Board 294: First-Year Engineering Students' Desired Practices in Mechanical Engineering

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Abstract

Student perceptions of the nature of the work that engineers do can influence their decisions to pursue engineering as well as what discipline within engineering they choose. In this study, we conducted semi-structured interviews with three first-year mechanical engineering students to explore their perspectives about the engineering practices (e.g., problem-solving, teamwork, being creative) they identified as motivating their interest in the field of mechanical engineering. The findings revealed that the students felt motivated to pursue mechanical engineering to engage in practices including building tangible artifacts, design work, impacting society, fundamental technical knowledge, creativity, real-life application, problem-solving, and teamwork. The findings demonstrate diverse practices that drew different students to pursue engineering as a major and a career. This work can contribute to our understanding of how engineering courses can recognize and provide development opportunities for a wide variety of engineering practices, ultimately supporting students in achieving their goals as engineers.

Introduction & Motivation

Engineering practice leverages a variety of technical and social knowledge and skills. However, engineering coursework tends to emphasize technical knowledge and skills required to practice engineering work, and students encounter limited opportunities to engage in social aspects of engineering in undergraduate programs [1], [2]. Research has shown that the perception of engineering as a "technical-only" field can alienate students who hold beliefs in communal goals, which rely on social knowledge and skills, even if they achieve excellent academic performance in their engineering coursework [3], [4]. Such research findings point to the need for developing greater understanding of the types of skills and practices that could potentially draw students to particular disciplines within engineering.

Thus, our research focused on understanding aspects of engineering practice that first year mechanical engineering students described as important to their reasons for pursuing mechanical engineering. The data discussed in this study included in-depth interviews with three first-year students interested in pursuing mechanical engineering at a research-intensive university in North America. This data represents a subset of data from a larger multi-methods study investigating how perceptions of the nature of engineering work as communicated in engineering courses impacts participation in engineering. Through these semi-structured interviews, we focused on students' motivations for pursuing engineering, their first-year course experiences, and their own interests and goals in engineering. Understanding the range of engineering practices that first-year ME students find most motivating and interesting can provide insight into how engineering programs may better attract and retain students.

Background

Engineering is both a technical and social discipline. Barley et al. [5] described that engineers working in a perceived objective world solve problems using a reductionist approach in a deterministic system. However, the world, and engineering itself, is not objective, and problems have cultural and social elements that must be attended to during problem solving [6]. One social aspect of engineering problem solving is engaging with stakeholders to understand project parameters, user and community needs, and implications of different solution choices on people's experiences [7], [8]. Teamwork and collaboration are also a central practice in engineering that relies on social skills and knowledge [9]. There is growing recognition of the importance of engineers to account for the broader impact their work may have on social well-being, the global economy, and the environment and the need for engineers to weigh complex ethical considerations in their work [10]. In the early 2000s, the Committee of Engineering Education in the National Academy of Engineering developed a vision to understand engineering education and engineering practice in a broader context to serve the interests of the society [6]. The experts in the committee made specific recommendations to incorporate more comprehensive engineering practices, that include both technical and social skills and knowledge, into engineering undergraduate programs.

Despite such calls, the engineering curriculum continues to be dominated by technical or object-oriented foci (e.g., math, principles of natural sciences). As a result, social aspects of engineering practices are rarely discussed in traditional engineering courses. Research suggests that engineering undergraduate students' interests in public welfare actually declined over their years of study in engineering programs [1]. This finding suggests a narrowly focused technical culture of engineering shapes students' perception of professional work in engineering to place less emphasis on the public impact of their work. Correspondingly, students with strong motivation for communal goals were alienated from engineering learning and potentially lost their interest in future engineering careers [4], [11].

Research suggests students are interested in engaging in engineering work for a variety of reasons, including both technical competency and social impact of engineering work [2]. Similarly in Main et al's study [12], engineering students choose majors based on technical aspects, such as math and science subject interest, as well as such social aspects, such as a desire to make a positive social impact and contribution to technological innovation. Socially engaged engineering work that includes a consideration of people and the broader social context appeals to a more diverse group of engineers [2], [12]. In order to advance diversity and inclusion in engineering, it is crucial to consider the risk of alienating students most motivated by the broader social aspects of engineering practice in light of research that suggests these aspects may be disproportionately prioritized by women and minoritized students already underrepresented in engineering [13]–[17].

