How Do Student Perceptions of Engineers and Engineering as a Career Relate to Their Self-Efficacy, Career Expectations, and Grittiness?

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Abstract

This complete research paper examines the potential connection between student beliefs about engineering as a profession, as well as the perceptions of their family and friends, to their reported self-efficacy, career expectations, and grittiness.

The student responses examined were obtained from non-calculus ready engineering students at a large land grant institution in the Mid-Atlantic region. The students participated in a well-established program focused on cohort formation, mentorship, professional skill development, and fostering a sense of inclusion and belonging in engineering. The program, consisting of a one-week pre-fall bridge experience and two common courses, was founded in 2012 and has been operating with National Science Foundation (NSF) S-STEM funding since 2016. Students who received S-STEM funded scholarships are required to participate in focus groups, one-on-one interviews, and complete Longitudinal Assessment of Engineering Self-Efficacy (LAESE), Motivated Strategies for Learning Questionnaire (MSLQ), and GRIT questionnaires each semester.

The researchers applied qualitative coding methods to evaluate student responses from focus groups and one-on-one interviews which were conducted from 2017 to 2019. Questions examined in this paper include:

1) How would you describe an engineer?
2) Please describe what you think an engineer does on a daily basis.
3) What do you think your friends/family think of engineering?
4) What skills or characteristics do you think good engineers have?
5) What types of careers do you believe are filled by degree holding engineers?

Student responses on the aforementioned questions were related to the self-efficacy, career expectations, and grit values obtained from the LAESE, MSLQ, and GRIT instruments. The nature of this longitudinal study allows the evolution of student responses to also be examined as they matriculate through their education.

Results of this research are presented in an effort to further highlight the importance of exposure to STEM fields during an individual's K-12 education, and express how student perceptions, self-efficacy, GRIT, and career expectations evolve over their undergraduate education.

1.0 Introduction

In an effort to provide the context in which this research was conducted, a background summary of current research related to reported self-efficacy, career expectations, and grittiness among engineering students is included in addition to a brief description of the program where the study data was collected.

1.1 Summary of Background Research

Social cognitive career theory suggests that many factors impact a person's choice of career. One of the more influential factors according to the theory is a person's belief that they will succeed, or self-efficacy, in a career [1]. Engineering is frequently discounted as a career option due to misconceptions about the field including: (1) engineering is only for very smart students, (2) engineering is a career for only men, (3) engineers must love mathematics, (4) engineers only work in offices, and (5) engineers do not help and serve people [8].

Self-efficacy beliefs are reportedly linked to mastery experiences, vicarious experiences, social persuasions, and physiological states. Mastery experiences have the strongest impact on a student's efficacy beliefs and refer to an individual's perception of their performance on a certain task. Self-efficacy can also be influenced by vicarious experiences, the observation or awareness of another person's experience with a certain task, and through social persuasions, the shared thoughts of others, positive or negative, toward an individual and their likelihood to accomplish a task. Physiological states that are experienced by an individual during an activity such as emotions or stress also have been shown to impact one's self-efficacy [15].

In an effort to relate the self-efficacy aspect of cognitive career theory to engineering students' and engineers' perceptions of important skills and abilities Winters et al. [9] conducted a longitudinal study. This research study questioned engineering students about their perceived importance of various abilities such as math, science, and business. The individuals were surveyed throughout their undergraduate education and then again four years post-graduation. The researchers determined that as students' progress through their undergraduate engineering education, the importance of math ability decreases, with the most drastic decrease occurring between graduation and four years post-graduation. The importance rating of professional skills such as communication steadily increased from freshman year to post-graduation [9].

Anderson-Rowland et al. [7] cite lack of information about engineering as a major factor contributing to a low interest in engineering among high school and community college students. This lack of knowledge about engineering as a career leads to a lack of confidence in an ability to succeed in engineering, and therefore engineering is not viewed as a viable career option. It has been well established that if a student has a parent who is an engineer they are more likely to select engineering as a career than a student without an engineer for a parent. Media such as movies and television programs are widely available sources of information. Many storylines include doctors, lawyers, and nurses, while few feature engineers. Due to the lack of exposure in entertainment media and daily interactions, students commonly lack an understanding of engineering as a career and therefore are less likely to pursue it [11].

