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Can a Five-Minute, Three-Question Survey Foretell First-Year Engineering Student Performance and Retention?

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Abstract

This research paper examines first-year student performance and retention within engineering. A considerable body of literature has reported factors influencing performance and retention, including high school GPA and SAT scores,[1,2,3] gender,[4] self-efficacy,[1,5] social status,[2,6,7] hobbies,[4] and social integration.[6,7] Although these factors can help explain and even partially predict student outcomes, they can be difficult to measure; typical survey instruments are lengthy and can be invasive of student privacy. To address this limitation, the present paper examines whether a much simpler survey can be used to understand student motivations and anticipate student outcomes.

The survey was administered to 347 students in an introductory Engineering Graphics and Design course. At the beginning of the first day of class, students were given a three-question, open-ended questionnaire that asked: "In your own words, what do engineers do?", "Why did you choose engineering?", and "Was there any particular person or experience that influenced your decision?" Two investigators independently coded the responses, identifying dozens of codes for both motivations for pursuing engineering and understanding of what it is. Five hypotheses derived from Dweck's mindset theory[7] and others[8,9] were tested to determine if particular codes were predictive of first-semester GPA or first-year retention in engineering.

Codes that were positively and significantly associated with first-semester GPA included: explaining *why* engineers do engineering or *how* they do it, stating that engineers create ideas, visions, and theories, stating that engineers use math, science, physics or analysis, and expressing enjoyment of math and science, whereas expressing interest in specific technical applications or suggesting that engineers simplify and make life easier were negatively and significantly related to first-semester GPA.

Codes positively and significantly associated with first-year retention in engineering included: stating that engineers use math or that engineers design or test things, expressing enjoyment of math, science, or problem solving, and indicating any influential person who is an engineer. Codes negatively and significantly associated with retention included: citing an extrinsic motivation for pursuing engineering, stating that they were motivated by hearing stories about engineering, and stating that parents or family pushed the student to become an engineer.

Although many prior studies have suggested that student self-efficacy is related to retention,[1,5] this study found that student interests were more strongly associated with retention. This finding is supported by Dweck's mindset theory: students with a "growth" mindset (e.g., "I enjoy math") would be expected to perform better and thus be retained at a higher rate than those with a "fixed" mindset (e.g., "I am good at math").[7] We were surprised that few students mentioned activities expressly designed to stimulate interest in engineering, such as robotics competitions and high school engineering classes. Rather, they cited general interests in math, problem solving, and creativity, as well as family influences, all factors that are challenging for the engineering education community to address.

These findings demonstrate that relative to its ease of administration, a five minute survey can indeed help to anticipate student performance and retention. Its minimalism enables easy implementation in an introductory engineering course, where it serves not only as a research tool, but also as a pedagogical aid to help students and teacher discover student perceptions about engineering and customize the curriculum appropriately.

Introduction

Student attrition within engineering programs has remained an issue for decades at colleges and universities across the United States and elsewhere in the world, with some graduation rates as low as 35%.[11] Fewer students graduating from these programs results in fewer engineers in the workforce. A growing concern for colleges and universities is to pinpoint the main reasons why students leave their programs, as well as to produce methods to increase retention rates.[1,18,19,20]

Numerous studies have used various methods to measure retention and the reasons why students choose and leave their programs. Themes explored in the literature vary, but commonly cited factors include: high school GPA, self-efficacy, personality, academic and non-academic factors, financial support, socioeconomic status, perception of engineers and themselves as engineers, etc., as indicated in Table 1.

Although these studies have identified key factors influencing retention, the approaches they used can be lengthy, invasive of student privacy, closed-ended, and/or confusing. For example, an extensive study conducted in 1966 considered attrition at three Midwestern universities.[3] Academically proficient male students, selected at random from a group of qualified students, were categorized as persisters or non-persisters based on their academic performance and their retention in the engineering program during their freshman and sophomore years. Study participants were first asked to complete a 35 question, fill-in-the-blank and multiple choice questionnaire examining educational, personal, and family history. Question topics related to academic interest, future academic and career goals, siblings, social status, parents' education, father's present and past occupations, the sacrifices the family made for the student to attend college, and financial support.

The study participants were then interviewed for 30-40 minutes to discover why proficient students chose engineering and changed majors, as well as their reaction to their experiences in their engineering program. Interviews were electronically tape recorded, transcribed, and coded. Key factors found to influence retention included socioeconomic status, personality traits, geographic location of high school, finances, involvement in clubs and industry-sponsored organizations, and low college GPA.

At the culmination of the study, researchers had only received completed questionnaires from 221 of the 326 students invited to participate, and were only able to interview 176 of those students. The questionnaire and interview approach may have been too lengthy for full participation by the students invited. In addition, the study was somewhat invasive of student privacy, as the information obtained through the questionnaire and interview was at times quite personal.

