Exploring First Year Engineering Students' Career Motivations and Expectations

Dr. Rahul Sharan Renu, Francis Marion University

Dr. Renu is an associate professor of mechanical engineering at Francis Marion University. He also serves as the program coordinator for mechanical engineering. His research interests are in the fields of digital manufacturing, AI in design, and engineering education.

Michael V Potter, Francis Marion University

Dr. Michael Potter is an Assistant Professor of Mechanical Engineering at Francis Marion University (FMU). He teaches both upper and lower-level courses in FMU's mechanical engineering program. Dr. Potter received bachelor's degrees in Mechanical Engineering and Physics from Ohio Northern University. He then went on to attend the University of Michigan, where he received his M.S. and Ph.D. degrees in Mechanical Engineering with a concentration in Biomechanics. His research uses body-worn sensor networks to better quantify and understand human performance in applications including health and sports.

Dr. Mark Kanaparthi, Francis Marion university

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Rahul S. Renu, Michael V. Potter, and Mark A. Kanaparthi
Francis Marion University, Florence, South Carolina, USA

Abstract

This research explores first-year engineering students' perceptions and motivations about the engineering curriculum and profession. Approximately 60 students enrolled in Francis Marion University's (FMU) engineering programs take a University Life 100 (UL100) course each Fall semester. This one-credit hour course serves to help students transition from high school to college and orients them to the FMU Physics and Engineering department programs.

Engineering faculty teaching this course in Fall 2022 conducted a survey to understand 1) student motivations to pursue engineering, 2) student perceptions and knowledge of the difference between engineering and engineering technology degrees, and 3) student's assumptions of the skillsets required to be a practicing engineer.

The survey consists of Likert scale questions as well as questions that solicit free-text responses. This paper reports on the results from statistical and Natural Language Processing analyses of the responses and provides recommendations for content to be included in courses similar to FMU's UL100 course.

Keywords

Engineering Education; First-Year Students; Engineering; Engineering Technology;

Introduction and Motivation

Francis Marion University (FMU) is a public, liberal arts university in Florence, South Carolina, USA. With a large majority of its programs being offered at the undergraduate level, FMU has recently been designated as a Professional Doctoral University. All the doctoral programs offered at FMU are within the School of Health Sciences. The university has a 15:1 student-faculty ratio with an average class size around twenty students. Of the approximately four-thousand students, 96% are from the state of South Carolina and 33% of the full-time degree-seeking undergraduate students identify themselves as first-generation college students.

The university began a Bachelor of Science in Industrial Engineering program in 2014 and Bachelor of Science in Mechanical Engineering in 2019. As of August 2022, approximately 40 students have declared Industrial Engineering as their major and approximately 100 students have declared Mechanical Engineering.

Both engineering programs share nine engineering courses and have common general education requirements. The first three semesters of engineering coursework are identical and include courses such as Introduction to Engineering, Engineering Graphics, and Engineering Mechanics. In addition, first semester university students are encouraged (during advising) to enroll in a one-credit University Life 100 (UL100) course. This is first-year seminar course whose objective is help students transition from high school to university. The official course description is as follows:

Students will be introduced to skills and strategies for studying, test-taking, note-taking, and time management to enhance their study habits and ability to succeed in their academic careers. Students will become familiar with the university's support resources to help solve academic, personal, and social problems. Some discipline-specific sections will provide first-year students with an early introduction to the specific needs and expectations of their respective degree programs.

This UL100 course is particularly useful for students who do not have strong mentorship from family and friends. In Fall 2022, the authors each taught a section of UL100. These twenty-student sections are primarily composed of engineering students. Anecdotally, it has been found that many first-semester engineering students are 1) unclear about the difference between engineering and engineering technology, 2) unaware of the science and mathematics concepts involved in engineering, and 3) lack motivation to persevere through difficult course topics. To investigate these anecdotal observations in formal manner, the following research objectives (RO) were established:

- RO1. Study student motivation to pursue an engineering degree
- RO2. Understand students' perception of the difference between engineering and engineering technology
- RO3. Study students' assumptions of the skillset required to become an engineer
- RO4. Investigate student motivation in general

Background and Relevant Literature

While students generally have a positive impression of engineering, it is well recognized that the public generally lack understanding of what engineers actually do [1]. For example, Cunningham et al. developed the "What is an Engineer?" assessment and found that elementary school students had many misconceptions including largely associating engineers with things (e.g., cars) rather than the work engineers actually do [2]. They also found these students had many misconceptions of what technology is. Hammack et al. found that a week-long engineering summer camp helped shift middle school students' perceptions of engineering work from building things towards designing things, however many misconceptions still remained [3].