Godwin et al. [10] found that high school students' interest and believed competence in math and physics contribute significantly to the likelihood of them pursuing engineering as a career choice. The study also found that students who have a high level of feelings of empowerment to make change coupled with strong physics and math identities are more likely to select engineering as a career than students who have strong physics and math identities, but lack the high level of empowerment to make change.

The reported self-efficacy of engineering students has been shown to relate to their retention persistence, and interest in their major [12],[13]. It is common for male engineering students to report higher self-efficacy scores than their female peers [14].

Beyond self-efficacy, motivation has been linked to student retention. Students who find intrinsic value in engineering are more likely to retain in engineering than those who lack interest in engineering topics [16].

Jones et al. [17] studied students' self-efficacy, intrinsic interest value, and extrinsic utility value throughout their freshman year of their engineering curriculum. At the end of the freshman year the reported values of self-efficacy, the intrinsic value of learning engineering, and the utility value of engineering all decreased from the initial values reported when students entered their freshman year. This research also showed that intrinsic interest in engineering and the utility value of engineering were better predictors of career path than self-efficacy.

1.2 Brief Description of AcES Program

The Academy of Engineering Success (AcES) program was established in 2012 to increase retention of students who are traditionally underrepresented in engineering with the goal of ultimately diversifying the engineering workforce. The program has been funded through an NSF S-STEM grant since 2016. The main aspects of the program include a focus on cohort formation, professional development, student success skills, career guidance, scholarship opportunities, and an industry mentor program. AcES students arrive on campus a week prior to the start of their first semester to participate in a bridge experience, complete a two credit hour professional development course in the fall semester, and in the spring semester students complete a three credit course which covers the role of engineers in shaping society throughout history. Since fall of 2016 select students from the AcES program have received scholarships funded by the NSF S-STEM grant. Table 1 displays the number of scholarship recipients from each incoming AcES cohort.

Table 1: Scholarship Distribution per Cohort

Scholarship Distribution per Cohort				
	Fall 2016	Fall 2017	Fall 2018	Fall 2019
# of Students	5	7	6	3

2.0 Methodology

Scholarship participants in the AcES program consented to participate in qualitative and quantitative data collection for this research project. Quantitative data was obtained by employing three survey instruments, the GRIT, an abbreviated version of the Motivated Strategies for Learning Questionnaire (MSLQ), and a modified version of the Longitudinal Assessment of Engineering Self-Efficacy (LAESE). The aforementioned survey instruments were administered to all AcES scholarship recipients at the start and end of each fall semester, and the end of each spring semester starting in the fall of 2017. Table 2 displays the survey distribution schedule.

Table 2: Survey Distribution Schedule

Survey Distribution Schedule								
	2017		2018			2019		
Instrument	Start of Fall	End of Fall	End of Spring	Start of Fall	End of Fall	End of Spring	Start of Fall	End of Fall
GRIT	X	X	X	X	X	X	X	x
LAESE	X	No Data	X	X	X	X	X	X
MSLQ	X	X	X	X	X	X	X	X

The GRIT survey was developed by Angela Duckworth and consists of 12 Likert Scale questions [2]. Grit, defined as "perseverance and passion for long term goals", was recognized as a trait by Duckworth [3].

The LAESE survey was developed at Penn State University with support from the National Science Foundation. The LAESE was designed to measure the self-efficacy of undergraduate engineering students by using 31 Likert scale questions. Self-Efficacy aspects of students measured by the survey include outcomes expected from studying engineering, the process of selecting a major, expectations about workload, coping strategies in challenging situations, career exploration, and the influence of role models on major and career decisions [4]. The research discussed in this paper focused on three subscales of the LAESE survey, (1) Engineering Self-Efficacy 1, (2) Engineering Self-Efficacy 2, and (3) Engineering Career Expectations. Engineering Self-Efficacy 1 is a measure of the student's perception of their ability to earn an A or B in physics, math, and engineering courses and succeed in their engineering curriculum without sacrificing outside interests. Engineering Self-Efficacy 2 is a measure of the student's perception of their ability to complete engineering requirements such as their science and math coursework, as well as their general ability to complete any engineering major [5].

