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An Overview of First-Year Engineering Students' Perceptions of Problem Solving in Engineering during a Major Exploration Course

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Introduction

Deciding on a major is one of the most important decisions first-year students must make. Students who are confident they want to major in engineering often have the ability to delay their commitment to a specific discipline until the end of their first year of study. During the first year, students are ideally exposed to all their options and learn about each of the engineering majors offered at their institutions to help them make an informed major choice. However, the literature contains only limited findings about students' understanding of what engineers do. If first-year engineering students' perceptions of engineering and the engineering majors are not in agreement with the perceptions of students enrolled in the major or faculty in that major, this disconnect could lead to dissatisfaction and retention issues.

This work will present initial findings from a single-institution study of an optional major exploration course in engineering where students were asked to describe what engineers do for a living both before and after completing the course. This work will later be expanded to illustrate the impact the major exploration course has on first year engineering students' perceptions of engineering. Additional future work will also connect course completion with future major switching or lack thereof and graduation rates.

Literature Review

In Seymour and Hewitt's seminal work, they conclude, among other things, that interest in a discipline and the careers that follow are "conducive to persistence" [1]. The factors that influence major selection are important for engineering educators to foster such interest [2]. The work to identify these factors includes understanding the perceptions students have of the engineering disciplines. Research has shown first-year engineering students consistently identify many important topics common to all engineering disciplines, such as maintenance, research, and processes [3]. Additionally, students have described mechanical engineering as having the most "options;" this may be due to the marketing of the major or its general perception as a broad discipline. This study found that while some perceptions were broadly held, the disciplines were perceived differently based on the students' majors and the institution they attended [3].

While first-year engineering courses have been found to have impacts on students' major selection, not all first-year engineering courses are the same. Reid and Reeping [4] developed a classification scheme to categorize the different types of first-year engineering courses based on course content. The scheme has eight unique categories for classification including Academic Advising, Math Skills, Design, and the Engineering Profession. It is difficult to categorize courses over time because, as the authors note, these courses are often "designed by instructors to meet their preferred objectives" [4] which can lead to changes in course content as instructors change. However, courses that focus on the Engineering Profession and Academic Advising are likely more beneficial to students deciding on or confirming their engineering major selection.

Course Description

The course being studied here is an optional component of a first-year engineering program. During the study period, Fall 2016 - Fall 2019, inclusive, there were no significant changes to the course format. During each of the 50-minute course periods, the instructor invited an engineer from industry or a member of the university's engineering faculty to present on their work experiences. As an example, one speaker who graduated from the university with a degree in Industrial Engineering discussed her experiences working at many different companies including Amazon and Walmart. Another speaker, with degrees from the university in Mechanical Engineering, shared his experiences working for a local company testing power tools and discussed previous work he had completed in China. As a final example, an Electrical Engineering graduate shared her personal experience as a co-op and then continued development of leadership skills at General Electric. Most speakers also provided advice for the first-year students in their coursework and for when they enter the job market.

Methods

This study uses data from course surveys that asked first-year engineering students about their perceptions of engineering at large and of the engineering major they were most interested in pursuing. The data was collected at one public research university in the southeastern United States with a required first-year engineering program. The survey was distributed at the beginning and end of a one-credit, half-semester, pass / no pass major exploration course.

The survey asked students about knowing an engineer personally, their top choice of major, their confidence in that choice of major, and two free-response questions. The first free response question, which is the focus of this paper, asked students "What do engineers do for a living?" and the second asked students to "Describe what you believe engineers in your top-choice major do at work." The survey has asked both free-response questions since the Fall 2016 semester for approximately 400 students each fall term and 35 students each spring term. Over the seven semesters studied, 1697 students completed both beginning-of-course and end-of-course surveys. Using institutional records, 1761 students earned a final grade in the course during the same time period, which means that over 96% of students who completed the course also completed both surveys.