Table 1: Literature Search Themes

Theme	Frequency	Sources	Theme	Frequency	Sources
High school GPA	8	1,2,3,6,11,13, 21,22	Skills and abilities	1	1
Gender	5	1,4,11,13,22	Math SAT scores	1	1
Self-efficacy	5	1,2,5,6,24	High school study habits	1	1
Motivation	4	1,16,23,24	Parents' education	1	1
Financial support	4	2,3,6,23	Intro math course	1	1
Social status	3	2,3,6	Learning disabilities	1	1
Personality	3	1,6,22	Advanced high school math and science courses	1	11
Social integration	3	6,21,23	Living in residence halls vs. not	1	21
Personal assessment of skills	3	4,13,16	Interaction with faculty	1	21
Race / ethnicity	3	11,13,16	Time put into outside job	1	21
Academic / career goals	3	2,6,23	Educational background	1	16
Tinkering	2	3,13	Understanding realities of engineering	1	16
Academic integration	2	6,23	Perception of engineers and themselves as engineers	1	16
Academic factors	2	2,6	Being "people oriented"	1	3
Non-academic factors	2	2,6	Curiosity	1	3
ACT scores	2	2,6	Coming from an "engineering home"	1	3
Demographic area / state / hometown	2	3,11	Structure dependence	1	24
Institutional selectivity	2	2,6	Mistrust of instructors	1	24
Institutional commitment	2	2,6	Psychological adjustment	1	6
Commitment to a career	2	3,16	Degree commitment	1	6
Support services / social support	2	2,6	Sense of community	1	13
Hobbies in leisure time	2	3,5	Likes to fix / build things	1	13

As another example, a survey distributed to students at Arizona State University examined students' reasons for choosing an engineering or science major.[14] Students were asked to select their top three reasons from a list of statements, which had been generated from a pilot survey. The results indicate that motivations for choosing engineering include a good potential salary, interesting work, job opportunities, the challenge of solving problems, opportunities to solve societal problems, and that it was the hardest possible undergraduate major and the students desired to prove that they could do it. Although such surveys are easy to analyze, their closed-ended format makes it impossible for students to express motivations that do not appear on the list of options.

Alternatively, open-ended survey approaches have been used to examine student understanding of engineering and reasons for pursuing the major. An international study aimed to gain understanding of students' thinking by using the *Possible-Selves Framework*,[15] allowing international and domestic students to examine their perception of their personal competencies, identity, self-efficacy, motivation, and career.[16] Students were asked to answer three open-ended questions: 1.) How do students characterize an engineer?; 2.) What differences do students perceive between their characterization of an engineer and themselves as individuals?; 3.) In what ways do students relate their learning to their development as an engineer? Responses to these questions were coded using codes from a previous study.[17] The research indicates differences between international and domestic students' perceptions of self, suggesting that international students' low self-esteem, lower self-efficacy, and challenge of assimilating themselves into the program may be related to student understanding of engineering and their reasons for pursuing the major. Although this study's survey instrument is more concise than others, the three questions are worded very academically, which may make it difficult for students to comprehend what is being asked of them.

The preceding examples illustrate the limitations of past methods: excessive length and invasiveness, as well as closed-ended and/or confusing questions. The present study aims to eliminate these issues by providing students with a clear, concise, non-threatening survey that still generates useful information for understanding student expectations and motivations for pursuing engineering, as well as anticipating their academic performance and retention.

Theoretical Framework

Throughout their four (or more) years of undergraduate education, engineering students are required to take a variety of difficult math, science, and engineering courses. Within their first year, it is not uncommon for engineering students to change their major, or in some cases leave the institution completely, due to the difficulty of course material, disinterest in the program, and other factors.

Social psychologist Leon Festinger suggested through his Cognitive Dissonance Theory that if an individual participates in a behavior that is opposed to his attitudes, it can create pressure for him to change those attitudes to be consistent with his behavior; otherwise, he is forced into uneasiness due to inconsistent cognitions.[8] Undergraduate students may begin their first year of engineering confident in their major decision; however, it is easy for a student to lose confidence and motivation when confronted by complex engineering concepts and poor grades. Thus, failure to perform well and loss of confidence conflict with the original cognitions. To make cognitions consistent, some students feel pressured to change their career path, leaving the engineering field to pursue an easier major.

Each undergraduate student enters with a specific mindset, and has a particular set of motives for following their career path. Blazer proposes that pupils with a "fixed mindset" generally have set beliefs about their abilities and engage in tasks they know they can perform well in, while avoiding challenges.[10] On the other hand, students with a "growth mindset" are not afraid to take risks in expanding their ability, embrace challenges presented to them, work harder when faced with a setback, and view criticism and advice as valuable to personal development.[10] Although individuals may not identify with one of the two mindsets all of the time, approximately 40% of people have a growth mindset, 40% have a fixed mindset, and 20% do not identify with either mindset.[10]

In a study relating mindset to academic achievement in math and science, Dweck found that students with a growth mindset show superior performance compared to those with a fixed mindset, because they are more willing to develop their abilities.[7] It follows that if students are more willing and motivated to improve their abilities, there is a higher chance that they will be retained.

Such motivation for becoming an engineer differs from person to person. Some undergraduates pursue engineering because of intrinsic motivations, or learning goals, while others study engineering due to extrinsic motivations, or performance goals.[12] Intrinsic motivations may relate to personal enjoyment and interest or a desire to expand knowledge, while extrinsic motivations include lucrative incentives such as money, prestige, and job opportunities.

The present study examines the motivations and other stimuli that influence students to pursue an Engineering degree, as well as their initial understanding of engineering prior to the commencement of the program. The study seeks to determine whether student responses to a three question, open-ended survey distributed on the first day of an introductory Engineering course correlate with students' first-year academic performance and retention within an Engineering program.

