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Factors that Influence Students to Major in Engineering*

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In order to improve recruitment in engineering at the undergraduate level, it is important to examine how current engineering students perceive the engineering field and the factors that influence major selection. This qualitative study explores why students choose their engineering majors and how they perceive their field. The results show that students perceive engineering as problem solving, improving society, innovation, and an applied science. Additionally, students major in engineering due to personal interests, perceived aptitude, career options, and to improve society. The findings further show that students' interests in engineering can be predicted by certain classroom environments in current and previous engineering courses.

Keywords: engineering education, motivation, undergraduate education, major selection

1. Background

The selection of an undergraduate major is an important decision for many high school students. Often, the choice of major may have a profound influence on a student's life since it may affect their future studies and career paths. A current issue that engineering education is facing is the underrepresentation of women and minorities in the field in terms of enrollments in engineering courses at the undergraduate level [1]. A variety of strategies have been used to engage K-12 students in engineering and other STEM fields, such as outreach programs, summer camps, and guest speakers. To better design such programs to improve and broaden recruitment, engineering educators must first understand how and why current engineering majors select their field as well as the issues surrounding their achievement and retention.

1.1 Initial interest

College students select majors that are aligned to their individual interests [2]. Students that have an individual interest in a subject find personal value and are intrinsically motivated to study it. Interest is a driving force in the level and quality of work and value in which they place in the subject matter [3, 4]. Students who have intrinsic value in the engineering field are more likely to pursue a degree in engineering than those that pursue non-engineering fields [5]. Donaldson and Sheppard found that students with preliminary interest in engineering were more likely to choose that as their major than students who had other preliminary discipline interest choose their preliminary interest as their major [6]. Furthermore, students who were initially interested in engineering did less changing between majors than students in other disciplines. Similarly, Luewerke, Robbins, Sawyer, and Hovland reported that high interest in engineering may sustain students' persistence in engineering despite low academic performance [7]. These examples imply that there is a strong correlation between interest and persistence.

Individual interest in engineering may get students to major and persist in it, but there are also problems with waning interest and demotivation. Ohland, Zhang, Thorndyke, and Anderson's longitudinal study, spanning 1987–2002, of nine universities in the southeastern US showed that the majority of students leaving engineering have a grade point average of 2.0 or higher [8]. Although these engineering students were performing fairly well (2.0 GPA or higher), there may have been other issues that influenced their decision to switch majors, which were not limited to achievement. One of the possible causes could have been a loss of interest in engineering. Baillie and Fitzgerald examined motivation issues that led to students dropping out of a university in the UK [9]. They found that 75% chose to major in engineering due to interest or career advising, but the range of demotivators that led to dropouts included: large class sizes, concepts being too high level and abstract, and the academic pressures of success and exams. In these cases, loss of interest could be due to the lack of a supportive learning environment, disconnect between students' perception of engineering and what is being taught in class, and low achievement.

Ohland et al. [8] found that students that leave engineering select business if their GPA was less than 2.5 while students with higher GPAs choose the physical sciences. Anderson-Rowland and Urban [10] also found that 30% of students that leave engineering at their university go into the

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business major. Ohland et al. [8] believed that students with the lower GPAs select business as their next major since it does not require the high-level math and science found in engineering. These findings are in contrast to Luewerke et al. [7] where interest can still outweigh low achievement in terms of persistence. It could be surmised that there is a limit on how far individual interest can take a student given their academic performance. Also, the students who switched to business majors [8, 10] may have developed a more pragmatic plan in terms of their academic and future professional paths. They switched to a major that was better suited to their talents.

Thus, perceptions of one's own ability in related fields may also impact how they persist in the major field. In the cases above, students settled on another major that was more suitable to their own perceived abilities. Since it is closely tied with math, physics, chemistry, and many other science fields, the onus of engaging and supporting students is not just limited to engineering, but to all related fields as well.