Integrating broader social and technical aspects into engineering courses can be both appealing for students and effective preparation for their future work. In a study of a senior engineering capstone course, Banios [18] found an increase of the amount of broader engineering practices (e.g., need analysis, ethics, risk assessment and analysis, iteration, management, and etc.) in the capstone course resulted in positive exit comments from students. A follow-up study also proved that the engineering capstone course predicted students' success working as early engineer professionals, including broader social and technical practices impact students' pursuit of

engineering because the practices enrich students' learning experience, and potentially encourage students' interest in engineering [19].

Methods

Goal: This study focused on first-year engineering students' perceptions of the engineering practices they perceived as important in their choice to study mechanical engineering. The research question that guided our work was:

> What types of engineering practices do first year students describe as motivating their interests in the field of mechanical engineering?

Participants: The study presented here included data from interviews of three first-year students who were interested in pursuing mechanical engineering at a research-intensive university in North America. The participants are a subset of a sample from our team's ongoing multi-methods study, which focuses on the curricular messaging about the nature of engineering work in core courses in two disciplines and how these curricular messages align with students' own engineering interests and career ambitions. The three interviews were chosen from the larger data set to reflect a diversity of practices emphasized.

The participants included in the present study varied in their interests, pre-college experiences, and self described social identities. Participant 1 identified as a South Asian woman; Participant 2 self-identified as a White/Caucasian woman; and Participant 3 identified as a White man. We elected to focus on first year students in this analysis because they are at an early stage of their engineering educational journey, perhaps cognizant of why they want to be engineers without much impact yet by undergraduate engineering courses, and are forming their understandings of what engineering work in their field entails.

Data Sample: The semi-structured interviews conducted to these three participants ranged from 30 to 90 minutes. Interviews focused on participants' perceptions and personal experience [20], [21] in their engineering courses. Sample questions from the interview protocol included:

- What prompted you to study ME at this university?
- Is the work you are doing in your engineering courses what you hoped you would be doing?
- How much has this course material <in ME/engineering> aligned with what you are personally most interested in about engineering work?
- Do you feel that your instructors and peers in your program value and care about what you value and care about?
- When do you most feel like an engineer? That is, what sort of work are you engaging in or learning about when you most feel you're doing engineering?
- Looking forward to after you complete your education, what kind of job would you ultimately most like to have?

Data analysis: The interviews were analyzed to draw out common themes of engineering practices that students identified as important in their choice to study mechanical engineering as

a major. We used an inductive analysis process [22] that included: 1) one researcher identified information related to students' desired engineering practices by tagging all relevant quotes from the three students' interview transcripts that related to the aspects of engineering practices that motivated their interest in mechanical engineering. 2) Each of the relevant quotes were grouped and named according to the engineering practice emphasized. The names of the practices were informed by literature [23], [24] and conversations with engineering professors about practices. The practices identified by the researcher were then compared to the practices identified by another researcher on our team for the same transcript to check for consistency. 3) we compared the practices emphasized across the student cases. We also developed short summaries for each of the three participants focused on their emphasized practices, including excerpts from their transcripts for evidence.

Findings

Table 1 shows three students' desired engineering practices obtained via interview. The findings revealed that a wide range of engineering practices were identified as reasons for why participants pursue ME. All three participants were excited about solving problems and building tangible artifacts in the engineering design projects. With a strong interest in design, Participant 2 and Participant 3 named real-life application and design as motivators for pursuing an engineering career. These two participants also reported their interests in the fundamental technical knowledge of the field, such as physics, as main driving factors for their choice to pursue ME. Furthermore, the other motivating reasons for pursuing the field by the two were their desire to have a positive impact on society. More specifically, Participant 1 named an interest in creativity and a desire to integrate her artistic and creative skills into her work as a motivation for pursuing ME. In addition, Participant 1 and Participant 2 mentioned an interest in teamwork as a core aspect of engineering practice shaping their major choice.

