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WIP: Engineering Identity and Professional Skills Development in the Software Engineering Curriculum

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Abstract

Engineering education has long emphasized technical proficiency, as the development of professional skills and personal resilience has often been underrepresented in engineering curricula. This paper examines the role of engineering identity in shaping students' academic and professional journeys, with a case study currently being implemented in a third-year software engineering course at the University of Calgary. The authors explore current practices and theories surrounding engineering identity, including barriers posed by exclusionary stereotypes and the dynamic interplay between personal and engineering identity, positioning these topics in the context of the first author's personal experience. This paper also addresses the integration of professional skills, such as communication and teamwork, into a technical course to better prepare students for industry challenges. Proposed interventions include reflective assignments, mock meetings, and mental health workshops, aimed at fostering resilience and broadening engineering identity. By aligning technical and professional development, this work offers a roadmap for holistic curricular reform, ensuring students are both competent and confident as they transition into the workforce.

1. Introduction

What does it mean to be an engineer? The field of engineering education has long recognized the significance of developing both technical and professional skills to prepare students for complex workplace challenges. With the rapid rise of enrollment in software engineering, and the industrial shift towards digitalization and new technologies like artificial intelligence (AI) and Internet of Things (IoT), the software engineering curriculum at the University of Calgary has undergone major updates to keep up with current trends. One change has been to add a "project spine", to connect the first-year design course with the fourth-year capstone project. Two project-based courses were added, aimed at bridging the gap between technical expertise and professional development. However, since technical content has been the primary focus of these courses, critical interpersonal skills such as teamwork, communication, and resilience often remain underemphasized.

The need to address these gaps has been supported by industry stakeholders and accreditation bodies. Graduates entering the workforce consistently demonstrate strong technical knowledge but struggle with skills such as knowledge-sharing, negotiation, conflict resolution, and collaborative problem-solving. By exploring how engineering identity intersects with professional skills development, this paper provides a framework for more holistic engineering education practices. The future work for this project will be to evaluate what skills are missing and to gather feedback from the students on any additional changes that could be made to better support their professional development.

2. Literature Review

Engineering identity has been studied to understand why students choose to become engineers and why marginalized groups do not persist in the profession. Many different frameworks have been developed to better understand the various factors that impact engineering identity, both as an individual and as a group. This section reviews the relevant literature that discusses the definition of engineering identity, the barriers that minorities face in identifying as engineers, and the connection between engineering identity and professional development.

2.1 Engineering Identity

2.1.1 Definition and Importance

Engineering identity refers to the perception of oneself as an engineer and how others perceive one's role in the field. The development of a strong engineering identity is linked to persistence in STEM disciplines, higher academic performance, and confidence in professional settings [1]. Three key dimensions define this identity [2]-[3]:

- **Interest**: A sustained curiosity and engagement with engineering tasks
- **Performance/Competence beliefs**: Confidence in one's ability to perform engineering-related activities
- **Recognition**: Validation from peers, mentors, and industry professionals as an engineer

Identity can also be defined from different perspectives. The authors of [4] divided the engineering identity literature into three categories: personal identity, social (group) identity and societal identity. The authors of [3] and [5] described these categories as a Venn diagram, to highlight the overlap between someone's personal identity and how they view themselves as an engineer. The authors of [6] build on this concept by adding an additional Venn diagram to describe engineering identity within two different aspects: sense of belonging and grit (interest and effort in the program).

These categories are defined slightly differently by [7], where they were separated by academic identity (a combination of academic performance and occupational aspirations), how students view themselves as engineers and how they are recognized as engineers by other members of society. Each framework in [7] identified a combination of factors and characteristics that form an engineering identity. One relevant paper [8] divided engineering identity into two different components: a technical identity and a heterogeneous identity that focused on non-technical (soft) skills.

As described in [3]-[5], engineering identity can intersect with an individual's personal identity. Sometimes, the personal identity can conflict with their perspective of what an engineer is. The authors of [9] and [10] both examined the development of engineering identity – how it is influenced by self-belief and gendered conceptions, and how different situations can make certain aspects of someone's identity more prominent. The study in [10] discovered that a strong personal identity could help someone become more resilient in the workplace when faced with different barriers due to their marginalized status.

2.1.2 Evolution Across the Academic Journey

Engineering identity develops dynamically, influenced by educational experiences, peer interactions, and societal perceptions. Early stages of engineering identity formation in academia are marked by exposure to hands-on learning and problem-solving exercises, while advanced stages involve complex real-world applications. The study conducted in [11] revealed that students who engage in project-based learning and internships are more likely to solidify their engineering identity. The authors of [12] found different results when they incorporated non-traditional learning methods, like project-based learning, reflection assignments and e-portfolios to reinforce engineering identity and competence and expose the students to other identities, e.g., entrepreneur and leader. This study found that there was no noticeable change in engineering identity metrics compared to students in the traditional, except for the collaboration metric. The limitation of this study is that they only considered quantitative metrics to measure identity and did not conduct any qualitative studies. The authors of [14] found similar results when examining the intersection between engineering identity and leadership identity, as most students in leadership roles struggled to see the connection between these roles and their future engineering career.