Compeau found that high school students in Canada who were on track to apply for university education often described the work that engineers do with words associated with skilled trades or physical processes (e.g., building things) [4]. Elrod and Cox surveyed high school students enrolled in STEM courses in the US and found that students often associated specific engineering disciplines with elements of that discipline rather than the work an engineer would do in that discipline [5]. Such misconceptions may critically impact recruitment and retention efforts in engineering. For example, Compeau notes that when students have such misconceptions about the work that engineers do, it is difficult for them to appropriately select a career path [4].

In addition to misconceptions about the work that engineers do, there may be gaps in understanding what skills are important to success in engineering. Kuleshov and Lucietto found that students, university faculty, and industry often have different views of what skills are actually important for success in engineering [6]. Often individuals associate engineering with important hard skills such as physics and math. For example, Denson et al. investigated the perceptions of seven urban African American students' towards engineering and found that even students to who didn't understand what engineering was identified math as an important skill [7]. However, Kuleshov and Lucietto note that soft skills are increasingly becoming important for success in industry [6]. With such gaps in expectations for engineering skillsets between academia and industry, it is important to recognize that the skillsets required for success in an engineering program may not be perfectly aligned with the skillsets required for success in engineering industry. Thus, a student understanding the skills required for success in engineering industry may have incorrect perceptions of the skills needed to succeed in their engineering program or vice versa.

Beyond these perceptions, motivations may also have a significant impact on attracting and retaining engineering students. In the NAE report "Changing the Conversation", they note that while messaging focused on the importance of math and science in engineering has been used heavily in the past to attract students to engineering, it may be a turnoff to students. In fact, this overemphasis on hard skills may be a contributing factor behind many students not thinking they are smart enough to be an engineer themselves. The report suggests that messaging around the impact the engineers have on humanity should be more prominent in seeking to attract and retain engineering students [1]. Denson et al. further observed that the students they interviewed lacked sufficient exposure to engineering in their K-12 education, despite the fact that their schooling plays a large role in their career path decisions [7]. Instead, they observed that these students' motivations to consider engineering largely came from personal curiosity or interest or from family.

A key element of the engineering-focused sections of UL100 course at FMU is to prepare students for success in their major. Hensel et al. studied a cohort of underprepared (starting university in pre-calculus or lower math) students entering an engineering program and monitored factors related to their retention between their first and second years of the program. This cohort received special programming aimed at improving retention outcomes. Hensel et al. found that students leaving engineering between their first and second years exhibited much larger decreases in their perceptions of their own ability to succeed within the major than those students who were retained, despite both groups scoring similarly in these measures upon entering the program [8]. However, further work is needed to investigate how programs similar to that taught at FMU can improve student success rates.

Survey and Survey Participant Description

To gather information regarding students' perceptions and motivations related to engineering and thus address the research objectives (see Section 2), a 21-question survey was deployed to the engineering-focused section of UL100 in Fall 2022. The complete survey can be found in the appendix.

This survey consisted of questions that solicited responses of the following types: multiple choice, multiple response, Likert scale, free text, and a combination of multiple response and free text responses (Table 1 shows the number of each question type). The survey was reviewed and approved by FMU's IRB (IRB #Renu_10_07_2022_004). All participants signed written consent to participate in the study.

Table 1: Count of Question Types in the Survey

Question Type	Count
Free Text	4
Likert	5
MRQ* + Write In	4
MCQ**	7
Total	**21**

*MRQ are Multiple Response Question **MCQ are Multiple Choice Question

The questions were generated to gather information on 1) motivations, both general and specific to pursuit of an engineering degree, 2) perceptions of the engineering profession, 3) knowledge of the skillset required for engineering, and 4) students' knowledge of the difference between engineering and engineering technology. Sample questions of each type are provided in Table 2, and the entire survey is available in the appendix.