Specific hypotheses include:

- A student whose response reveals intrinsic motives will perform better and be more likely to be retained than a student who expresses extrinsic motives. Intrinsic motives, such as desires, interests and ambitions, will influence the student to perform with greater interest, advancing to a growth in mindset; likewise, students influenced by external factors, such as people, set ideas, or trends, will be less likely to exhibit an expansive mindset, as things are predetermined for them.
- Students who indicate interest or efficacy in math and/or science will perform better and be more likely to be retained than those who do not indicate such interest, due to their engrossment in these key subjects as well as their realistic understanding of what engineering entails.

- Students who were influenced by a teacher or professor will perform better and be more likely to be retained than those who were not, as the influence comes from an individual who can accurately assess the student's academic strengths and potential.
- Students who are "pushed" or pressured by parents and/or other family members to study engineering will be less likely to perform well and be retained, as it may not be their personal desire to learn about this subject.
- Students who provide longer responses, as measured by the number of characters, and/or richer responses, as measured by the number of codes embedded within their responses, will perform better and be more likely to be retained than those who provide shorter responses and mention fewer codes. More in-depth responses are hypothesized to indicate greater understanding of, and motivation for, engineering.

Methods

The 347 students surveyed in this study were enrolled in the introductory Engineering Graphics and Design course at a small private university in the Northeastern United States. The survey was distributed to students at the beginning of the first day of class, just after they entered the classroom and received a welcome from the professor. At this point, students have not yet been presented with information about what engineering is, what engineers do, or what will be accomplished in the course – they take the survey based on their own knowledge of engineering prior to walking into the classroom. The survey questionnaire consists of a single page and features three questions, listed in Figure 1. The questions are intentionally open-ended, allowing capture of the students' own ideas, without biasing them by providing closed-form response choices. Furthermore, the questions were designed to use straightforward language, making them easy for students to comprehend. This is particularly important for the approximately 20% of students who are not native speakers of English.

Students were given about ten minutes to complete the survey. The responses were collected and reviewed by each course instructor, then given to the senior investigator for storage. After collecting data for four years, the responses were analyzed. First, the students' names were removed from the completed questionnaires and replaced with code numbers for anonymous analysis. Next, each student response was transcribed into a database. Two investigators independently performed open coding on the responses to each of the three survey questions, generating dozens of codes for both motivations for pursuing engineering and understanding of what it is. The two investigators then worked together to organize the identified codes into thematic categories. The coding schemes developed for each question are explained in the Results section, and included in the Appendices.

1.) In your own words, what do engineers do?

2.) Why did you choose engineering?

3.) Was there any particular person or experience that influenced your decision?

Figure 1: The Survey Used in this Study

The two reviewers then separately re-coded the survey responses using the agreed-upon coding schemes, and compared their responses to ensure inter-rater reliability. After coding the student responses, each student's first-semester GPA and first-year Engineering retention status were determined from institutional records.

Four distinct analyses were performed. First, the frequencies with which each code was mentioned were counted and tabulated. Next, the hypotheses derived in the Theoretical Framework section were tested. Student's *t*-test was used to determine if the average first-semester GPA of students mentioning particular codes related to the study hypotheses differed from that of those not mentioning those codes. Then, the *z*-test for difference of proportions was used to determine if retained and non-retained students mentioned particular codes with different frequencies. Finally, the length and richness of each response were tallied. Length was measured by the number of characters in the response, while richness was measured by the number of codes used to code it. Student's *t*-test was used to determine if the length and richness of responses differed between students who were and were not retained. Correlation analysis was used to determine if there was a relationship between response length and/or richness and students' first-semester GPA.

Sample Demographics

With inclusion of six cohorts, a total of 347 students were considered for this study. The number of students in each cohort is displayed in Table 2. The Fall 2011 cohort was small because it only contains the two sections of the course taught by the principal investigator. After finding that the survey was a useful first-day exercise, it was deployed across all course sections in later years.

Table 2: Number of Students in Each Cohort

Cohort	***Number of Students***
Fall 2011	35
Fall 2012	105
Fall 2013	68
Spring 2014	18
Fall 2014	93
Spring 2015	28
Total	***347***

Results and Discussion

Qualitative Results

The content and length of student responses to each of the three survey questions varied. Illustrative examples are listed below.

Question 1: What do engineers do?

Typical Responses

"They construct and create ideas to make things work better or more efficiently. They try to find ways to make everyday tasks and complicated processes work much easier."

"Engineers can be people who have a good understanding of math and science and how they can work together. Engineers apply this knowledge in the world through a number of jobs and many fix, design, build, and imagine innovative and helpful technologies."

Atypical Response

"Create and look at the world with a different view."

Question 2: Why did you choose engineering?

Typical Responses

"I love math and science, particularly physics. I thought engineering would best fit my personal interests in these areas."

"Many of my uncles are engineers. My dad was. 4 years on a robotics team. I've always liked it. I'm good at math and science."

Atypical Responses

"Honestly, I am not highly interested in engineering. I had so many dreams in my high school but I am still not quite sure what I am going to be in my future. So based on my grades, the math and physics are both of my best grades and I think it would be appropriate for me to study engineering. That is why I chose undecided engineering for now."

"I was unsure of what I wanted to be when I become older so I thought I would try this."