1.2 Self-efficacy and aptitude

In addition to interests, aptitude and ability may affect major selection. College students' self-perceptions of abilities are important to their pursuit of and persistence in selected majors [11, 12]. Academic achievement—particularly, in mathematics—is important indicators due to engineering's foundation in math and science. For example, French, Immekus, and Oakes [13] found cumulative GPA, SAT math score, high school rank, and motivation were significant predictors of students selecting engineering as a major. Though students have the initial interests and aptitude, they may still drop out of the major if they lose confidence in their ability or only envisage failing scenarios. Such perception of one's abilities is known as self-efficacy. Bandura posited that self-efficacy can have an impact on how children perform on intellectual tasks—that is, a student with a strong sense of self-efficacy can perform better than another student with lower self-efficacy even if they are at the same level of cognitive development [14]. Learners with high self-efficacy are seen to set higher goals and challenges for themselves, exert more effort toward their tasks, and can visualize success [14].

Self-efficacy has been shown to be a significant predictor of or have an effect on GPA in engineering [15–17] as well as persistence in undergraduate engineering programs [18]. Therefore, it is beneficial for educators to provide opportunities to students in which they can become confident in their abilities, be successful, and enjoy moments of achievement and accomplishment. Self-efficacy and motivation can be facilitated by a social structure throughout the learning process [14, 19, 20]. Such social structures provide students with support from peers and mentors that can guide them through the trials and tribulations of engineering studies. Those social structures can also be used to connect students with practitioners, who can give them real-life perspectives on the engineering field.

One strategy to sustaining improving students' sense of self-efficacy is to provide them with real-world, authentic learning experiences. Students that have more experience in engineering are more likely to have a higher level of self-efficacy, motivation, and expectancy [21]. Having industry experience in engineering affords students the ability to know what it is like to be a real engineer and see the real-world application of topics they learn in class. However, such opportunities are usually seen toward the end of the program. Since such real-world experience (e.g., through internships) may not be readily available or feasible for K-12 students, teachers would need to provide plenty of engineering experiences in their classrooms where students can engage in authentic engineering activities so that they can apply their knowledge and interest. Such environments would also allow students to work within a complex problem space with their peers and facilitated by their teachers. Thus, in terms of recruitment, K-12 classrooms have the responsibility of making sparking interest in engineering and then sustaining that interest so that students will choose to major in engineering. When students get to an undergraduate engineering course, faculty will need to continue that strategy to keep students in the major.

1.3 Classroom environment

Though learner issues—such as motivation, aptitude, and self-efficacy, are important—the classroom environment can also affect students at the undergraduate level [8, 9]. According to Ohland et al. [8], another area that these students go to after leaving engineering is education and the social sciences, though there is no relation to GPA and education as the next major. Like the engineering students in Ohland et al., the female math master graduates observed by Stage and Maple were interested and excelled in math, but changed majors for their doctoral degrees [22]. The women in their study reported differences between the culture of the mathematics field and their own goals and identities that included the competitive nature of peer interactions, lack of faculty-student relations, the nature of mathematical concepts, disconnection between mathematics and the real world, and the perceptions of mathematicians. Similarly, in these cases, students require a supportive and interactive environment to maintain their motivation levels [17, 18, 20].

Research has shown that positive impressions of the academic environment and faculty lead to better learning results [17]. The use of computer-based platforms has been greatly enabled by the advances in information technology and motivated by globalization, which has prompted a need to change traditional lecture-based learning environments. In addition to face-to-face classroom environments, online platforms are widely used to provide a means to engage learners through both synchronous and asynchronous interactions (e.g., [23], [24]). Such systems can give students more access to instructors, other students, and other resources, which could alleviate the problems of isolation and the feeling of lack of support. Additionally, a major affordance of computer-based classroom environments is that technology can continue motivating and engaging students in engineering. For example, educational simulations and games have been used to positively change students' attitudes toward science [24]. Such technologies can be used to support instruction while motivating and engaging students within the content.

In order for engineering educators to create an engaging and nurturing learning environment for students, there must be an understanding of students' interests and the factors that influence major selection. This study examines first year engineering students' personal interests and perceptions of the engineering field and classroom environments and how they are related to choosing engineering as a major. Findings from this study will provide educators and curriculum designers the knowledge needed to recruit more students into the engineering majors, engage engineering students, and retain them.