Table 2: Sample Survey Questions

Question Type	Sample Question
Free Text	In your opinion, what does a professional engineer do? Can you give an example of the work they do?
Likert	Rate how well you believe you understand the following branches within the engineering profession: Mechanical Engineering 1 (I have no understanding) 2 3 4 (I understand it very well)
MCQ	In your opinion, what is the relevance of mathematics in engineering? a. Very relevant: Impossible to do engineering without mathematics

	b. Quite relevant: I can get away with a foundational knowledge c. Irrelevant: Just tell me how it works, who cares about mathematics d. Unsure
MRQ	Which of the following describes you the best (select all that apply) a. Persistent and consistent b. Courageous c. Independent d. Afraid to be ignored.
MRQ + Write In	Your dream job would involve (select all that apply and add write-in options) a. Hands on work b. Sitting in front of a computer and investigating simulations c. A good mix of option A and option B d. Write in: _______________

This survey was administered in seven weeks in to three engineering focused UL100 sections in Fall 2022 and received 41 responses, of which 36 students indicated they are majoring in engineering and the five other students indicated a STEM major other than engineering. Over 90% of these respondents are first semester college students at FMU. This is known since the authors of this paper are the instructors of the UL100 sections where the survey was administered. Demography-related questions were excluded from this survey but may be included in future versions of the survey.

Survey responses were modified to 1) correct clear and obvious spelling mistakes, and 2) expand clear and obvious abbreviations. Cleaned survey responses were then analyzed using descriptive statistical methods and Natural Language Processing (for the free text responses.)

Analysis of Survey Responses

Table 3: Mapping Survey Questions to Research Objectives

	RO1	RO2	RO3	RO4	Other
Q1					1
Q2				1	
Q3				1	
Q4	1				
Q5					1
Q6	1				
Q7		1	1		

	RO1	RO2	RO3	RO4	Other
Q8				1	
Q9	1		1		
Q10	1		1		
Q11	1		1		
Q12		1	1		
Q13		1			
Q14		1			
Q15		1			
Q16		1			
Q17	1		1		
Q18			1		
Q19	1		1		
Q20	1				
Q21	1		1		
Total	9	6	9	3	2

In Table 3, ‘1’ represents a mapping between a particular question to a RO. To perform the analysis, the questions pertaining to each of the five categories are considered together. For example, observations related to RO1 are based collective analysis of responses to Q4, Q6, Q9, Q10, Q11, Q17, Q19, Q20 and Q21. The student responses are analyzed to ascertain the drive behind pursuing engineering. This process is repeated for all the other categories.

Based on the data collected for RO1 (see Figure 1) from Q9, about 57% of the student participants set their sights on “hands on work”, with the rest (43%) desiring a good mix of hands-on work with investigating computer simulations. Based on the responses from Q10, about 80% of students sought jobs with great salaries, and perceived that engineering could further that endeavor, and 68% of students further reinforced the goal of performing “hands on work”. This could be motivated by many students have a parent, close relative, or friend/neighbor who is an engineer (44%, Q19).

The proclivity for hands on work is further confirmed from the data from Q11 (Figure 1), where students were given pictorial representation on the tasks that excited them the most. 61% of students selected the top left picture (option number ‘1’), which displayed hands-on work being performed. This finding raises a question on whether the students understand the differences between engineering and engineering technology, especially since 48% of them do not know an engineer outside of their professor(s) (Q19). This overlapped with RO2: perception of the differences between engineering and engineering technology.

To understand the perceived differences between engineering and engineering technology, Q12 and Q13 were framed to quantify the level to which students believed fifteen different skills were important to success in each field. The fifteen skills include both "hard" skills and "soft" skills, including many "soft" skills identified as important by Kuleshov and Lucietto [6].