Question 3: Influential person or experience

Typical Responses

"I have always enjoyed math and science, but having a dad who is an industrial engineer has pushed me to study engineering."

"No, I'm just really interested in math and science fields."

Atypical Responses

"My experience with Marine Biology made me realize I wanted to change majors."

"Honestly, my mom put me between two choices 1.) Doctor 2.) Engineer :(So I chose engineering because it's less complicated than the other choice."

Each response was coded using a set of codes formed from trends in student responses. A separate coding scheme was created for each question. The codes for Question 1, gauging student understanding of what engineers do, were organized into categories that answer the questions: What do engineers do?; What do they work on?; Who does it?; For whom?; How do they do it?; and Why do they do it? Appendix 1 shows the resulting scheme.

In creating this set of codes, it was apparent that students mentioned some codes in certain contexts, for example, as a different part of speech (verb, noun, etc.), or as an approach to how engineers do something (physically or mentally). These contexts are noted for such codes in Appendix 1 and are used to obtain useful results regarding student understanding of engineering.

A second set of codes was established to address Question 2, asking students why they chose to pursue engineering. Codes for this question were separated into four main categories as shown in Appendix 2: Intrinsic, Self-Image, Extrinsic, and Other. Characterizing motives as either intrinsic or extrinsic allows us to test the hypothesis that a student whose response reveals intrinsic motives will perform better and be more likely to be retained than a student who expresses extrinsic motives. Codes that reflected students' expression of self-image, such as codes relating to self-efficacy, are denoted to provide insight on another hypotheses: students who indicate interest or efficacy in math and/or science will perform better and be more likely to be retained than those who do not indicate such interest or efficacy.

Codes for Question 3 were organized into categories that denote the influences that affected a student's decision to study engineering. These categories relate to People, Experiences, Technology, and Other Influences. The "Family" section of the People category distinguishes between simply mentioning a family member and mentioning that a family member is an engineer or does related things. Experiences are categorized based on different periods in the student's academic career, as well as occupational experience away from the classroom. The "Other Influences" category includes students who claimed there was no influential person or experience for their decision, as well as those who indicated various personal interests or feelings of obligation. The complete coding scheme is included as Appendix 3.

Although a great number of codes were needed to fully describe all the student responses to the three survey questions, some codes were mentioned far more often than others. These are listed in Tables 3, 4, and 5, regarding results for Question 1, Question 2, and Question 3 respectively. Each of the frequently mentioned codes is listed with its respective code category, as described above, along with the total number of mentions for that code.

Frequently mentioned codes for Question 1 mostly answered the question "What?" in referring to what engineers do, both as a verb and as a noun. The results suggest that students generally have a good understanding of engineering, though they mentioned *designing* and *making* far more frequently than they mentioned *math* or *science,* the activities that comprise the bulk of an engineering curriculum. Such a mismatch between students' expectations and experiences could cause some students to become dissatisfied, particularly in the first and second years before they reach the more applied engineering courses. On the other hand, it could simply be that the students saw math and science as means to an end rather than ends in themselves, and so did not mention them.

Table 3: Frequently Mentioned Codes for Question 1 – What do Engineers Do?

Code	***Code Category***	***Number of Mentions***
Design	What? (verb)	112
Build / Make / Construct / Fabricate (not mass produced)	What? (verb)	87
Structures / Buildings / Bridges / Roadways	What? (noun)	70
Things / Something / Stuff	What? (noun)	61
Solve problems	What? (verb)	51
Create	What? (verb)	50
Specific pieces of technology / Everyday items	What? (noun)	38
Generic technology / Devices / Inventions	What? (noun)	37
Simplify / Make life easier	Why?	34
Improve / Re-design / Modify / Advance	What? (verb)	32
Make Efficient / Productive / Make life more convenient/ Cheap	Why?	27
Engineering specialization (Mechanical, Civil, Electrical, Chemical, Industrial)	What? (noun)	27
Fix / Repair	What? (verb)	27
Improve standard of living for society / Help people, the public, society	What? (verb)	26
They do math / Crunch numbers	How? (mentally)	24

Table 4: Frequently Mentioned Codes for Question 2 – Why did You Choose Engineering?

Code	***Code Category***	***Number of Mentions***
Response uses words indicating emotion	Intrinsic	82
Enjoys math	Intrinsic	71
To build / Make things	Extrinsic	66
Enjoys problem solving / Solving puzzles	Intrinsic	62
To design things	Extrinsic	57
Response indicates long-term feeling	Intrinsic	54
Response uses the word "Enjoy"	Intrinsic	52
Math self-efficacy / Good with numbers	Self-Image	44
Likes to know how things work / function	Intrinsic	47
General interest	Intrinsic	41
Enjoys science	Intrinsic	35
Humanitarian / Make the world a better place / Help people	Extrinsic	32
Expresses future goals (in STEM)	Other	31

Table 5: Frequently Mentioned Codes for Question 3 – Influential Person or Experience

Code	***Code Category***	***Number of Mentions***
Response mentions father	Family	79
Father was an engineer	Family member who is an engineer	42
High school teacher / College professor	People	38
Personal interest / "Really interested"	Other	38
Father does things related to Engineering	Family member does related things	32
"No"	No	31
Response expresses uncertainty	No	21
Observed engineering work	Occupational	21
Someone taught student about engineering	People	21
Mentions technology or software	Technology	20
Enjoys creating / building things	Other	19
Childhood building / creating / tinkering	Experience	18
Uncle	Family	17
Always wanted to do Engineering / Something they wanted to do	Other	17
Mentions specific company / university	Technology	17

In response to Question 2, students tended to mention intrinsic motives more often than extrinsic motives. Interestingly, both the enjoyment of math and the enjoyment of science appear in this list, indicating that many of the students do understand the reality that engineers focus their studies in mathematics and science.

