Exploring the impact of first-time internships on mechanical engineering student perceptions of engineering

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Abstract

Student perceptions on what engineering, and more specifically, what mechanical engineering is and what mechanical engineers do are important because these perceptions may relate to constructs like self-efficacy, outcome expectations, and interest, thus impacting subsequent decisions to remain in engineering or pursue a future career in the field. Further, student perceptions on what mechanical engineering is and what mechanical engineers do likely change over time based on coursework and informal learning experiences such as internships. Engineering literacy—the ability to solve problems using engineering design processes and make informed decisions about crucial issues such as energy consumption and climate change—is also a vital component of engineering education. Much of the research on student perceptions of engineering focuses on K-12 students and teachers rather than current engineering undergraduates. However, limited work examines how student perceptions of engineering change during their first engineering internship. Engineering students enhance their understanding of their profession as they progress through their academic journey. Although much of the coursework focuses on applying math and science to solve technical problems, many students tend to associate engineering with this limited perspective, overlooking its wider social impacts. By fostering awareness of these wider impacts, we can enhance their educational experience and better prepare them for future roles in the field. Therefore, we believe that understanding what engineering is and what engineers do can help us to design innovative and impactful learning experiences. In this paper, we investigate two primary research questions: 1. What are mechanical engineering students' perceptions on engineering and mechanical engineering? and 2. How do these perceptions change after completing their first internship?

We interviewed 12 mechanical engineering students who were completing their first engineering internship. These students varied in levels of program completion from students who completed their first semester of their second year of studies in Spring 2024 to students who had completed their second semester of their third year of studies in Spring 2024. These students were interviewed both at the beginning of their internship and upon completion of their internship. We asked them to define engineer, engineering, mechanical engineer, and mechanical engineering before and after their internships. We use thematic analysis to explore first-time engineering interns' perceptions on what these terms mean, along with how these perceptions changed over the course of their first engineering internship. Our analysis suggests that there are certain aspects of engineering that students don't recognize before internships, such as criteria and constraints and the social and collaborative nature of engineering. There are other aspects that students did not address much before or after their internships, suggesting that there may be opportunities to expand student perceptions of engineering and mechanical engineering to better align with the reality of the engineering fields.

1.0 Background and motivation

Student perceptions on what engineering is, what engineers do, and what the different fields within engineering are matter because they may impact undergraduates' initial decisions to major in engineering, their desire to remain in engineering throughout their undergraduate career, and their decisions to pursue engineering as a career after graduation. Developing a better understanding of student perceptions of engineering, and more specifically, mechanical engineering can help educators highlight key aspects of engineering that students are not aware of and aspects that may be misunderstood, which may help broaden interest in the field of engineering.

Additionally, student perceptions on what engineering is likely change over time based on coursework and informal learning experiences such as internships [1], [2]. Much of the research on student perceptions of engineering focuses on K-12 students and teachers rather than current engineering undergraduates [3], [4], [5], [6]. However, limited work examines how student perceptions of engineering change during their first engineering internship. In this paper, we investigate two primary research questions: 1. What are mechanical engineering students' perceptions on engineering and mechanical engineering? and 2. How do these perceptions change after completing their first internship?

1.1 Engineering internships

Internships have been identified as a high-impact practice in higher education, meaning they have substantial impacts on student learning and development [7]. There are numerous benefits for students participating in internships, including gaining hands-on experience with industry engineering practices [8], receiving guidance and coaching from practicing engineers and professionals [9], and developing professional skills such as communication and collaboration [1], [9]. Internships have also been shown to impact student goals and future career plans [8], [10]. Internships also significantly impact the development of engineering identity [11]. It is therefore likely that internships influence student perceptions of engineering and subsequent career choices.

1.2 Nature of engineering

Teachers and K-12 students often hold misconceptions about the nature of engineering, its definition, and the role of engineers, and perceptions on the nature of engineering remains an underexplored area in research [12]. Various organizations, including the National Academy of Engineering [13] and the National Research Council [14], have emphasized the need to enhance the understanding of the engineering discipline among K-12 students and teachers.

The Nature of Engineering (NOE) explores several fundamental aspects of the engineering discipline [12]. It investigates what engineering is, how it functions, and the methodologies engineers employ. Furthermore, it explores the interplay between engineering and other academic fields, including science, as well as the impact of engineering on society and vice versa. Kaya et al. [15] outline nine nature of engineering aspects which guided our analysis. These nine aspects include demarcation, social and collaborative, engineering design process, criteria and constraints, failure-laden, empirical, creativity and imagination, multiple solutions, and social and cultural embeddedness. Additional details on these NOE aspects are discussed in our methods and findings sections.