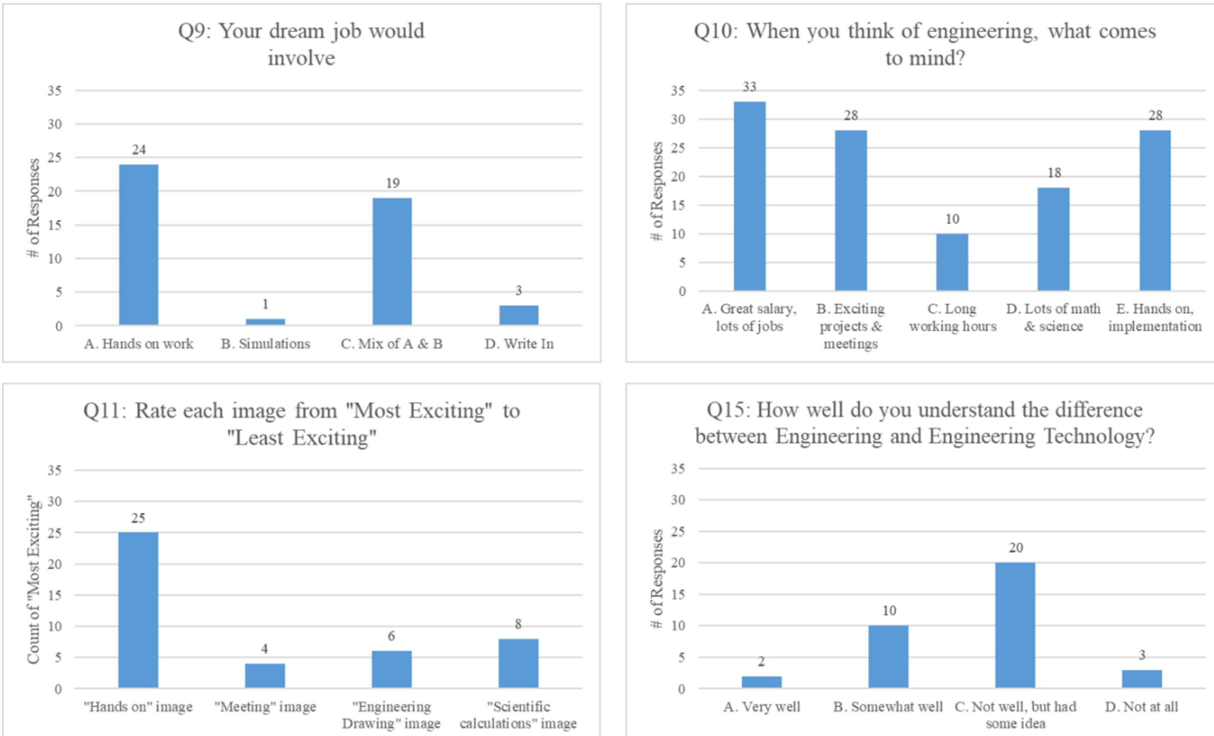

Figure 1: Data gathered for questions that relate to RO1 and RO2

The student-rated importance of having fifteen skills for engineering and engineering technology are presented in Figure 2. While none of the differences are statistically significant (due to low sample size), the survey suggests that incoming engineering students believe:

a. Engineering involves more building than engineering technology
b. Microsoft Office tools are more important to engineering technology than to engineering
c. Mathematics is of approximately equal importance to both disciplines
d. Writing, Data Collection, and Networking are also of approximately equal importance to both disciplines

Responses to Q15, where more than 90% of students revealed that they had a vague understanding of the differences between engineering and engineering technology (Figure 1) confirms the false beliefs observed in a-d above. The data also reveal a lack of understanding of the differences between the engineering curriculum, and the engineering technology curriculum (Q20).