Researchers from the University of Michigan and the National Center for Research to Improve Postsecondary Teaching and Learning developed the MSLQ survey. AcES scholarship recipients completed the abbreviated version of the MSLQ survey consisting of five subscales measured using a Likert scale. The five subscales provide information about a student's intrinsic value of learning, self-efficacy, test anxiety, strategy use, and self-regulation [6]. The research discussed in this paper focuses on the results from the self-efficacy subscale.

Table 3 displays each of the survey instruments used to acquire quantitative data. The facets of the surveys examined in this work are denoted with asterisks.

Table 3: Survey Instruments and Related Measures [16]

Instrument	Measures	
GRIT	*Grittiness	
LAESE	*Engineering Self-Efficacy 1	Feelings of Inclusion
	*Engineering Career Expectations	Efficacy in Copying with Difficulties
	*Engineering Self-Efficacy 2	Math Outcomes Efficacy
MSLQ	Intrinsic Value	Strategy Use
	*Self-Efficacy	Self-regulation
	Test Anxiety	

In addition to completing surveys, AcES scholarship recipients participated in focus groups and one-on-one interviews. Focus groups are conducted three times each semester, once at the start, once around midterm, and once at the end of the semester. Focus groups are organized so that students participate in the groups with their incoming cohort of peers. One-on-one interviews were conducted twice a semester, once at the start and once at the end of each semester. Table 4 displays the focus group and interview schedule.

Table 4: Interview and Focus Group Schedule

Interview/Focus Group Schedule															
	2017			2018						2019					
Instrument	Start of Fall	Mid Fall	End of Fall	Start of Spring	Mid Spring	End of Spring	Start of Fall	Mid Fall	End of Fall	Start of Spring	Mid Spring	End of Spring	Start of Fall	Mid Fall	End of Fall
Focus Group	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
One-on-One	X		X	X		X	X		X	X		X	X		X

During one-on-one interviews, students were asked questions related to their interests outside of school, motivation for studying engineering, definition of engineering and engineers, family's perception of them studying engineering, types of careers for engineers, motivation to persist in engineering, ability to overcome challenges, feelings of inclusion and belonging, and level of participation in class. Questions aimed at determining student perceptions of and benefits from the AcES program were also asked during the one-on-one interviews.

The focus groups addressed similar topics as the one-on-one interviews, asking questions of students related to what being an engineer means to them, why they chose to study engineering, how they overcome challenges, if they see themselves as part of the engineering community as a whole and at the institution, and what aspects of their experiences have helped them succeed in college.

The research discussed in this paper examines a subset of the focus group and one-on-one questions, shown in Table 6.

Table 6: Questions from Focus Group and One-on-One Interviews Examined

Questions Examined		
Question	Focus Group	One-on-One
How would you describe an engineer?		X
Please describe what an engineer does on a daily basis.		X
What do your family/friends think of engineering?		X
What skills or characteristics do you think good engineers have?		X
What types of careers do you believe are filled by degree holding engineers?		X
What does the word "Engineering" mean to you?		X
What kinds of problems do you think engineers solve?		X
What does being an engineer mean to you?	X	
Why are you interested in becoming an engineer or obtaining your engr degree?	X	

All focus group and one-on-one interviews were video recorded and then transcribed. The transcriptions were then coded by two individuals. Coding of the one-on-one interviews and focus group sessions was conducted in two phases, an exploratory coding phase and a structured coding phase. The exploratory coding phase consisted of the two coders separately reading through 40 interviews chosen at random (~1/3 of the total sample size) from the entire set and coding reoccurring ideas or themes. The exploratory coding phase resulted in a list of codes that each of the coders had developed separately. Prior to the structured coding phase, the coders compared code lists and either included or excluded codes based on their relevance to the research questions posed in the funded grant proposal, resulting in a master list of codes. The structured coding phase then consisted of the coders separately coding the remainder of the interviews with only codes included in the master code list and then comparing coded interviews for code agreement in order to calculate the inter-coder percent agreement. During the comparison of coded interviews it was permissible for the coders to discuss instances of disagreement on codes and for codes to be changed or removed based on this discussion, in an effort to improve accuracy of code identification in the interviews.