For Question 3, the most frequently mentioned codes prominently refer to people who were influential to the student's decision to pursue engineering. Many students mentioned their father, and many of these stated that he was an engineer or did something related to engineering (professional trades, computer science, project management, etc.). It is noteworthy that only male figures were frequently mentioned –female influences, such as a mother, aunt, grandmother, sister, etc., were mentioned only occasionally. It is also striking that relatively few students mentioned influential experiences. We expected that more would have mentioned engineering outreach activities such as FIRST robotics and high school engineering classes. It is unclear whether these were not mentioned often because few students had participated in them, or because they had but did not consider them to be influential. Many students did mention childhood building and tinkering, a less structured experience, and one probably being influenced more strongly by family than by the engineering community.

Quantitative Results

After examining how frequently the various codes were mentioned in student survey responses, we took a closer look to determine which codes were positively and negatively associated with first-semester GPA and first-year retention in Engineering.

Results from Student's *t*-test indicate that the average first-semester GPA of students mentioning particular codes related to the study hypotheses did in fact differ from that of students not mentioning those codes. Some codes that were positively and significantly associated with first-semester GPA, as shown in Table 6, included: answering "Why?" (p = 0.005), "How?" (p = 0.023), or "What (verb)" (p = 0.026) to Question 1, stating that engineers use ideas/vision/theory (p = 0.014), stating that engineers use math, science, physics or analysis (p = 0.029), expressing enjoyment of math, science, physics, or chemistry (p = 0.003), and being influenced by a high school teacher (p = 0.019) or someone who was an engineer or did related things (p = 0.026). In contrast, expressing interest in specific technical applications (e.g., electronics, buildings, bridges, robots, cars, etc.) was negatively and significantly related to first-semester GPA (p = 0.005).

These results support the original hypotheses. Both enjoyment of math and science as well as physics self-efficacy support the hypothesis that students who indicated such codes will be more likely to perform better. Student understanding that engineers study science resonates well with Festinger's Cognitive Dissonance Theory. If a student enters an engineering program with the understanding that there will be a heavy academic focus in science, they will not be caught off guard with the science-related course load. On the other hand, if a student thinks that engineers only build things and use technology more than science, they may not perform as well. The results also support the hypotheses derived from mindset theory. Students pursuing engineering because of an interest in one particular technology (an extrinsic motivation, reflective of a fixed mindset) might not be sufficiently motivated to study other topics, including math and science.

The retention analysis showed that many codes are positively and very significantly associated with first-year retention, as noted in Table 7. Some of these include: the number of codes mentioned when answering Question 1 (p = 0.0002), stating that engineers use math (p = 0.003), stating that engineers test things (p = 0.010), expressing enjoyment of math (p = 0.0001), enjoyment of science (p = 0.001), mentioning problem solving when answering Question 2 (p = 0.005), and being influenced by someone who is an engineer (p = 0.012). Some codes negatively and significantly associated with retention included: stating that engineers have many roles (p = 0.006), answering "no" or showing signs of uncertainty (p = 0.016), and stating that parents or family pushed the student to become an engineer (p = 0.035).

The results indicate that if the student understands what subjects engineers study, or is interested in those subjects, they are more likely to be retained in the engineering program than students who do not understand what engineers study, or who state that engineers "have many roles" (perhaps a way to hide the fact that the student does not really know what engineers do).

Table 6: Codes Significantly Associated with First-Semester GPA

	Question Number	***Code***	***p-value***
Positively and Significantly Associated with GPA	Question 1	Mentions a Why? code	0.005
	Question 1	Test (verb)	0.011
	Question 1	States that engineers use ideas / vision / theory	0.014
	Question 1	Mentions a How? code	0.023
	Question 1	States that engineers study science	0.025
	Question 1	Mentions a What? (verb) code	0.026
	Question 1	States that engineers use math, science, physics, or analysis	0.029
	Question 1	People / Others / The public (for Whom)	0.038
	Question 1	New / Future (adjective)	0.055
	Question 2	Mentions enjoyment of math, science, physics, or chemistry	0.003
	Question 2	Enjoys math and science	0.048
	Question 2	Physics self-efficacy	0.059
	Question 2	Major fits or suits student	0.082
	Question 2	Math self-efficacy	0.085
	Question 2	Enjoys math	0.085
	Question 3	High school teacher	0.019
	Question 3	Influential person was an engineer or does related things	0.026
	Question 3	Uncle	0.028
	Question 3	Teacher or professor	0.030
	Question 3	Member of extended family (grandparent, uncle/aunt, cousin)	0.044
	Question 3	Mentioned any high school class	0.049
	Question 3	Influential person is/was an engineer	0.051
	Question 3	Parents / family supported, suggested, helped or pushed	0.085
Negatively and Significantly Associated with GPA	Question 1	Engineers simplify and make life easier	0.052
	Question 1	Mentions a Who? code	0.064
	Question 2	Mentions interest in specific technical applications	0.005
	Question 2	Mentions interest in hands-on activities (combination of hands-on work, building/making, fixing, taking things apart)	0.096