2. Methodology

The research questions for this study are:

RQ_1: How do engineering students perceive the engineering field?

RQ_2: What motivates students to major in engineering at the undergraduate level?

2.1 Participants

Fifty students participated in this study (N = 50), which was over 10% of all the students taking an introductory mechanical engineering (ME) or civil and environmental engineering class (CEE) during the Fall 2010 and Spring 2011 semesters at a large public university in Texas. In both semesters, the courses were the first in their respective major sequences. Participation was voluntary and was done outside of class. IRB approval for human subjects research was approved prior to data collection. Table 1 summarizes the demographics of the participants.

Table 1. Participant demographics

	ME	CEE	All
Gender			
Males	21	18	39
Females	3	8	11
Total Students	24	26	40
Ethnicity			
Asian	1	0	1
African-American	0	0	0
Caucasian	12	15	27
Hispanic	9	10	19
Native American	0	0	0
Other	2	1	3
Total Students	24	26	50
Age			
Age (Average)	21 (SD = 4.35)	23.65 (SD = 7.27)	22.38 (SD = 6.14)

2.2 Instruments

Participants were asked to complete an online questionnaire. There were two parts to the questionnaire: a demographic survey and open-ended questions about engineering. The questions were: what is engineering, and why are you majoring in engineering? Participants responded to each question with short responses, generally less than 30 words. The responses to the open-ended questions were the primary data source for this study.

2.3 Reliability

For each open-ended question, the responses were coded, categorized, and counted. Coding involved two passes. In the first coding phase, one researcher made an initial pass of the data using an open coding analysis. Similar categories of responses were merged together while categories with counts of less than five were discarded. Four main categories of responses emerged from the data for each question. In a second round of coding, two researchers coded the responses again using this framework to determine inter-rater reliability. The overall inter-rater reliability was $k = 0.739$, which indicates a substantial level of agreement between the raters [25]. Further discussion on each category will be discussed in the following sections.

3. Students' perceptions of engineering

Participants were asked the open-ended question: What is engineering? Table 2 shows the average number of occurrences of the four main themes of answers.

Problem solving is the primary activity that participants associate with engineering. They believe that

Table 2. Occurrences of themes in responses to: What is engineering?

Construct	ME	CEE	All
Problem solving	11	11	22 (44%)
Improving Society	9	8	17 (34%)
Innovation	7	7	14 (28%)
Applied Science	13	14	27 (54%)

engineers design solutions that will solve a technological or societal problem using a multidisciplinary approach. Forty-four percent of participants believe that engineering is problem solving. A major component of engineering is designing a solution to a problem. Participants were aware that problem solving requires knowledge in other fields. Math and science were the most repeated subjects within this category of responses. As one participant put it, engineering is *"using math and science to solve problems."* In this category, engineering's purpose was *"how to improve on the knowledge we already have"* and *"create and/or improve technological achievement[s]"* to *"solve technical problems."*

Improving society is the belief that engineering advances society by making it a better and easier place for people. Thirty-four percent of participants responded that engineers *"invent and design machines to make society's life easier"* and "*to benefit society as a whole*" by imagining *"new ideas to improve society"* and creating *"solutions to the needs of society."* The problems engineers solve are based in the community, the environment, and world problems. This finding suggests that many participants find a social aspect and higher calling behind the concepts and mechanics behind the engineering field. Within this category of responses, there is a recurring theme of *"benefit[ting] society and increas[ing] the standard of living."* Improving society also infers a context for engineering in which the field is viewed as a vehicle for the development, advancement, and improvement of social welfare and humanity. These students realize the scope and reach of engineering on a societal level rather than just personal or extrinsic rewards as indicated in the other categories.

Innovation is the creation of new ideas or improving existing ideas and technologies. For 28% of participants, engineering is *"inventing new technologies"* and requires *"innovation[s] that will determine the path of society's future."* Another aspect of problem solving is using this engineering knowledge to build and construct machines, bridges, buildings, and other real-world products. For example, one participant said, the *"Engineer designs, build [sic], and repairs machines they have created,"* which may imply that engineers go beyond the problem solving and design phase and physically build the products as well. It also implies that such innovations will affect society's situation by updating existing ideas and creating new ones.