3.0 Results and Discussion

Researchers examined the question, "is there a connection between student beliefs about engineering as a profession, as well as the perceptions of their family and friends, to their reported self-efficacy, career expectations, and grittiness?". Responses from the surveys, focus groups, and one-on-one interviews from a single cohort of students will be examined in this paper. This cohort was selected due to the completion of both the surveys and transcribed one-on-one interviews and focus groups. The year of the cohort is intentionally omitted to protect the identity of the students in the cohort. The inter-coder percent agreement for the one-on-one interviews was 97.4% and the inter-coder percent agreement for focus groups was 97.3%. The inter-coder percent agreement was calculated by totaling the number of instances of both coders agreeing on a code and dividing by the total number of instances of agreement and instances of disagreement.

In the following figures, survey data is displayed for a single cohort from the start of their first semester up through the end of their fifth semester. Each figure represents a different subscale from one of the three survey instruments, denoted with an asterisk in Table 3, and depicts the evolution of the individual students' score for that subscale. Five students were selected due to the completion of their data for both surveys, interviews, and focus groups. Each student in the program has been assigned a number in order to keep their identities confidential, for the purposes of this paper the students will be referred to as students one, two, three, four, and five. It should be noted here that due to the small cohort sizes, no statistical significance has been found in any of the trends discussed.

Figure 1 displays the GRIT scores for the cohort of students. Only one student reported an increase in GRIT score between the end of their second semester in the program and the start of the third semester. All students with the exception of one showed an increase in GRIT score from the start of their first semester to the end of their first semester. Only one student's GRIT score decreased from the start of their third semester to the end of their third semester. A single student's GRIT score increased between the end of the third semester and the start of the fourth semester. The lowest average GRIT score for the entire cohort occurred at the start of the first semester, and the highest average cohort GRIT score occurred at the end of the third semester.

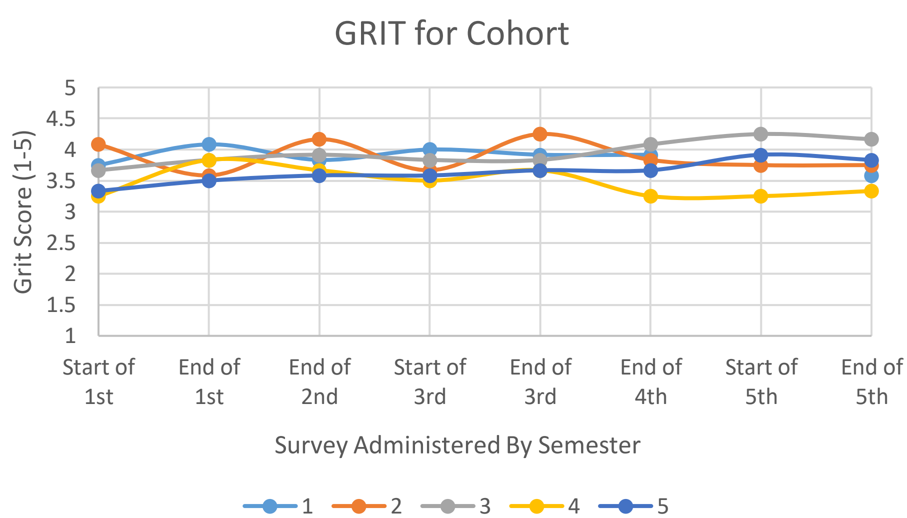

Figure 1: GRIT Scores Cohort from Start of Semester to End of Fifth Semester

Figure 2 displays the Self-Efficacy scores from the MSLQ survey from the cohort. Data for the first semester is not available for the MSLQ due to an error in data collection. The cohort's average score for the self-efficacy from the MSLQ survey was reported at the end of the second semester. From the end of the second semester to the end of the fifth semester the average cohort score for this self-efficacy metric decreased with each administration of the survey, indicating the further along in their engineering program, the lower their reported self-efficacy. Only student four reported a decrease in self-efficacy with each subsequent survey completed.