Table 7: Codes Significantly Associated with First-Year Retention in Engineering

	Question Number	***Code***	***p-value***
Positively and Significantly Associated with Retention	Question 1	States that engineers use math	0.003
	Question 1	States that engineers test things	0.010
	Question 1	States that engineers perform design	0.013
	Question 1	Mentions a What? (noun) code	0.018
	Question 1	States that engineers use science	0.019
	Question 1	States that engineers work with ideas, visions, or theories	0.019
	Question 1	Mentions a What? (verb) code	0.077
	Question 1	Mentions buildings, bridges, roadways, structures	0.083
	Question 2	Enjoys math	0.0001
	Question 2	Enjoys science	0.001
	Question 2	Mentions problem solving (across all categories)	0.005
	Question 2	Expresses long term desire to be an engineer	0.034
	Question 2	Math self-efficacy	0.045
	Question 2	Enjoys creating/building things	0.046
	Question 2	Uses “fun” as an adjective	0.071
	Question 3	Mentions any influential person who is an engineer	0.012
	Question 3	Uses the word “fun”	0.071
Negatively and Significantly Associated with Retention	Question 1	States that engineers have many roles	0.006
	Question 2	Mentions Electrical Engineering specialization	0.017
	Question 2	States that engineering is important in the student’s country	0.040
	Question 3	Student answers “No” or shows signs of uncertainty	0.016
	Question 3	Student cites an extrinsic motivator	0.030
	Question 3	Mentions hearing stories about engineering	0.033
	Question 3	States that parents/family pushed the student to become an engineer	0.035

The positive significance of the enjoyment of math and science, as well as math self-efficacy, support the original hypothesis that students who expressed interest or efficacy in math and/or science would be more likely to be retained. What is most surprising is the strength of the results for enjoyment of math (p = 0.0001) and enjoyment of science (p = 0.001). These are very strong effects.

The negative significance of codes such as hearing stories about engineering, and parents/family pushing the student to become an engineer, also support an original hypotheses. As predicted, students who were pushed by parents/family to pursue engineering would be less likely to be retained.

A main story that arises from the retention analysis is that students are more likely to be retained if they have a realistic understanding of engineering and what engineers do. Furthermore, being intrinsically motivated, being personally interested, and showing dedication right from the start, indicate a higher chance of the student being retained within the engineering program.

Table 8: Correlations for Response Length and Richness to First-Semester GPA

	Correlation Coefficient, *r*	*p*-value
Question 1		
Response Length	0.110	0.076
Response Richness	0.190	0.002
Question 2		
Response Length	0.120	0.054
Response Richness	0.022	0.730
Question 3		
Response Length	0.110	0.070
Response Richness	0.051	0.410

After analyzing the responses based on their content, the investigators evaluated them based on their length and *richness* - the number of codes mentioned per student response. Correlation analysis indicates that there is a modest, positive, linear relationship between the length of a student's response to any of the three questions and his first-semester GPA (Table 8). The richness of the student's response to Question 1, but not Questions 2 or 3, is very significantly correlated to first-semester GPA.

For retention, both the length and richness of the response to Question 1 have strong, positive relationships to retention (Table 9). The richness of the response to Question 2 has a nearly significant positive relationship with retention. Retained students also gave longer and richer responses to Question 3, though the differences were not statistically significant.

It is clear that students who give longer responses to any of the questions are more likely to perform well. Similarly, students who mention more codes while explaining what engineers do are also more likely to perform well. These results support the hypothesis regarding response length and richness.

Table 9: Comparison of Response Length and Richness for Retained and Non-Retained Students

	Retained Students	Non-Retained Students	*p*-value
Question 1			
Mean Response Length	129.2	108.2	0.020
Mean Response Richness	6.924	5.720	0.003
Question 2			
Mean Response Length	130.1	119.8	0.311
Mean Response Richness	3.611	3.135	0.067
Question 3			
Mean Response Length	101.7	93.6	0.410
Mean Response Richness	5.115	4.509	0.223

Conclusions

This study examined whether a five-minute, three question survey can assist in projecting first-year engineering student performance and retention. Results from students enrolled in an introductory engineering course indicate that certain words and phrases used in open ended responses are significantly associated with performance and retention. Further, the length and richness of students' responses are also significantly associated with performance and retention.

Results from this study support the hypothesis that students who express intrinsic motives, reflecting a "growth mindset," are more likely to outperform and be retained at a higher rate than those who express extrinsic motives, suggesting a "fixed mindset." Codes that were positively and significantly associated with first-semester GPA, including the understanding that engineers study science and the enjoyment of math and science, were considered intrinsic motives by the two evaluators in this study.

Codes negatively and significantly associated with retention, including responding "no" to Question 3, showing signs of uncertainty, or indicating that parents or family are pushing the student to become an engineer, indicate that the student may not be fully committed to studying engineering.