Table 1. Summary table of the three participants' desired engineering practices

Desired Engineering Practices	Participant 1	Participant 2	Participant 3
Real-life application		x	x
Fundamental technical knowledge		x	x
Design		x	x
Building tangible artifacts	x	x	x
Problem solving	x	x	x
Impacting society		x	x
Teamwork	x	x	
Creativity	x		

Participant 1

Participant 1 was a first-year ME student from South Asia. She described four engineering practices as important to her in choosing to pursue a mechanical engineering degree: teamwork, creativity, building tangible artifacts, and problem solving.

Participant 1 described teamwork as an important engineering practice that motivated her pursuit of engineering as a field of study. Her exposure to teamwork as a central engineering practice began in her high school robotics team. She said:

> *I was part of my high school's FRC robotics team, through the FIRST program, so I did that. I was on the electrical team and then I was president of [the] team at [the] end of my high school year, so that was a lot. That definitely was one of my main commitments during high school. And that was also probably what led me toward engineering and think[ing] about it as something that I wanted to pursue in college.*

Participant 1 also valued the collaborative team she had on the electrical team of the robotics project.

> *I was on the electrical team there, but I'm not thinking of doing electrical engineering… I guess I really liked that collaborative, challenging ... You're working with a group of people to get a solution that's never been solved before…*

She also discussed how engaging in teamwork in engineering during an engineering introduction course made her feel like she belonged as a mechanical engineer:

> *I think that teamwork aspect that we've been building has probably increased a sense of belonging, just because when you get to know people, you form a relationship with them. And so that's nicer than just sitting in a lecture and not knowing the names of the person who's sitting to the right of you or something like that, so just getting to know people and facilitating those relationships through a collaborative environment is something that's been positive.*

Participant 1 also considered the opportunity to practice creativity as one of the reasons she chose mechanical engineering. She described how her interest in art and a desire to engage in creative engineering work was evident in her high school robotics team experience. She said:

> *I was really drawn to the more creative aspects of mechanical engineering, in terms of you're drawing up designs, you're prototyping, you're testing. All of that resonated more with me than the work that I was doing on [the] electrical team was, so that's what shaped my decision to pursue mechanical engineering, specifically.*

Participant 1 also saw the creative aspects of mechanical engineering in her introduction to mechanical engineering course and she enjoyed the opportunity to engage in an open-ended design project:

> *Creativity is a big part of why I chose engineering and definitely, I do see [my introduction to engineering course] is the easiest one to talk about because we were given a prompt and we had to solve, create [the design], design an experiment to address that prompt. And it was very open-ended compared to some of the other things I've done in high school and other classes, because usually you're given a set of steps.*

Participant 1 emphasized that while creativity might not be a practice that others notice about engineering work, it was a practice important to her in choosing mechanical engineering:

> *I mentioned creativity and I think that is maybe not the first thing people think of when they think of engineering. And so for me, art is a really big part of my life. So when I was deciding what I wanted to pursue, I didn't want to leave that behind, but I knew I really did like science and math as well, so I think engineering was a good choice because it took that creative approach from art and let me apply it to a more technical field.*

She also described building tangible artifacts as a motivator to declare a ME major over Industrial and Operations Engineering, explaining:

> *I wanted that hands-on building stuff. So while I really loved that problem solving aspect of IOE, which was super interesting – the data analysis and how do we make this better – I really like that aspect, but I felt like I would miss out on all the hands-on stuff I'd be doing [in mechanical engineering].*

Finally, Participant 1 expressed a strong interest in the engineering practice of solving problems.

> *[My] interest is problem solving, analytical, logical side of things. I really do like to look at a problem, [and] be like, "Hey, why is this not working the best?" And then figuring out how to tackle that and how to make it better.*

Participant 2

Participant 2 was a first-year White student in ME. She described six important engineering practices that motivated her to pursue a mechanical engineering degree: real-life application, foundational technical knowledge, building tangible artifacts, design, problem solving, teamwork, and impacting society.