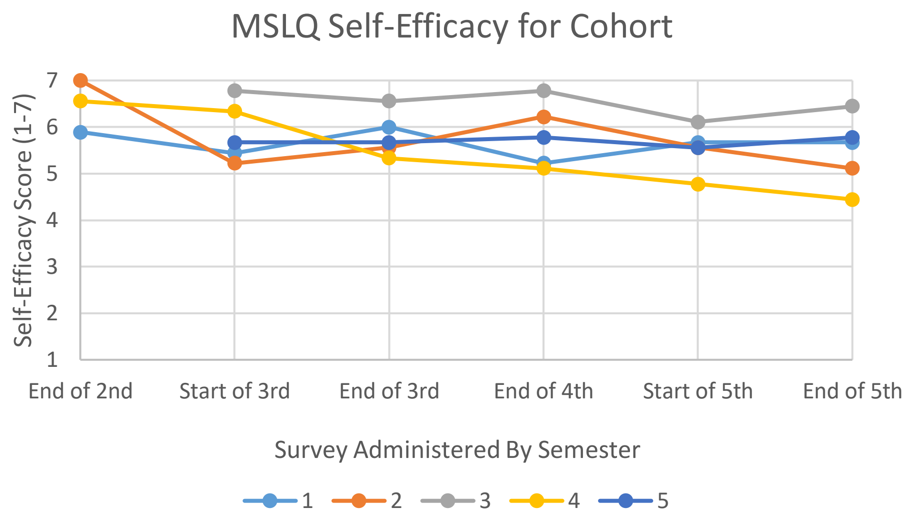

Figure 2: MSLQ Self-Efficacy Scores for Cohort from Start of First Semester to End of Fifth Semester

The career expectations measured by the LAESE survey for the cohort are displayed in Figure 3. Data was not available for the end of the first semester. The average cohort score was the highest at the end of the second semester, where all students who completed the survey reported the maximum value of seven. Throughout the first year in the program students are exposed to the different engineering disciplines, guest speakers from industry and research areas, and are encouraged to develop a resume and seek internships, it is possible this high reporting of career expectations is a result of the programmatic exposure to related content.

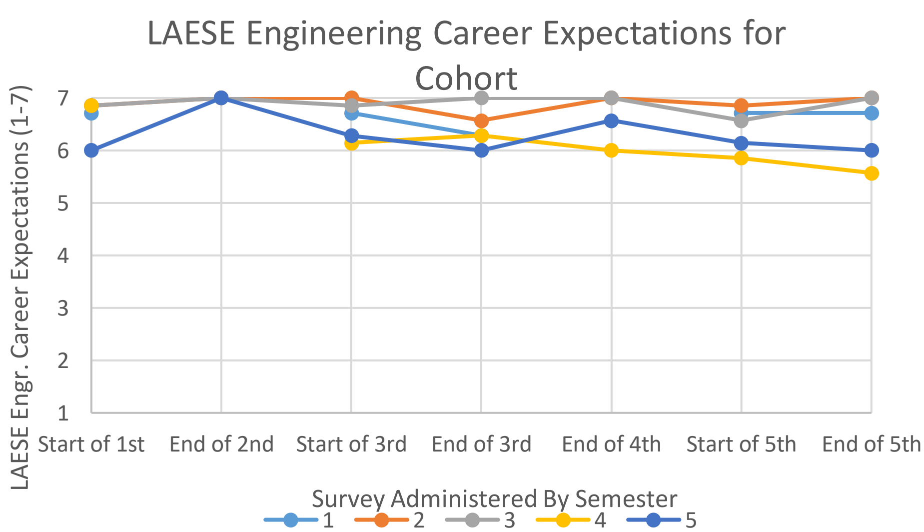

Figure 3: LAESE Engineering Career Expectations Scores for the Cohort from Start of First Semester to End of the Fifth Semester

Figure 4 shows the Engineering Self-Efficacy 1 survey responses from the cohort. Engineering Self-Efficacy 1 is a measure of the student's perception of their ability to earn an A or B in physics, math, and engineering courses and succeed in their engineering curriculum without sacrificing outside interests. The highest average score for the cohort was reported at the end of the third semester, and the lowest average score was reported at the start of the fifth semester.