Other hypotheses for this study were also supported by the findings. Results from correlation analysis suggest that the length of a student's survey response has a positive, significant correlation to first-semester GPA. Finally, some of the most significant results from this study indicate that the enjoyment of math ($p = 0.0001$) and the enjoyment of science ($p = 0.001$) have incredibly strong effects on retention, supporting the prediction that students who indicate interest or efficacy in math and/or science will perform better and be more likely to be retained than those who do not indicate such interest.

While this in and of itself is not a new finding, what is surprising is that it can be replicated using a five minute, three question survey. A major strength of this study is the high participation rate – while 347 students took the survey, only ten were not included in the analysis, and these were only excluded because they had not included their name, or were taking the course for a second time after failing it the first time. High participation reduces the risk of non-response bias, yielding more reliable results. This survey also serves as a useful class exercise for students enrolled in the introductory engineering course. While it is minimally invasive, it allows students to start to reflect about what engineering is and to explore their motivations for choosing to be a student in this major. It also helps the instructor to better understand the students' incoming perceptions about engineering, and to realign them if necessary.

A minor limitation of this study is that it was not anonymous. Student responses may have been influenced by the fact that students were required to write their names on the survey and knew that their professor would be reading their responses. Perhaps, if students were not required to include their name, they would have been less likely to feel "judged" or feel uneasy about having to provide a "correct" answer. If this approach was taken instead, students might have said other things in their responses. Of course, it would make it much more difficult to track the students' academic performance and retention.

Another limitation of this study was that we were unable to analyze full, 4-year retention for each of the cohorts; essentially the Fall 2011 cohort was the only group with full retention data available, as those students had mostly graduated before the completion of the study. Due to this limitation, we limited the study to focusing on first-year performance and retention. However, it is well established that first year performance correlates strongly with four-year persistence and performance.

A third limitation is the somewhat fluid distinction between an "intrinsic motivation" and an "extrinsic" motivation. What motivates one person may be completely different than what motivates another; thus, it is difficult to categorize a person's motives. For this study, the power of distinguishing between these two types of motivation was given to the evaluators.

Finally, this study was conducted at a single institution with a modest sample size. This study provides results that emerge solely from the given student populations at the study university; however, the simplicity and time-effectiveness of the survey serves as an excellent model for other engineering faculty who are interested in obtaining an indication of first-year engineering student performance and retention at their own institutions. To save time, those interested in using the survey might consider using a computer to automatically code responses based on keywords, rather than coding each response manually. The benefit of manual coding, of course, is the possibility of identifying ideas that emerge from particular combinations of words, rather than just the words themselves. Such nuance would be lost on a computer program. On the other hand, the computer would be less subjective, and more consistent.

The results from this study help to conclude that the use of a five-minute, three question survey can indeed help foretell first-year engineering student performance and retention. Instructors and faculty interested in learning about students' potential performance and retention within an engineering program have a tool to do so using the simple survey provided in this research study.

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Appendix 1: Coding Scheme for Question 1 – What do Engineers Do?

What do Engineers do? (verb)

- Solve problems
- Create solutions
- Calculate / Compute
- Question
- Imagine
- Design
- Create
- Invent
- Build / Make / Construct / Fabricate (not mass produced)
- Manufacture / Fabricate (mass production) / Industrialize
- Conduct experiments
- Prototype
- Develop
- Produce
- Apply / Real life application
- Test
- Fix / Repair
- Improve / Re-design / Modify / Advance
- Optimize
- Analyze / Evaluate
- Research
- Maintain
- Manage / Lead / Instruct
- Sketch
- Graphic Design
- "Engineer"
- React to requests
- Proactive / Entrepreneurship
- Economize
- Plan
- Understand how / Make things work
- Come up with ideas

What do Engineers work on? (noun)

- Engineering specialization (Mechanical, Civil, Electrical, Chemical, Industrial)
- Structures / Buildings / Bridges / Roadways
- Environmental systems / Water & soil
- Chemical
- Prototypes
- Specific pieces of technology / Everyday items
- Programs / Applications / Software / Computers / Electronics / Electricity
- Sketches / Blueprints / Schematics / Assembly instructions
- Energy
- Machines / Tools
- Materials
- Cars / Vehicles
- Things / Something / Stuff
- Everything / Anything / Whatever
- Method
- Idea / Theory
- Product
- Technology / Devices / Inventions
- Projects
- Designs
- Problems

Who does Engineering?

- "Engineers are people who"
- "They are the ones that" / "An engineer is anybody that"
- Uses "We"
- Good at math and science
- Engineers are people who do things that other people cannot
- See things differently
- Professionals
- Developers
- Understand how things work
- Designers
- Planners
- The "minds"
- Efficient / Creative individuals
- Problem solvers

For Whom?

- People (small scale)
- Society / the Public
- Everyone / "of/in the world"
- Government
- Business
- Environment / Animals

How do Engineers do it?

Mentally

- Come up with / Use ideas
- Analyze
- Logic / Critical thinking
- Broad knowledge base
- Study how things work
- Math / Crunch numbers
- Science
- Creativity
- "Skill"
- Solve problems

Physically

- Solve problems
- Design
- Create
- Improve
- Test ideas and theories
- Use tools / machinery
- Use a system / Design process / Plan to do things
- Turn an idea into reality
- Technologically
- Resources
- Work with different materials
- Work with their hands / Get their hands dirty
- Run a business / Industry / Factory
- Sit in an office
- Have companies produce their ideas
- Handle aesthetic qualities
- Invent based off of specifications
- Check work that other people have done physically / Inspect
- Make things we use every day
- Work together / With others
- Not sure

Why do Engineers do it?