Participant 2 chose to study engineering because of her interest in aviation, which she saw connecting to engineering foundations in math and physics:

> *I would say I've been pretty interested in all of the [course materials]. Definitely though, the thing I was most excited about was some of the aerodynamic stuff we covered in [my introduction to engineering course]. Obviously, one of my big personal interests is aviation. I took a ground school [focus on theoretical knowledge needed to operate an aircraft] course. So I get excited about just planes and stuff. My instructor talked a lot about wind tunnel testing. So definitely getting to do that was probably the highlight of my semester. That was awesome. So that definitely aligned. I would say, obviously, I*

enjoy math and physics, so I would say those classes definitely were in my interests range for sure. I would say all of them aligned with my interests and values because I think they're all important for just the foundation of what I'm going to be learning the next couple years.

Sparked by her prior experiences exploring aviation in high school, Participant 2 expressed a particular interest in being able to develop the foundation needed for real-life engineering applications related to sustainability in aviation:

I think it was just based on my own personal interests. Obviously because I'm leaning towards mechanical or aerospace. I know they're relatively similar, but that just happens to be the area [aerospace and aviation] that I'm more interested in just based on the experiences [STEM summer camps, high school engineering courses] I've had because I hope to maybe one day, work on improving sustainability in aviation. I think that would be pretty cool.…one of my big interests is sustainability and renewable energy. So being able to do a class that focused on wind energy was pretty cool, I would say. And obviously my other pre-req courses are laying the foundation [coding and math] for me to be able to further explore my main interest was for pretty much just aviation, sustainability, just general space exploration.

Participant 2 enjoyed designing using CAD, building tangible artifacts, and solving problems in a group project in the first-year engineering introduction course. When asked "What about the work of the field of mechanical engineering first interested you?", Participant 2 answered:

Some of the summer camps I was at, there was a section about orthopedics, kind of the mechanical engineering behind that area. And helping people be able to walk better. That was one of the first exposures besides obviously planes and cars and other structures and stuff. And also just manufacturing kind of thing……This year in [my introduction of engineering course] actually was pretty cool. I was in the green energy section with wind turbines. So we got a ton of background information about aerodynamics and electrical circuits. So we could build a wind power generator…… They don't have a solidified power grid. So we were kind of addressing that problem. So that was pretty cool. So yeah, basically all these classes have taught me how to tackle different problems

When asked "what sort of work are you engaging in or learning about when you feel you're doing engineering", Participant 2 answered

…especially when I'm actively designing or building something. So definitely, the wind turbine project I did. It lasted a couple weeks, but that felt really cool because it was the biggest project I've worked on. So it's definitely then, but just, in general, just when I'm learning, I just feel like kind of an engineer all the time…I definitely enjoy doing work in CAD, just kind of seeing how a design fits together and works. But also just manufacturing, it is also important. So, yeah.

Finally, Participant 2 expressed that both she and her peers in ME were motivated and excited to have an impact on society with their engineering work.

> *I feel like, to me, just based on people I've talked to, everybody kind of has their little niche thing that they get really excited about. So that, for me, it's planes and aviation. Some of my friends are really into CS or it's robotics, but definitely, I think we all just kind of want to make the world a better place. Just learn as much as we can while we're here. I definitely think everyone seems pretty motivated and just like excited to be here. So it's pretty cool.*

Participant 3

Participant 3 was a first-year ME student who identified as White. He described seven engineering practices as important to him in choosing to pursue a mechanical engineering degree: real-life application, design, problem solving, impacting society, fundamental technical knowledge, and building tangible artifacts.

Participant 3 most felt like an engineer when he was doing a real-world design in an engineering project team at university. He also enjoyed the creativity aspect of design, and building tangible artifacts. This experience drove him to become a Mechanical Engineer in the future.