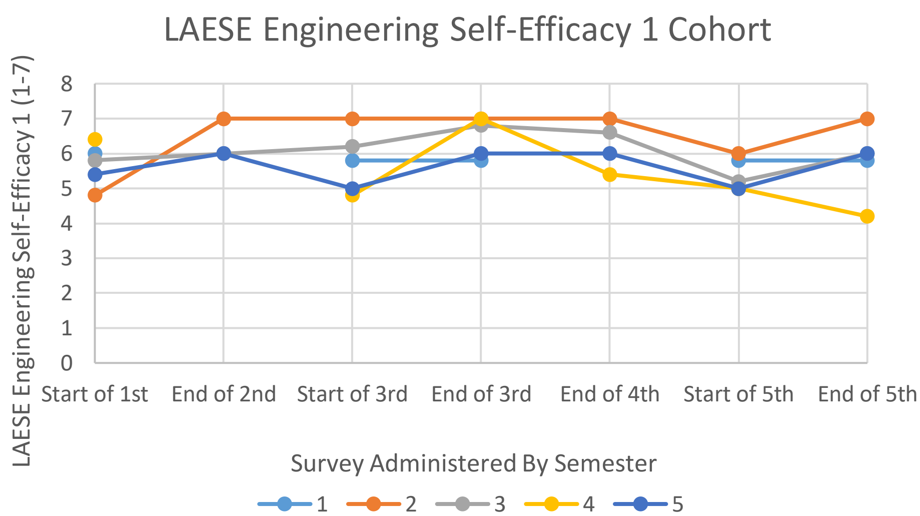

Figure 4: LAESE Engineering Self-Efficacy 1 Scores for Cohort from First Semester to End of the Fifth Semester

The LAESE Self-Efficacy 2 scores for the cohort are displayed in Figure 5. Engineering Self-Efficacy 2 is a measure of the student's perception of their ability to complete engineering requirements such as their science and math coursework, as well as their general ability to complete any engineering major. The lowest cohort average Engineering Self-Efficacy 2 score was recorded at the end of the fifth semester, and the highest cohort average score was reported at the end of the second semester. When compared to the Engineering Self-Efficacy 1 scores, the Self-Efficacy 2 scores are higher on average and do not decline as steeply, indicating that while students may no longer be confident in their ability to earn an A or B in their STEM courses, they are still somewhat confident in their ability to complete an engineering degree.

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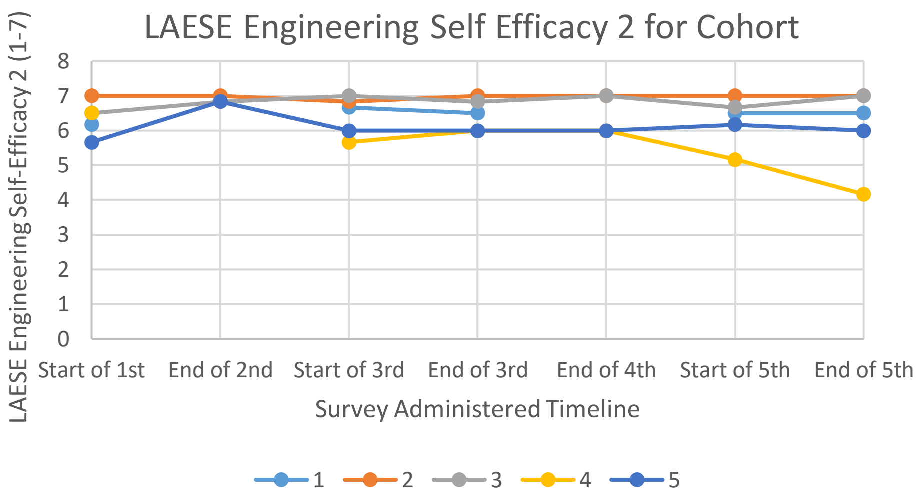

Figure 5: LAESE Engineering Self-Efficacy 2 Scores for Cohort from Start of First Semester to End of Fifth Semester

In addition to the quantitative results from the survey instruments, qualitative results were obtained from focus groups and one-on-one interviews. Students participated in one-on-one interviews at the start and end of each semester. One of the questions they were asked was "What skills or characteristics do you think good engineers have?". Student responses to this question are shown in Figure 6. Reoccurring themes found when examining this question included time management, value teamwork, and hands-on skills. At the start of their first semester, the cohort students did not mention teamwork as a skill possessed by good engineers, but by the start of their forth semester, four out of the five students indicated teamwork being a skill of good engineers. Much of the freshman engineering program and the ACES program specifically is centered on teamwork and cohort formation, therefore these responses appear to show that students are learning what is intended by their curriculum. Interestingly, while the students do not commonly mention hands-on ability as a skill that good engineers possess, it is the most commonly mentioned reason they are interested in pursuing an engineering degree throughout their first year.