- Solve problems
- Make the world more sophisticated / "Push society forward / Modern growing world
- Fix consumer complaints / Consider needs of society
- Efficient / Productive / Make life more convenient / Cheap
- Make sure things work properly / are functional
- Safety / Make the world a safer place / Prevent accidents
- Simplify / Make life easier
- Improve standard of living for society / Help people, the public, society
- Improve / Repair / Make better / Strengthen
- To be reproduced
- Design
- Construct
- Create
- Accomplish a goal / For a purpose

Appendix 2: Coding Scheme for Question 2 – Why did You Choose Engineering?

Intrinsic

- Like to know how things work / function
- Like to know how things are made / built
- How products are developed / designed
- Uses the word "enjoy"
- Desire to learn / further intelligence
- Creativity
- Likes the details
- Curiosity
- "The challenge"
- Prefers it over architecture
- Prefers it over computer science
- Cars
- Yachts
- Military / Aircrafts
- Sci-Fi movies
- Humanitarian / make the world a better place / help people
- Enjoys hands-on work
- Enjoys math and science
- Enjoys science
- Enjoys physics
- Enjoys chemistry
- Enjoys engineering curriculum
- "Want" to be an engineer
- General interest
- Problem solving / puzzles
- High school classes got them interested
- Dream
- Words of emotion
- Indicates long-term feeling
- Explore

Self-Image

- Good with computers
- Good at visualization
- Good at putting things together
- Good at planning
- Math self-efficacy / "good with numbers"
- Science self-efficacy
- Physics self-efficacy
- Good at school
- Mechanically inclined
- Self-efficacy with problem solving
- Good at analyzing
- Work hard
- Attention to detail
- Believe that they will do well in engineering / are well suited for it

Extrinsic

- Lucrative benefits / high salary
- Jobs available
- Success / fulfillment / opportunity
- Need for engineers / major is important in my country
- Real world application
- Experience with software (ex. CAD) / Drafting
- Sketching
- Machines / mechanical systems
- Taking things apart / putting them back together
- Fixing things
- Designing things
- Creating things
- Building / making things
- Previous job experience
- Robots
- Buildings / bridges / architecture / structures
- Mechanical engineering
- Civil engineering
- Construction
- Electrical engineering
- Environmental engineering
- Chemical engineering
- Environmental work
- New ideas
- Improving things
- Think critically / think "outside the box"

Other

- Engineering was suggested / recommended
- Uncertainty / good major to start in, regardless of where they end up
- Dream
- Engineers have the opportunities to make an impact
- Good career for women
- Engineering will help them prepare for another background
- Help myself / "use it to my advantage"
- Expresses future goals (in STEM)

Appendix 3: Coding Scheme for Question 3 – Influential Person or Experience

People

Family member who is an engineer

- Grandfather
- Father
- Mother
- Parents
- Sister
- Brother
- Great Uncle
- Uncle
- Cousin
- Aunt
- Family (general)

Does things related to engineering

- Father
- Mother
- Brother
- Grandfather
- Great Uncle
- Uncle
- Cousin
- Family (general)
- Related trades
- Related professions
- Construction
- Other related things
- Is / Was an engineering student
- Taught student about engineering
- Was creative

Family

- Father
- Mother
- Parents
- Grandfather
- Great Uncle
- Uncle
- Cousin
- Brother
- Sister
- Family

Other

- High school teacher / College professor
- Family friend
- Friend
- Roommate
- Famous engineer
- Coach
- Teammates
- "People"
- Mentor

Experience

College

- College Engineering Course

High School

- Engineering Course
- Design & Graphics Course
- Classes taken in high school (general)
- Science class
- Physics class
- Math class
- Experiment
- Competition
- Robotics

Middle School

- Project / Experiment / Building

Childhood

- Building / Creating things / Tinkering

Occupational

- Internship
- Job
- Camp
- Shadow / Visiting / Experience
- States future occupational goal
- Observed engineering work
- Stories about engineering work were told to them
- College visit / Meeting with faculty

Technology

- Worked on cars / motor bikes
- Worked on yachts / boats
- Mentions technology or software
- Company / University
- Legos
- Travel
- News
- TV / Internet

Other Influences

No

- “No”
- Expresses uncertainty
- “Not really”

Other

- Always wanted to do engineering / Something they want to do
- Switched majors / Major interest
- Parental / Family support
- Parent / Family / Other suggested
- Parent / Family pushed
- Was a role model / Admired
- Parent / teacher / mentor thinks the student would be good at engineering
- Personal Interest / “Really interested”
- Felt obligated to become an engineer / Make parents proud
- Did research on careers / Came into it on my own
- Enjoys problem solving / Making things easier
- Enjoys hands-on aspect
- Enjoys creating / building things
- Finds engineering appealing
- Like the challenge
- Math & science efficacy
- Curious / understand how machines and gadgets work
- “Fun” / enjoy
- Service / Humanitarian / Environment
- Need for engineers
- Interest in math and science
- Inspired by a place
- Words indicating emotion
- Happiness with career
- Feeling of personal achievement
- Lucrative / Success
- Prestige