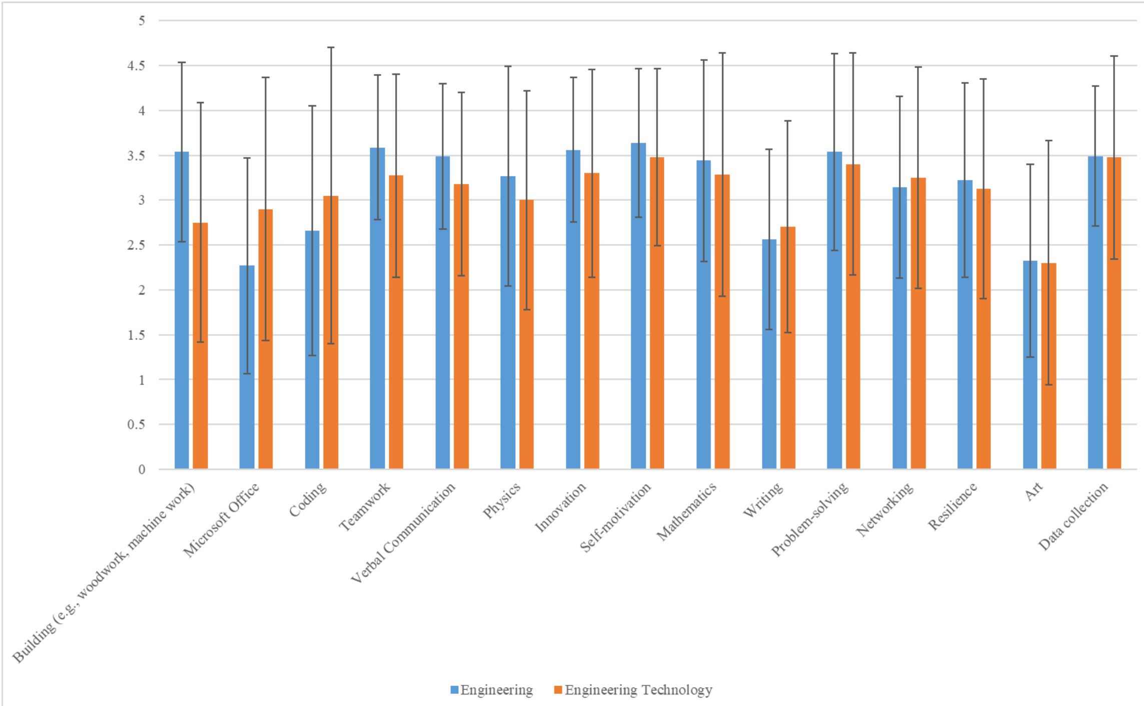

Figure 2: Average Student Importance Ratings of Skills for Engineering and Engineering Technology

To address RO3, students' assumptions of the skillsets required to become an engineer, Latent Semantic Analysis [9] was performed on responses to Q18 where students were asked to describe what a professional engineer does. The LSA scores were clustered and responses that shared 50% or more semantic similarity were analyzed manually. This resulted in the extraction of four themes in the responses: "Design innovative solutions to solve specific problems", "Build things", "Fix broken things", and, "Improve system efficiency". Furthermore, from the data collected from Q12, the students perceive having skills like self-motivation, and problem solving is most important for engineering. Although, self-motivation and problem-solving are essential capabilities, they do not address the technical core skill set required of engineers.

RO4 studies students' motivation in general. Specifically, Q8 was a multiple response question which asked students to select phrases which described them the best. The four options of phrases were: "Persistent and consistent", "Courageous", "Independent", "Afraid to be ignored". In general, students classified themselves as being more independent, persistent and consistent than courageous and afraid to be ignored (see Figure 3).

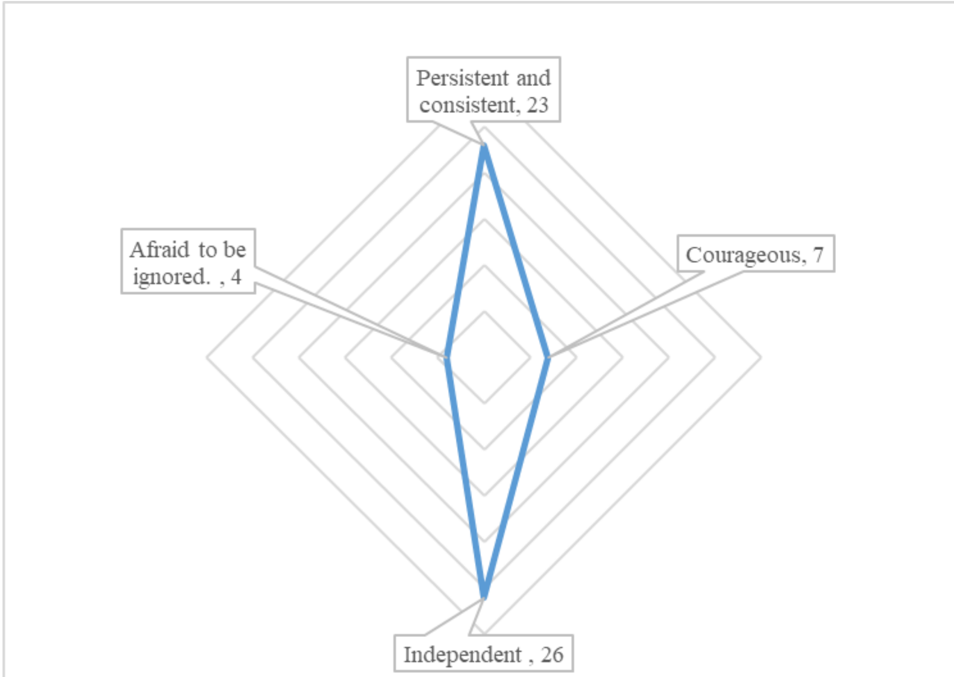

Figure 3: Distribution of responses to Q8: 'Which of the following describes you the best (select all the apply)'