Figure 7 displays codes and their occurrence frequency found in student responses to the question "Why are you interested in engineering or obtaining an engineering degree?". Reoccurring themes found when examining this question includes hands-on, philanthropic, value teamwork, and interested in STEM. During their first semester in college the majority of students cited hands-on work as a reason they are pursuing an engineering degree, but by the end of their third semester no students reported hands-on work as their motivation for studying engineering. During their first semester no students mentioned the philanthropic nature of engineering as their motivation for pursuing an engineering degree, but by the end of their third semester the majority of students cited philanthropy as a reason they are studying engineering.

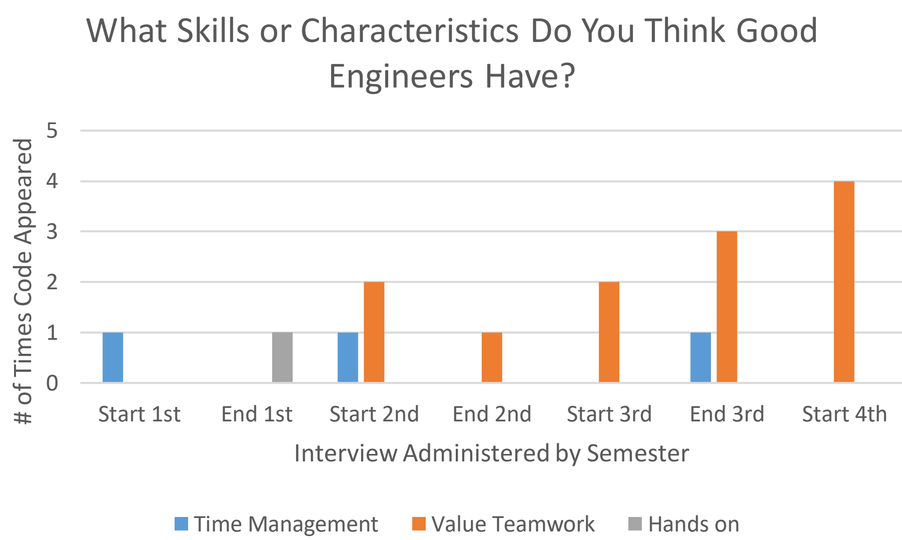

Figure 6: Codes from Student Responses to "What Skills or Characteristics Do You Think Good Engineers Have?"