2.0 Methods

We address two primary research questions with this work. First, what are mechanical engineering students' perceptions on engineering and mechanical engineering? And second, how do these perceptions change after completing their first internship? To answer these questions, we conducted qualitative, semi-structured interviews with mechanical engineering students who were participating in their first internships over the summer of 2024. They were first interviewed at the beginning of their internships, and they were interviewed again upon completion of their internships. This research was approved by the university's Institutional Review Board.

2.1 Participants and research context

Participants were all full-time mechanical engineering students at a large, public, research-intensive university in the southern United States. Participants were recruited by emailing all mechanical engineering students, and all students who were interested in participating were accepted into the study. To participate, students must have been starting their *first* engineering internship during the summer of 2024. There were 12 students who completed both the pre- and post-interviews. Table 1 shows a basic summary of participant characteristics. The average age of participants was 21.3 years. 83% (n=10) were male and 17% (n=2) were female. 17% (n=2) of participants were Black, 8% (n=1) were Latinx, 25% (n=3) were two or more races, and 50% (n=6) were white. Students varied from having completed their third semester of college in Spring of 2024 to having completed their 6th semester of college in Spring of 2024.

Table 1 Summary of participant characteristics, including age, sex, race, and semesters completed in program

Characteristic	Response	Count
Age	Years, mean	21.3
Sex	Male Female Other/Prefer not to say	10 2 0
Race	Asian Black Latinx Middle Eastern/North-African Prefer not to say Two or more races White	0 2 1 0 0 3 6
Semesters of undergrad completed in Spring 2024	3 (Year 2, semester 1) 4 (Year 2, semester 2) 5 (Year 3, semester 1) 6 (Year 3, semester 2)	1 5 1 5

Participants worked in a variety of industries that align well with the industries mechanical engineering graduates from this program often work in. These industries include transportation and logistics, construction, aerospace, HVAC, and food industries. Table 2 provides an overview of our participants including their selected pseudonym, the industry that they interned in, and the number of semesters they had completed at the end of the Spring 2024 semester.

2.2 Interview protocol

Participants completed semi-structured interviews via Zoom at the beginning and at the end of their internship. These interviews ranged in length from 28 minutes to 116 minutes, with an average interview length of 50 minutes. The post-interviews were slightly longer on average (56 minutes) than the pre-interviews (44 minutes). These interviews were recorded with participant permission and were later transcribed for analysis. The interview questions relevant to the research questions in this paper included "What is engineering?", "What is an engineer?", "What is mechanical engineering?", and "What is a mechanical engineer?" These questions were adapted from Lakin et al. [16] and Dietz [17].

Table 2 Participant pseudonyms, internship industry, and semesters completed in program

Pseudonym	Industry of internship	Semesters of undergrad completed in Spring 2024
Dalton	Transportation and logistics	4
Charles Edward Cheese	Consulting/design	6
David Ortiz	Industrial automation	4
Don Beshie	Aerospace	4
Jeff Bevis	Food processing	6
John Doe	Aerospace	4
Kiara	HVAC	4
Michael Burns	Construction	3
Rose	Construction management	6
Sydney	Food	6
Tom	Construction materials	6
Wally Higgens	Construction	5

2.3 Analysis

We analyzed interview transcripts using thematic analysis [18]. We used a combination of deductive and inductive coding [19]. Our deductive codes were based on the 9 aspects of the nature of engineering as identified by Kaya et al. [15] and included demarcation, social and collaborative, engineering design process, criteria and constraints, failure-laden, empirical, creativity and imagination, multiple solutions, and social and cultural embeddedness. Additional inductive codes were generated from the data based on participant responses and our research questions. Two independent coders analyzed the data and met regularly to discuss any disagreements.

3.0 Findings

We have split our findings into several sections. First, we discuss participant perceptions of engineering, broadly construed, before and after their internships. Next, we discuss participant perceptions of mechanical engineering before and after their internships. In each section, we discuss changes we see in participant perceptions after their internship. Themes are discussed in order of most common to least common among participants.

3.1 Beginning perceptions of engineering

In our interviews, participants were asked to share their definitions of what engineering is and what engineers are. Most of these responses fell into one of the nature of engineering aspects discussed earlier.