Conclusions and Future Work

The data comprising of student responses from a survey examining the five ROs for first-year undergraduates in engineering was analyzed. A summary of the conclusions for each RO are presented in Table 4.

Table 4: Summary of Conclusions

RO #	RO Description	Conclusion
RO1.	Study student motivation to pursue an engineering degree	Students are motivated by high-paying, hands-on jobs, and in some cases, also by family members who are engineers.
RO2.	Understand students' perception of the difference between engineering and engineering technology	Students have misconceptions about the careers that an engineering degree will lead to. They tend to believe that engineering degrees will result in hands-on, implementation work where they will be fixing broken "things".
RO3.	Study students' assumptions of the skillsets required to become an engineer	There is a tendency for students to believe that computer software, writing and coding skills not critical for engineers. However, they do believe that self-motivation, mathematics, physics, and teamwork are important skills for engineers.
RO4.	Investigate student motivation in general	Students typically report themselves as being independent, persistent, and consistent, but not courageous (see Figure 3)

The data reveal that more than 90% of students are motivated to pursue engineering due to job security and to perform hands on work. However, the data suggest that students have a lack of understanding regarding the differences between engineering and engineering technology curriculum. The understanding is further linked to a poor understanding in the skillset needed to pursue engineering and might stem from insufficient exposure to both disciplines during their school years. Thus, the results of this study indicate that engineering programs should take greater steps to expose future and current students to skillsets and job responsibilities associated with engineering and engineering technology.

Future work should investigate specific interventions that are likely to improve student understanding of engineering and engineering curriculum. A larger study which more directly assesses student motivations to pursue engineering should also be pursued in the future. Based on results observed for RO4, further research is required to 1) understand what impact perceived independence has on affinity for mentorship, 2) study the effect of perceived lack of courage on choice of major, and 3) investigate how perceived persistence and consistency translates to study habits. Additionally, a longitudinal study should be pursued to investigate the effect of student misconceptions about engineering and engineering curriculum on their likelihood to persist and succeed in their program.

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Rahul S. Renu

Rahul S. Renu holds a PhD in Mechanical Engineering and is an associate professor in the Department of Physics & Engineering at Francis Marion University, Florence, South Carolina. He teaches courses across the four-year Mechanical Engineering curriculum, and currently serves as the Coordinator for Mechanical Engineering at FMU. His research focusses on the use of datadriven techniques to bridge the gap between design and manufacturing. He also pursues research related to engineering education.

Appendix – Full Survey

1. What major are you pursuing at FMU? ____________________

2. When faced with a problem, do you
    a. Get help
    b. Try it on your own until you succeed
    c. Get frustrated and quit
    d. Write in: _______________________

3. Do you like to review classwork for mistakes and add notes later to improve your work?
    a. Yes: love to do it
    b. Yes: because I must do it
    c. No: I dread seeing my notes

4. Do you enjoy learning about the functioning of a particular system/product?
    a. Yes: the more details the better
    b. Yes: just about enough that I can use the system without hurting myself
    c. No: the fewer details the better

5. Do you like to examine written instructions
    a. Yes: love to do it. I get excited looking at a manual
    b. Yes: because I need to
    c. No: I hate instructions

6. Do you like imagining how a system (e.g., a car, tv, computer) functions?
    a. Yes: I daydream about it all the time
    b. Yes: only when my job/coursework requires me to do so
    c. No: I don't care

7. In your opinion, what is the relevance of mathematics in engineering?
    a. Very relevant: Impossible to do engineering without mathematics
    b. Quite relevant: I can get away with a foundational knowledge
    c. Irrelevant: Just tell me how it works, who cares about mathematics
    d. Unsure

8. Which of the following describes you the best (select all that apply)
    a. Persistent and consistent
    b. Courageous
    c. Independent
    d. Afraid to be ignored.