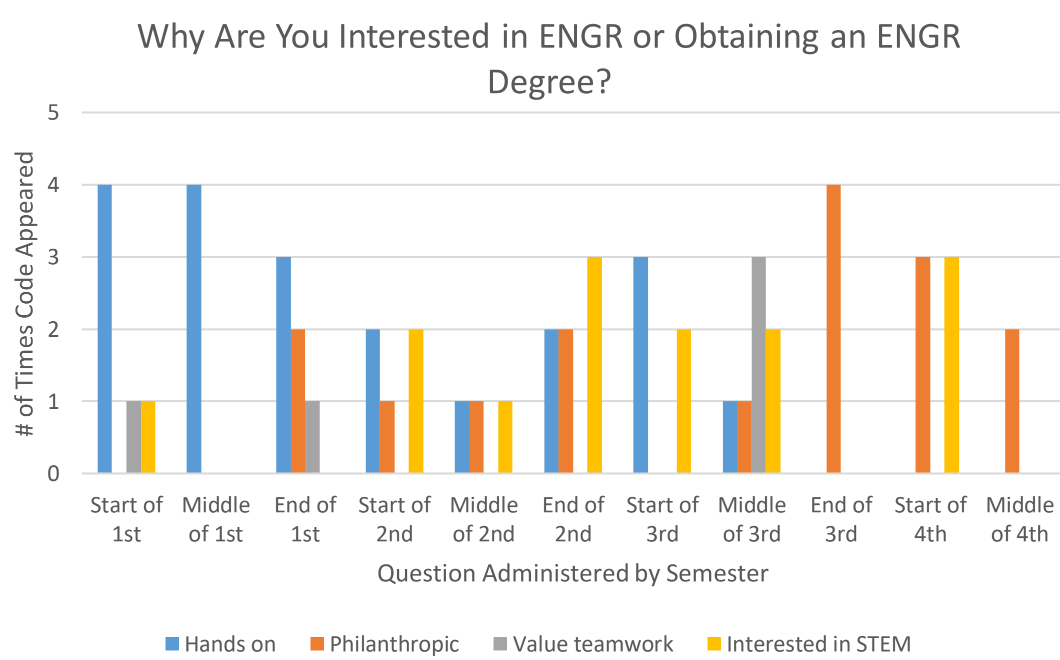

Figure 7: Codes from Student Responses to "Why Are You Interested in ENGR or Obtaining an ENGR Degree?"

Table 7 displays a summary of the additional questions that were asked of the AcES scholarship recipients in one-on-one interviews and focus groups. There were far fewer codes found in student responses to these questions than the two questions that were previously discussed. For example, only two student responses to the question "What does being an engineer mean to you?" held codes out of the 55 occurrences of the question. The two responses stated that being an engineer meant working in teams, an idea that is strongly emphasized throughout their undergraduate education. In response to asking questions about the meaning of the word engineering, the types of careers engineers have, and the kinds of problems engineers solve, the code indicating engineering is broad was present. Examining the frequency and occurrence on these codes along the longitudinal timeline of student responses does not indicate any clear pattern, it was not evident that student understanding of the broad engineering career options changed over time.

Table 7: Summary of Questions and Related Codes

Question	***Codes Found in Student Responses***
What does the word engineering mean to you?	ENGR is broad
What kinds of problems do you think engineers solve?	ENGR is broad
What is your family's perception of you attending college for engineering?	ENGR is Challenging Hands-on Family Motivation
What types of careers do you believe are filled by degree holding engineers?	ENGR is broad
What does being an engineer mean to you?	Value Teamwork

4.0 Conclusions

Due to the limited number of AcES program scholarship recipients the sample size for this research is very small, and unable to produce statistically significant results. The findings from the analysis of both the qualitative and quantitative data in this research suggest that expanding the data collection beyond the AcES program participants would provide not only insight into why students are motivated to pursue engineering degrees, but also how that motivation changes over time. The motivations of the students in this study appeared to change from their initial semester, in which they cited the perceived hands-on nature of engineering, to their third semester, in which they cited the philanthropic nature of engineering. The students also appeared to learn the value of teamwork in the engineering profession during their first year in college, implying that prior to entering college they were unaware of the team-centered nature of engineering careers. Beyond what students share about their motivation and knowledge of engineering during their first year, perhaps what is of more interest is what students don't share about their knowledge of engineering.

It is widely established that early exposure to STEM careers, and STEM role models increases the likelihood of a student to pursue engineering as a profession. By examining the codes that are not commonly reported by students, areas of improvement in STEM outreach can be identified. For example, this small data set appears to imply that prior to entering college these students were unaware of the philanthropic nature of engineering careers. The code philanthropic encompasses statements such as "improving society", "helping others", and "making a difference in the world". Since it is commonly known that females tend to prefer careers with a humanitarian focus, perhaps increasing STEM outreach emphasis on how engineers help society may increase the number of female students pursuing engineering. This focus has been recommended by several in other engineering publications as well [19].

No clear connections appeared between the results from the survey responses and the codes recorded from the focus group and interview analysis. The researchers hypothesized there would be a connection between students' reported self-efficacy and their understanding of engineering as a profession, however this was not the case or was unable to be seen due to the limited data.

Although this paper discussed a longitudinal study and followed students beyond their first-year, the cohort was formed and the majority of programmatic activities occurred throughout the students' first year.

5.0 Future Work

The researchers will continue the longitudinal data collection via surveys, focus groups, and one-on-one interviews of the 2016-2019 AcES scholarship recipients, and the data will continue to be examined for trends. It is recommended that the data collection be expanded beyond the AcES scholarship participants in an effort to determine if early trends seen in this data hold true for a larger, more diverse population.

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