Applied Science is the belief that engineering is the intersection between theory and practice. That is, for 54% of respondents, engineering is *"the application of scientific principles to the design and implementation of projects."* Respondents referred to other fields, such as math and science, as the knowledge they needed to know. Then, there is a sense that engineering is also the *"practical application of science and math"* knowledge or *"application of conceptual knowledge in technology."* This is due to the fact that the problems they solve are authentic and relevant to the real world. This would support the finding that participants also believe the purpose of engineering is for the improvement of society since solutions are for the benefit of society.

4. Students' motivations to major in engineering

Participants were asked an open-ended question: Why are you majoring in engineering? Table 3 shows the average number of occurrences of the four main themes of answers.

Interests is the positive attitude or affinity that participants have with engineering or any of its related topics, including math, science, machines, and the environment. The interests that 68% of participants listed were mostly intrinsic in that engineering aligned with individual interests, the challenge of problem solving, and a moral sense of service to society. The design and development nature of engineering was interesting to participants: *"I enjoy being hands on. I enjoy working with numbers, science, and technology.", "Because I like building and constructing projects."* Several participants reported learning about why and how things work, which implies that curiosity about their surrounding world as a driving motivator to major in engineering. Some students were interested in challenges that engineering provides—ones that are suited toward their aptitude. One student noted, *"I am majoring in engineering because it is a challenge for me"* while another student said, *"[I] am majoring in engineering because of the challenge*

Table 3. Occurrences of themes in responses to: Why are you majoring in engineering?

Construct	ME	CEE	All
Interests	20	14	34 (68%)
Aptitude	3	4	7 (14%)
Career	5	6	11 (22%)
Improving society	2	4	6 (12%)

set upon myself." Another student was motivated to become an *"expert at solving difficult problem that require math and science."* Such sentiments are in line with research that suggests personal interest is a factor in major selection [2, 6, 11, 12]. Students enjoy the challenge that engineers face and the ability to apply their skills in an active and hands-on environment. This finding is similar to Ngambeki, Dalrymple, and Evangelou's study, which reported that civil engineering students are interested in "working outdoors" and "working with hands", and mechanical engineering students similarly indicated an interest in "working with hands" and having "mechanically inclined" attitudes [26].

Aptitude is the participant's self-perception of knowledge and skills—mainly in math and science. Generally, 14% of the participants rate themselves as having a strong academic background. For example, some participants remarked, *"I have been given the ability to work with the tools and knowledge I have been given.", "It's most suited to my aptitudes and interests.", "because [I] am good at math and science."* Twenty-six percent of students reported majoring in engineering due to their aptitudes in math and science and the ability to problem solve. This finding is similar to Korte and Smith who reported students choosing to major in engineering based on perceived skill [27]. It could be that these students that suggested aptitude as a reason behind majoring in engineering are confident about their math and science knowledge. Since self-efficacy affects persistence in engineering, it could be that these are the students that will have greater motivation to stay in engineering [15, 18, 27].

Career is the motivation for 22% participants to pursue an engineering degree. For them, it offers favorable employment opportunities and facilitates career advancement for those already working. One participant noted that engineering has *"a good positive job outlook."* Korte and Smith found that transfer students chose engineering due to the field's financial outlook [27]. For another participant, working in a field in which he was interested in was appealing, *"I want to make a real difference in the world and get paid to do so."* Some participants reported that becoming an engineer has been a lifelong dream due to their interests and family life, such as *"it will help me provide a better life for my family"* and *"My father is a car mechanic and never got the [opportunity] to get a degree. I want to do the same thing but with an education."* Veenstra, Dey, and Herrin [28] found that engineering students differed from other students in STEM and non-STEM areas in their career choice goals. Similarly, career flexibility and variety of job opportunities have been shown to be motivating factors [26]. Our findings suggest that students have a clear outlook on what jobs are available and of interest to them, which could be personally rewarding, profitable, and available. However, this finding could also show that students are looking toward the extrinsic reward of getting a good job and salary and not necessarily an individual interest in the topic.