9. Your dream job would involve (select all that apply and add write-in options)
    a. Hands on work
    b. Sitting in front of a computer and investigating simulations
    c. A good mix of option A and option B
    d. Write in: _______________

10. When you think of a career in engineering, which of the following comes to mind? (Select all that apply)

a. Great salary, and lots of jobs
b. Exciting projects and meetings
c. Long working hours
d. Lots of mathematics and science
e. Lots of hands-on, implementation work
f. Write-in: ________________

11. Rate the following images on a 1 to 4 scale, where 1 indicates “excites me the most” and 4 indicates “Excites me the least”

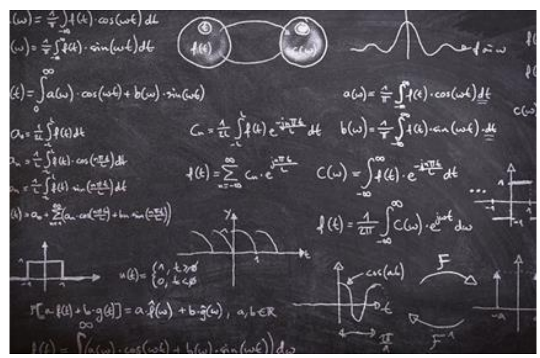

Image Sources:vaughn.edu; eng.ua.edu; degreequery.com; iotbusinessnews.com

12. Rate how important you believe the following skills are for a successful career in **Engineering**:

	1 Not Important	2	3	4 Very Important	I don't Know Enough to Answer
Coding					
Writing					
Mathematics					
Teamwork					
Physics					
Verbal Communication					
Art					
Problem-solving					
Microsoft Office					
Self-motivation					
Building (e.g., woodwork, machine work)					
Networking					
Data collection					
Innovation					
Resilience					

13. Rate how important you believe the following skills are for a successful career in **Engineering Technology**

	1 Not Im- portant	2	3	4 Very Im- portant	I don't Know Enough to Answer
Coding					
Writing					
Mathematics					
Teamwork					
Physics					
Verbal Communication					
Art					
Problem-solving					
Microsoft Office					
Self-motivation					
Building (e.g., woodwork, machine work)					
Networking					
Data collection					
Innovation					
Resilience					

14. Rate your how well you believe you understand the following professions:

	1 I have no understanding	2	3	4 I understand it very well
Teacher				
Lawyer				
Doctor				
Engineer				
Architect				
Engineering Technician				
Designer				

15. Coming out of high school, how well did you believe you understood the difference between engineering and engineering technology.
    a. Very well
    b. Somewhat well
    c. Not well, but had some idea
    d. Not at all

16. After your first few weeks at FMU, how has your belief in your understanding of the difference between engineering and engineering technology changed?
    a. It has improved a lot. I completely understand the difference now.
    b. It has somewhat improved. It is much better than before, but it is still not 100% clear.
    c. It has improved minimally. The difference is still largely unclear to me.
    d. It has not changed at all. My level of understanding has not changed since high school.

17. What are the first three words or phrases that come to mind when you think about:
    a. Mechanical engineering ________________ ________________ ________________
    b. Industrial engineering ________________ ________________ ________________
    c. Automotive engineering________________ ________________ ________________
    d. Civil engineering ________________ ________________ ________________
    e. Electrical engineering ________________ ________________ ________________
    f. Chemical engineering ________________ ________________ ________________

18. In your opinion, what does a professional engineer do? Can you give an example of the work they do?

19. Do you know any engineers? If yes, list how you know them?

20. What subjects do you think are essential to take in high school to prepare you for college education in engineering? (Select all that apply)

    a. Business
    b. Science

c. International Languages
d. English
e. Mathematics
f. Technical Education
g. Health and Physical Education
h. Computer Studies
i. Write in: _______________

21. Rate how well you believe you understand the following branches within the engineering profession:

	1 I have no understanding	2	3	4 I understand it very well
Mechanical Engineering				
Industrial Engineering				
Civil Engineering				
Electrical Engineering				
Biomedical Engineering				
Computer Engineering				
Nuclear Engineering				
Chemical Engineering				