3.1.1 Demarcation and problem-solving

At the beginning of their internships, the most prevalent perceptions of engineering had to do with demarcation, which considers that "engineering is systematically engaging in the practice of design to achieve solutions for specific problems" [15, p. 638]. Nine of our twelve participants discussed demarcation, most often in the context of problem solving. Charles Edward Cheese, for example, outlined how "to me, that's what engineering is, the ability to problem solve, and to innovate to solve the world's problems." Rose discussed that "engineering is thinking outside of the box to design and create solutions to real world problems." Jeff Bevis provided the most detailed description:

> Either identifying a problem or fixing a problem...at the end of the day, I think it's problem solving, but the way the engineer goes about it is a little different, a systematic or repeatable process. With a product that is a hundred percent good, you have to do everything the same way. I apply this to my life daily even if it's not engineering, like bowling. I bowl the exact same way: right foot on the exact middle square or middle circle, second one back, four steps, throw. It's trying to mimic something perfectly every time so that you get the same result.

3.1.2 Creativity, imagination, and innovation

The themes of creativity, imagination, and innovation were frequently discussed at the beginning of student internships as well, with seven participants mentioning something related to creativity, imagination, or innovation. Kaya et al. [15] outline "creativity and imagination" as a nature of engineering aspect, and we expanded this to include innovation. David Ortiz, for example, defined engineering as "designing, creating, and innovating." Michael Burns discussed both the creativity and imagination aspects:

> What engineering is to me is creativity, being imaginative, and applying that with the physics and math and science...being able to look at something that the world doesn't have...and finding a way to create it and make it happen. Engineering is being able to bring fantasy to reality...a lot of people didn't really think, like, back in the old times, like, oh we are gonna get to fly like birds.

3.1.3 Empirical

A third nature of engineering aspect that participants spoke to was the idea that engineering is empirical, or that "engineers optimize their design solutions and compare alternative solutions based on evidence obtained from test data" [15, p. 638]. This theme was present with four of our participants. While several participants discussed optimization and testing, no one spoke to the comparing alternative solutions aspect. Don Beshie talked about how in engineering, you "think of something, see if it works, get some more information, and test it to see if it will actually work." Sydney focused on "applying math and physics in a way that optimizes processes, makes objects stronger with the least amount of material...like optimization, I think, is what it's all about."

3.1.4 Social and cultural embeddedness

The fourth and final nature of engineering aspect that participants addressed was social and cultural embeddedness, or the idea that "sociocultural factors influence engineering, and in turn, engineering influences society" [15, p. 638]. We used this theme to capture the societal and human-focused aspects in participants' responses. This theme came up in three of our pre-interviews. Dalton discussed how engineering is "using mathematics and sciences to create things that can either better civilization or work towards a common goal." Wally Higgens talked about how "an engineer is also somebody who can interface with the human element, you know, when it comes to problem-solving."

3.1.5 Themes that were not discussed

A number of the nature of engineering aspects were not mentioned at all during our initial interviews. No participants discussed the notions of criteria and constraints, engineering design process, the failure-laden nature of engineering, engineering as a social and collaborative process, or the idea that there are multiple solutions to all engineering design problems.

3.2 Concluding perceptions of engineering

Upon completion of their internships, many students purported that their definitions of engineering didn't change much. While we saw several common themes as outlined below, we did also see a wider range of themes than in their earlier definitions. This suggests that their internships may have broadened their definitions of engineering and helped participants to recognize additional key aspects of engineering. Additionally, their concluding responses fit less clearly into the nature of engineering aspects than their beginning responses, suggesting that participants may have developed a more nuanced definition of engineering. Table 3 summarizes the themes that each participant discussed during their pre- and post-interviews.

3.2.1 Demarcation and problem-solving

Demarcation and problem-solving remained a prominent theme during our post-internship interviews, with nine students again mentioning things that fell in this category. John Doe defined engineering as "using science, technology, engineering, and math to solve problems." Rose defined engineering as "a discipline where you create solutions to problems, whether that's through medicine, or buildings; it's a wide variety of things, it covers a lot of different fields. Student perceptions as related to demarcation and problem-solving remained largely the same after their internships.

3.2.2 Creativity, imagination, and innovativeness

Two participants mentioned creativity, imagination, and innovation in their concluding interviews, which was a surprising drop from our initial interviews. John Doe discussed that engineers “should be able to get creative.” Michael Burns talked about inventing and the idea that an engineer is “someone that’s able to innovate.” This was an interesting and unexpected shift that may be worth additional research as to whether internships lead students to perceive engineering to be a less creative, imaginative, and innovative discipline.

