ perceptions. A follow up study with the goal of assessing perceptions and experiences after a semester of college was held. In that study, the same population of students were administered a second survey asking the same perception-based questions as this initial study, with additional questions asking participants to self-assess how their perceptions have changed, and what experiences may have influenced those changes. By comparing the results of the follow-up study with the results in this paper, the goal is to understand what experiences may positively or negatively impact first year engineering students and their perceptions of themselves as engineers.

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