Improving society was a motivator for 11% of the participants to major in engineering. With the recurring theme of engineering as social improvement, ten percent of participants are majoring in engineering to *"make life better for others using the strengths I have"*, *"benefit my fellow citizens and their enterprises",* and *"create, or help create, new useful technology using concepts of electricity, science, and math."* Since approximately half the students were civil engineering majors, there was also some emphasis on environmental issues, *"taking into heavy consideration our ecological status."* Such societal perspectives on the engineering field is similar to the concept of social utility of engineering [5]. These findings show that students major in engineering as a way to contribute to society, in terms of making life better for both people and the world. Other studies have shown similar results that improving society is a motivation for choosing engineering. Agrawal and Dill [29] found when studying why engineering students pick a certain specialization that over 74% of the students choose a specialization or major due to the importance of improving the quality of life in cities and towns. Another study by Sheppard, Gilmartin, Chen, Donaldson, Lichtenstein, Eris, Lande, and Toye [30] showed that "social good" was a factor that motivated engineering seniors.

Though the previous categories show that students have personal reasons for majoring in engineering (e.g., aptitude and career choice), this category shows that major selection may be influenced by societal or global needs.

5. Discussion

Overall, all categories contribute to major choices and persistence, even though their importance might be mixed. For example, a recent study finds that low attainment values coupled with high utility value and moderate interest can lead to persistence in choices [31]. Our findings also follow previously reported motivational patterns. In particular, social cognitive career theory (SCCT) explains career choices as based on student self-perception of strengths and their expectations of the results of those choices [32]. Thus SCCT asserts that an interest in an activity is driven by the perceived ability and projected outcomes from this activity such as career opportunities and improving society perspectives.

When trying to recruit students into engineering, educators must help students construct an accurate perception of engineering. The findings showed that current students perceive engineering as problem solving, improving society, applying theories and concepts from math and science to real-life situations, and creating new and innovative ideas. These perceptions describe processes and tasks that are fundamental to engineering, which infer that students are familiar with what engineers do. These students view engineering as an active field in which they problem solve, apply theories in hands-on activities, create new ideas, and help society with their innovations. These perceptions can also be viewed with the preconceptions and expectations that students have of engineering. That is, students are expecting active hands-on environments that represent authentic, real-world engineering problems, which means that undergraduate faculty should consider these expectations while designing their courses, especially at the introductory level for retention purposes.

The findings suggest that students initially major in engineering due to personal interests, perceived aptitude, career options, and to improve society. Individual interest is difficult to build since students need to develop their own sense of value for engineering. Educators must make connections between the engineering content and the students' own value system. For those students that do not have the aptitude in engineering and related areas, students must be given the opportunities to excel and make worthwhile accomplishments. This may require additional emotional support from educators or peers. A career in engineering may be lucrative and readily available for graduates, but students can be better informed about career choices. Educators, especially guidance counselors, can show what an engineering job entails, bring in actual engineers as guest speakers to talk about their jobs, and show the variety of engineering jobs that are available. An interesting finding is that some current students view engineering as the vehicle for improving society. For those who are not interested in engineering, students may become interested if they see how engineering innovations have affected them in their own daily lives. On a broader level, students may become interested in a field that has the potential to improve society at large. Though these are geared toward recruitment, similar strategies could be used to retain students—that is, by supporting and building upon their initial motives for majoring in engineering once they get to the university level.

6. Conclusions

This paper presents a snapshot of current engineering students who are just beginning their undergraduate career. Since these students have recently declared or will declare engineering as their majors, it is the best time to examine what influenced their major choices and use that information to guide our recruitment. This qualitative understanding of why students select engineering as a major and how they perceive the field provides a set of motivational and perception indicators that can determine students' ability to persist in engineering. The findings inform how we can improve recruitment through the K-12 pipeline so that we get more engineering majors at the undergraduate level. Future studies would follow undergraduate students through their engineering program and track their reasons to stay in (or leave) an engineering program and perceptions of engineering. It would be interesting to see how these motivational factors change over time and how it influences retention. Findings from future studies can help improve retention as well as recruitment in engineering.

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