3.2.3 Social and cultural embeddedness

Social and cultural embeddedness came up in two interviews, as opposed to three during the pre-interviews. Kiara discussed an engineer as “somebody who solves problems for the future in order to help people, the study of solutions to help humanity.” Wally Higgens hit on the human aspect as well, discussing that “engineering is basically the bridging of technical skills and know-how with the needs and desires of people to address complex problems and produce effective and competitive solutions.” The perceptions within this theme remained similar, though it seems like the lack of deeper discussion and prevalence of this topic is a potential area for improvement in our curriculum and in internships.

3.2.4 Other themes

Each of the other themes came up in just a single interview. John Doe spoke to the social and collaborative nature of engineering in talking about an “engineer is someone who can work in a team but also work by themselves.” Michael Burns was the only participant to address the notion of multiple solutions by mentioning that “the engineer can find different ways to solve that.” Dalton alluded to the engineering design process: “you follow it in every step as it goes through the process, whether that be design and even going as far as building it and being there while it’s being built and making revisions at that point.” Jeff Bevis hit on the empirical aspect in outlining engineering as “recognizing a process and trying to find efficient, more efficient, or better, efficient ways to do it.” Sydney spoke to the financial aspect of criteria and constraints by discussing engineering as “finding ways to make things work with as little money as possible.” The only nature of engineering aspect that was not addressed by a participant during their concluding interviews was the idea of engineering as failure-laden.

3.3 Beginning perceptions of mechanical engineering

Student perceptions of mechanical engineering more specifically were not as clearly aligned with the nature of engineering aspects. We included these NOE codes where applicable and added additional inductive codes as needed. Overall, we saw fewer themes of demarcation and problem-solving than in student perceptions of engineering more broadly. There was also a big focus on the physical nature of mechanical engineering and the focus on machinery of moving parts.

3.3.1 Demarcation and problem solving

Similar to student perceptions on engineering more broadly, many students (n=7) addressed the notion of demarcation and problem solving in their early definitions of mechanical engineering.

Don Beshie discussed how “a mechanical engineer essentially is someone who uses a whole bunch of different courses like physics, math to solve a problem. Usually the problem is something to do more on the physical side.” John Doe included some more specifics in his definition of “the study and use physics, mechanics, and robots to solve problems.” The concepts in these two quotes represent common suggestions from the participants who discussed demarcation and problem-solving.

Table 3 Summary of themes in participant responses during pre- and post-interviews

Pseudonym	Pre: What is engineering?	Post: What is engineering?	Pre: What is mechanical engineering?	Post: What is mechanical engineering
Dalton	Demarcation Social and cultural embeddedness	Engineering design process	Machinery/moving parts/physical systems	Engineering design process Machinery/moving parts/physical systems
Charles Edward Cheese	Demarcation Creativity, imagination, and innovation	Demarcation	Demarcation Hands-on Machinery/moving parts/physical systems	Machinery/moving parts/physical systems Broad
David Ortiz	Creativity, imagination, and innovation	Redesign/making changes	Demarcation Creativity, imagination, and innovation Social and collaborative Empirical	Creativity, imagination, and innovation Machinery/moving parts/physical systems Broad
Don Beshie	Demarcation Creativity, imagination, and innovation Empirical	Demarcation	Demarcation Machinery/moving parts/physical systems Broad	Demarcation Creativity, imagination, and innovation Machinery/moving parts/physical systems
Jeff Bevis	Demarcation Empirical	Engineering design process Empirical	Engineering design process	Engineering design process Social and collaborative
John Doe	Demarcation	Demarcation Social and collaborative	Demarcation	Broad Demarcation
Kiara	Creativity, imagination, and innovation Social and cultural embeddedness	Demarcation Social and cultural embeddedness	Demarcation Machinery/moving parts/physical systems	Broad
Michael Burns	Demarcation Creativity, imagination, and innovation	Demarcation Creativity, imagination, and innovation Multiple solutions	Broad Demarcation Machinery/moving parts/physical systems	Broad Demarcation Machinery/moving parts/physical systems
Rose	Demarcation Creativity, imagination, and innovation	Demarcation	Engineering design process Machinery/moving parts/physical systems	Demarcation Machinery/moving parts/physical systems
Sydney	Demarcation Empirical	Demarcation Criteria and constraints	Empirical	Machinery/moving parts/physical systems
Tom	Demarcation Empirical	Demarcation Creativity, imagination, and innovation	Engineering design process Machinery/moving parts/physical systems	Demarcation Machinery/moving parts/physical systems Criteria and constraints
Wally Higgens	Demarcation Social and cultural embeddedness	Demarcation Social and cultural embeddedness	Demarcation Broad	Demarcation Broad