Coding of the data followed the process outlined by Saldaña [5]. For the survey item, students' beginning-of-course responses were coded first using holistic coding so that the codes most closely matched the students' original words. Exactly 200 codes were developed during this coding pass. The codes from the first pass were then used to develop categories with a single definition. Each category contained multiple codes. Thirteen categories were identified. During the second coding pass, the categories developed from the first pass codes were applied to the data. Five of the 13 categories were divided into meaningful subcategories. After completing this cycle with the beginning-of-course data, the categories and subcategories used during the second coding pass were used as *a priori* codes with the end-of-course data. Emergent coding was also used with the end-of-course data so that any differences between the beginning- and end-of-course data were captured.

Overview of Categories

Students' responses to the item "What do engineers do for a living?" generated 13 unique categories. Some students mentioned ideas that belonged to multiple categories and were identified as such. The list of the six most mentioned categories, including their frequency in responses collected before and after the major exploration course and a definition, are provided in Table 1. These frequency counts are the numbers of unique students mentioning the category in their response. In the next section, as an example of our future work, the first of these categories, *Problem Solving*, and its subcategories will be discussed in more detail.

Table 1 – Most Mentioned Categories Used by First-Year Engineering Students to Describe What Engineers Do for a Living

Category	Freq. Before	Freq. After	Definition
Problem Solving	816	902	Engineers work to solve many different types of problems. Engineers solve problems by developing solutions.
Making Improvements	618	670	Engineers make changes and upgrades to existing products and / or processes. These upgrades often increase the efficiency of the process.
Creating and Designing	614	572	Engineers build novel products, processes, and / or technology.
Societal Impact and Quality of Life	546	668	Engineers make the world a better place and / or make life easier for people.
Applying Knowledge and Skills	286	308	Engineers use math and science. This may include specific examples such as calculus or chemistry.
Variety of Work	119	183	Engineers can work in various fields and have multiple options to choose for work. This may include that engineers work in a variety of physical locations. This may also include statements that engineers work on "large and small" problems.

Of these six categories, all but one has an increase in the number of students mentioning the category at the end of the course compared to the beginning. This indicates that, overall, students perceive engineers do more kinds of tasks for a living at the completion of the course compared to its start. The decrease in the *Creating and Designing* category could be the result of the course's speakers focusing less on ideas related to this category in their presentations and more on other categories, or students' exposure to new facets of engineering through the presentation that made this category seem less novel leading to fewer mentions.

Additional categories that first-year engineering students used to describe engineering as a field, but used by fewer students than the categories presented in Table 1 are:

- Creative and Critical Thinking
- Depends on Engineering Major
- Maintenance
- Planning and Testing
- Quality, Safety, and Cost
- Teamwork and Leadership
- Unsure

Example Category - Problem Solving

When asked what engineers do for a living, the most common idea among the survey responses of the sample of first-year engineering students both before and after completing a major exploration course was that engineers solve problems. Additionally, many students indicated what types of problems engineers solve. Some students also mentioned that engineers build solutions to solve problems. These additional details in student responses were used to develop seven subcategories for the main *Problem Solving* category. The frequency and definition for each *Problem Solving* subcategory is provided in Table 2.

Table 2 – Definitions of the Problem Solving Subcategories

Subcategory	Freq. Before	Freq. After	Definition
Generic Problems	444	605	Engineers solve problems; no descriptor of the types of problems included.
Real-World Problems	162	207	Engineers solve real-world or societal problems.
Everyday Problems	38	28	Engineers solve everyday or practical problems.
Complex Problems	37	35	Engineers solve difficult, challenging, or complex problems.
Technical Problems	17	20	Engineers solve technical, scientific, or physical problems.
Problems Others Cannot Solve	9	10	Engineers solve problems others cannot solve.
Build Solutions	185	166	Engineers build or design solutions to problems.

The first six subcategories, from *Generic Problems* to *Problems Others Cannot Solve*, offered indications of the types of problems that first-year engineering students believe engineers solve. Students' responses could be categorized as more than one subcategory. Responses that did not specify the types of problems engineers solve were categorized as *Generic Problems*; some of

these responses also mentioned offering a solution and would also be coded as *Build Solutions*. Additionally, some students explained how engineers solve problems, which are the subject of other main categories including *Applying Knowledge and Skills*, but did not elaborate about the type of problems being solved: “Engineers solve problems using math and science.”