When asked "Have there been any experiences that were more important to shaping your thinking about your future career?", Participant 3 answered:

> *I would say that my work on the Solar Car Team has put me leaning a lot more towards the design aspect of engineering, you know, actually building something, creating something.*

When asked "what sort of work are you engaging in or learning about when you most feel you're doing engineering?", Participant 3 answered:

> *I would say actual, real-world designing. I haven't really done a lot of it, I would say, in my classes, but, for example, on the Solar Car Team, we are designing a solar car that has never been done before. We're doing something new this year…… I think that's when I feel like I'm doing the most engineering……[In the project] I'm doing design work as the steering engineer, so I've been learning a lot about cars and steering systems and brake systems and suspension systems. And I found those personally really interesting to design and think about the different ways that you can create new designs and potentially change the way that cars are driven or built or something like that……but taking and actually looking at those ideas themselves and iterating on them and creating new ideas and combinations of idea's a lot more interesting to me.*

Participant 3 described his choice to pursue a Mechanical Engineering major as related to his interest in problem solving and designing, stating:

> *I've always really liked problem solving. And I've always really liked making things and designing things and stuff like that. So, that kind of felt right to do engineering.*

He expressed enthusiasm at the opportunity to engage in problem solving using fundamental technical knowledge in his introduction to engineering course:

> *[What] I liked the most about [my introduction of engineering course is] the actual technical homework, you know, solving equations and stuff like that, giving you material science questions and figuring them out. And I like that just because I like problem solving and that's just really what I enjoy. And it's pretty close to mechanical engineering, which is something that I really enjoy.*

Participant 3 also connected his interest in physics, particularly mechanics, as related to his choice of major:

> *And then mechanical specifically, I like physics. Don't really like biology or chemistry that much. And specifically, within physics, I'm more interested in the mechanics part rather than the electrical, magnetism, that stuff. So, it kind of felt right to do mechanical.*

These interests, however, were also motivated by a desire to do work in which he could solve problems that have a positive social impact.

> *Ultimately, I think there's also a lot of people [in engineering] like me that just want to solve problems and better the world or the community or whatever it is around them or help stop climate change, something like that.*

Discussion

The broad range of engineering practices reported by students as motivating their decisions to pursue ME echo literature that speaks to the breadth of skills and knowledge needed in contemporary engineering work. For instance, students' emphasis on teamwork and the desire to apply their engineering knowledge to have a positive social impact aligns with recent calls for greater attention to the social dimensions and impact of engineering work [6], [9].

Engineering training often underemphasizes social, contextual aspects of engineering [1], yet students in the study demonstrated that these social aspects of engineering were important to their plans for being engineers. Moveover, the literature suggests that an underemphasis on more comprehensive skills, like social considerations, may alienate students from continuing to pursue engineering [4], [11]. In particular, women and minority students who are normally more engaged in social aspects and communal goals of engineering would be put into a more disadvantaged position in engineering learning [13]–[15]. Increasing diversity in engineering relies on the culture and climate of the field, but also is impacted by the practices that are prioritized. Eventually, students who are unable to determine their future goals from the existing engineering curriculum may decide not to persist in the field.

Our study suggests that students learned and valued both technical and social engineering practices in their personal and academic experiences; these engineering practices were motivating for students to pursue ME as their major and in their future engineering careers. Though the first-year students in this study expressed their desire in both social and technical elements in their engineering introduction course, the majority of second and third year engineering courses are more narrowly focused on foundational technical principles. Students who wish to continue to engage in broader social engineering practices may need to seek out co-curricular activities outside of the engineering classroom, if they are able. In the future, we plan to follow up with students as they progress through their second and later years of engineering study in order to understand their experiences of and satisfaction with the emphasized engineering practices in later years of their undergraduate study.

Conclusion

In this study, we explored the aspects of engineering practice three first year engineering students named as influencing their decision to pursue a mechanical engineering degree. Students reported a strong desire to engage in a wide range of engineering practices that reflected both technical and social dimensions. While students expressed an interest in the fundamental technical knowledge of the field and hands-on building, they also named broader engineering practices such as teamwork, design, creativity, problem solving, applying their skills to real world-problems, and having a positive social impact with their work. Students' early interest in this broad range of engineering practices highlights the need to ensure engineering curricula includes a broad range of engineering skills to ensure a diverse student body.

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