3.3.2 Machinery/moving parts/physical systems

A new theme that emerged in the mechanical engineering questions had to do with machinery, moving parts, and physical systems. Six participants mentioned this in their descriptions of mechanical engineering. Tom, for example, shared that "mechanical engineering would, in my mind, encompass a physical solution and a design for a problem that you can build in real life...like designing mechanical things whether that be with gears or pulleys or anything with moving parts, I guess." Some participants, like Dalton, juxtaposed the physical aspect of mechanical engineering with other types of engineering: "Mechanical engineering is the design of machinery and the actual moving parts of machines as opposed to things like a software engineer that would work more with the coding and things like that." Other participants provided specific examples of physical things that mechanical engineers work on, like Rose: "Typically [a mechanical engineer is] someone who helps design machines, whether that's like cars or manufacturing plants or even just heavy duty, like bulldozer type machines, something that can do work for you."

3.3.3 Broad

Another new theme that arose in our discussions around mechanical engineering was how broad of a discipline it is. Three participants addressed this in our early interviews. Michael Burns simply shared that "mechanical engineering is more of a broad focus." Don Beshie shared that "usually a mechanical engineer can be, seen on a whole bunch of different projects. They can do anything from using thermo to make, like, a refrigerator, or using statics and dynamics to make something move or see how something will react." Finally, Wally Higgens discussed how mechanical engineers "seem to be a more generalized engineer than most other types of engineers like a chemical engineer...They're the generalist that can bridge the gap between various fields of engineering**."**

3.3.4 Empirical

Two participants discussed the empirical nature of mechanical engineering in their first interviews. David Ortiz mentioned that mechanical engineering is "physically speaking, can you make this wheel turn this much, and how is that going to impact the stress and tension on the part and so on." Sydney discussed optimization more broadly in his definition of mechanical engineering: "It's like related to everything optimization related to physical objects. A mechanical engineer is a person who uses science to optimize the design of things in the world."

3.3.5 Other themes

Three other themes came up with one participant. David Ortiz mentioned both the creativity, imagination, and innovation theme during his interview. He described "mechanical engineering is, like, to me, the creation, the innovation and all that of the physical machines and technology. The hardware component, I guess, of any product that goes out. He also spoke to the social and collaborative theme by talking about "talking to other people, like in the cross functional setting" and how the mechanical engineer is "the person who thinks about like the realistic ability, can we make this and can it work." Another theme that emerged from these interviews was the concept of mechanical engineering including hands-on aspects or actually building things.

Charles Edward Cheese shared that “mechanical engineering applies more to the physics aspect of things and the actual implementation of, like, the parts and the, you know, hands-on aspect of it.”

3.4 Concluding perceptions of mechanical engineering

3.4.1 Machinery/moving parts/physical systems

In concluding interviews with participants, nine of them discussed the theme of machinery, moving parts, and physical systems. The overall concepts discussed were similar to the pre-interviews, but several additional participants did bring up this aspect. Sydney talked about how mechanical engineering “is a field that’s focused on physical objects, so like structures and a lot of times heat, and like, they deal with mass, like physical matter.” Some students addressed some specific mechanical engineering topics or courses, like Rose did: “Mechanical engineering is the discipline of engineering that works with machines and mechanical systems. So a lot of, like, static and dynamic analysis on moving parts or just still parts in the statics case, and then also big on, like, the heat transfer once those parts are moving, and the fluid mechanics of it as well.”

3.4.2 Demarcation

Six participants brought up demarcation and the idea of problem-solving in their post-internship interviews, often tying the problem solving in with the physical nature of mechanical engineering or the application of physics. Wally Higgens shared that a mechanical engineer is “an engineer who is more focused on the mechanical side of things, like a physical understanding of kind of the fundamental laws of how things work for their problems solving.” Rose shared that “a mechanical engineer is someone who designs mechanical systems to solve problems or make work easier for others. Just come up with solutions for everyday problems that make sense.” Some participants, like Michael Burns, connected mechanical engineering to engineering and problem-solving more broadly: “Like the core heart of engineering in general is to solve a certain problem and it [mechanical engineering] is just a specific engineering field. It’s applying math and science to solve engineering problems using like hardware.”