For students who did elaborate on the types of problems engineers solve, the most popular descriptors were that engineers solve real-world problems or problems that exist in society: “Engineers solve problems that exist in all aspects of society.” Many students with responses categorized as *Real-World Problems* also mentioned that engineers’ work makes the world a better place. These details are captured in another main category, *Societal Impact and Quality of Life*.

Three other subcategories were developed to describe the types of problems that engineers solve. Some students responded that engineers solved challenging or *Complex Problems*; for example, engineers “[s]olve complex problems using their knowledge of how things work.” Other students described the problems as *Everyday Problems* or *Technical Problems*. Both categories include multiple similar ideas about the types of problems engineers solve for a living. Respectively, “[t]hey solve everyday problems and try to improve on ideas and products that could function better” and “I believe engineers solve scientific problems to make the world better.” Some students combined the descriptive subcategories in their responses. These combinations of multiple, different descriptions were not very common, but when combined, students would most likely comment that “[engineers] solve complex problems in real-world situations…” combining the subcategories of *Real-World Problems* and *Complex Problems*.

One final descriptor that students used is engineers “[s]olve problems that no one else can.” While it is possible to interpret these types of problems as challenging or complex problems because students mentioned that these problems could not be solved by people in other professions, a separate subcategory was created, *Problems Others Cannot Solve*. This idea that “…engineers go out into the world and solve issues that other people can’t” speaks to the fact that students believe engineers are able to make unique contributions to problem solving. To that end, many students mention that engineers are involved in *Teamwork and Leadership*, one of the other main categories.

The final subcategory students mentioned in their responses when discussing *Problem Solving* is that engineers *Build Solutions* to problems. When students wrote about building or designing solutions, many also described the types of problems being solved; for example, “[e]ngineers develop solutions to problems presented to them using their expertise and creativity.” Students also commented that engineers design and improve different products and processes for a living; these responses are categorized into the *Creating and Designing* and *Making Improvements* main categories, respectively.

Comparing the frequency of the categories between the survey responses at the beginning and end of the course, the two largest changes are increased frequencies in *Generic Problems* and *Real-World Problems*. Part of the increase in *Generic Problems* could be due to a decrease in specific descriptors being used; however, the other *Problem Solving* subcategories only decreased by a combined seven instances, which does not account for the observed increase.

Given that a large portion of the course is dedicated to presentations from program alumni working in industry, the increase in the frequency of the *Problem Solving* category is logical because students learn about the problems practicing engineers are solving in their careers. Additionally, because so many presenters are from outside of the academy, it would follow that students are more willing to describe the problems as *Real-World Problems*.

Conclusions

Collectively, students' perceptions of the work engineers do for a living is larger at the end of the major exploration course compared to the beginning. At the end of the course, the categories that had the largest increases in the number of mentions compared to the beginning of the course were *Problem Solving*, *Societal Impact and Quality of Life*, and *Variety of Work.*

During course presentations, students heard about the work engineers do, including the problems they face and solve in their roles. This is likely the cause of the increase in the *Problem Solving* category and the *Real-World Problems* subcategory. Additionally, students could make connections from the speakers' engineering expertise to their work, and ultimately to their work's *Societal Impact and Quality of Life* enhancements. Finally, because students were exposed to engineers from a variety of industries, it logically follows that the *Variety of Work* category would have more mentions because of the diversity of engineering backgrounds and industries represented by the invited speakers.

Future Work

Future work will include an analysis of the remaining categories and their relevant subcategories that have been developed using students' responses to the "What do engineers do for a living?" item. Additionally, data from a second survey item, "Describe what engineers in your top choice major do at work." will be coded and analyzed to understand similar changes in perceptions of individual majors during the course. Finally, students' academic data will be connected to determine if students who complete this course are more or less likely to switch their engineering majors after the first year compared to other students who did not complete the course.

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