3.4.3 Broad

Six participants also brought up the breadth of mechanical engineering as a discipline in their interviews; this was double the number of participants who discussed it in their earlier interviews. Charles Edward Cheese shared how “It's a wide variety of things. Just because we studied all of the basics, and pretty much can apply our skillset to any industry, since everybody is using something that obeys the laws of physics, or some sort of machinery Or just some sort of, you know, physical contraption…that, you know, have to obey different laws of physics, and you know fluid properties.” Other participants explicitly mentioned how broad the discipline is, like David Ortiz and Kiara who both mentioned the term “broad” specifically in their responses. This suggests that internships helped students to recognize how broad mechanical engineering truly is.

3.4.4 Creativity, imagination, and innovation

Two participants discussed the creativity, imagination, and innovation aspects in their concluding interviews on mechanical engineering. Don Beshie defined a mechanical engineer as “an engineer, someone who thinks of a solution in a creative way to a problem.” David Ortiz defined mechanical engineering as “creating, innovating, like in the physical world. Innovating, creating cars, machines, planes, and structures small or big. A mechanical engineer is someone who creates, designs, innovates, and works on concepts that are used in the mechanical engineering field.”

3.4.5 Engineering design process

Two participants addressed the engineering design process theme in their concluding interviews. Jeff Bevis hit on the process aspect: “The parts in a process that you really focus in on, like, there are a lot of things that make a car drive, but you focus on like a specific thing.” Finally, Dalton addressed the design work and design process in action: “Mechanical, for me, especially over the summer, was just a lot of design work and a lot of, you know, just putting things into practice, putting theories into practice. You follow the product through the process.”

3.4.6 Other themes

Two additional themes were raised by a single participant each. Jeff Bevis spoke to the social and collaborative aspect of mechanical engineering by discussing that “a lot of mechanical engineers will come together to build like a giant thing, or like, a big product.” Tom addressed the aspect of criteria and constraints in a fairly detailed response:

> Especially the other mechanical engineer, who's more of a process engineer. It pulls me a little bit away from the whole mechanical design aspect of it, because I mean if he's working on a project he has to still do cost analysis. And you know savings analysis. And there's other things involved with solving that problem that you need to do. I mean, how much are you gonna spend on that project and all of that? So I think mechanical engineering, I mean, you're still designing the solution. But I mean, you're also having to maintain your constraints

4.0 Discussion, implications, and conclusions

Interestingly, there were several NOE aspects that were rarely brought up during any of our interviews with participants. The ones that were addressed least frequently were the notions of engineering as failure-laden, the idea of multiple solutions, and criteria and constraints. This may have to do with the fact that in early engineering courses, much of the work is less design-based and focuses more on right and wrong answers that don’t require the same failure, iteration, and trade-offs that would lead to an understanding of these concepts. Some of the social aspects were also not discussed as frequently, with fairly limited discussion of the social and collaborative nature of engineering, and the idea of the social and cultural embeddedness in engineering. It could be worth exploring whether a better understanding of these concepts of engineering could improve recruitment of students into engineering and retention within the discipline, as students with interests in those areas may not realize that those are core aspects of engineering.

There were also limited NOE aspects addressed in participants' discussions of mechanical engineering. The same aspects were overlooked, with most participants focusing on the demarcation and problem-solving aspects and inductive themes like the breadth of mechanical engineering and the idea that mechanical engineers work with moving parts and physical systems

This suggests that engineering students may benefit from discussions and examples of engineering and mechanical engineering that hit on some of these less commonly discussed NOE aspects. This could be especially important in first-year engineering programs for undergraduates and in P-12 outreach to expand what individuals think of when they think of engineering and different disciplines within engineering. Future work could compare student perceptions across disciplines at the same school or within mechanical engineering at other schools to see whether certain focus areas of each department may impact student perceptions of their discipline and engineering more broadly.

Finally, we saw fewer differences before and after student's internships than we would have expected. There were some trends, with certain themes, such as criteria and constraints and the social and collaborative aspects, emerging more in participant's post-internship interviews. One of the most interesting differences we encountered was that students discussed the creativity, imagination, and innovation aspects of engineering *less* after their internships than before. This could be an interesting direction for future work.

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