Another study conducted in [13] evaluated the belongingness of first year engineering students when participating in design activities. The study found that the students who had design experience prior to entering post-secondary education felt that these prior experiences were more authentic and led to a higher feeling of belonging compared to the students who did not have these experiences. A similar study in [15] found that marginalized group participants were more open to design thinking and were better able to link the material to their personal experiences compared to their white male counterparts, which led to an increased sense of belonging in engineering.

2.1.3 Challenges and Stereotypes

The dominant stereotypes in engineering—often associated with masculinity, individualism, and technical mastery—pose significant barriers for underrepresented groups. Women and minorities report difficulty in reconciling their personal identities with these entrenched norms, leading to feelings of exclusion and lower retention rates [16].

To combat these issues, programs must incorporate narratives that celebrate diversity and foster inclusive learning environments [17]. The authors of [18] evaluated how student organizations can help create more inclusive environments for marginalized students outside the classroom. The interpretive phenomenological analysis conducted in [10] tried to find positive aspects in the workplace that contributed to higher retention. The study found that black women who persisted in engineering were able to do so because they were able to find spaces that celebrated their identity as a black woman engineer, instead of trying to hide it.

Another barrier to developing a positive engineering identity is the ableist nature of engineering. As stated in [19], "*...disability is a presumed divergence from the idealized embodiment of the "engineer" as a white, heterosexual, able-bodied, middle-class, US-born cisgender man".* The research conducted in [20] demonstrated that engineers with disabilities are more likely to be excluded by their peers and experience less professional respect. These engineers are less likely to persist in the profession because of the bias they face, which can increase when considering additional intersectional bias. Most of the literature referenced in this paper only considered the marginalized groups consisting of women, people of color and sometimes queer individuals, which further emphasizes the exclusion of disabled individuals.

2.1.4 Measuring Engineering Identity

Engineering identity can be measured in a variety of ways. The authors of [21] conducted a literature into the various quantitative and qualitative metrics that can be used to measure identity. These methods varied from surveys, interviews and focus groups, to collecting student course work and results from classroom activities. In their study, they used journey maps to help the students describe their engineering journey by mapping out key events that impacted their identity development.

Psychometric tools like the Utrecht-Management of Identity Commitments Scale (U-MICS) can also be used to assess the components of engineering identity. These tools provide insights into how students' perceptions evolve and help educators identify factors that support or hinder identity development [7].

After data is collected from the participants, there are several ways to evaluate the results. For quantitative studies, which typically use the Likert scale, analysis can be reduced to comparing numbers. However, as shown in [12], this may not give the full picture when it comes to analyzing engineering identity. Most studies conduct a qualitative analysis, which then requires a qualitative analysis method, like inductive coding and thematic analysis [22], to compile the results.

2.2 Professional Skills Development

2.2.1 Essential Skills for Industry

The integration of professional skills into engineering curricula addresses critical workplace demands. Industry feedback highlights the importance of:

- **Teamwork**: The ability to collaborate effectively in multidisciplinary teams
- **Communication**: Clarity in presenting technical ideas to diverse audiences, including clients and stakeholders

- **Resilience**: The capacity to adapt to challenges and recover from setbacks

2.2.2 Linking Identity to Skills Development

Professional skills are deeply intertwined with engineering identity. For instance, students who perceive themselves as competent engineers are more likely to take initiative in teamwork and communicate confidently [23]. Reflective practices, such as journaling and peer feedback, can reinforce this connection by encouraging students to evaluate their growth [12]. Multiple studies investigated the link between both project-based learning and design thinking, in building a stronger engineering identity [11]-[13], [15] and [24].

2.3 Broader Implications

There has been a focus, both nationally and internationally, to increase the number of members of marginalized groups to persist in engineering. Engineers Canada has created a goal of 30 by 30, to have 30% women registered in the profession by 2030, highlighting the number of women who drop out of the profession after finishing their education, referred to as the “leaky pipeline” [25]. It is important to support diverse voices in the profession, as research has shown that diverse teams are better for business and can help better meet societal needs [25].

Research also underscores the need for socio-technical approaches that connect technical expertise with an understanding of social and cultural contexts. For example, studies on algorithmic bias in AI reveal how exclusionary practices in data collection and system design perpetuate inequities [17]. Similarly, [26] investigates the impact of gender on the development of engineering identity and their commitment to the engineering profession. Engineering programs must address these systemic issues by embedding EDI (Equity, Diversity, and Inclusion) principles into the curriculum.

3. Positionality and Reflection

This section is a reflection from the first author, discussing their positionality in the context of the literature review.

You would expect that being an engineering faculty member would mean that you would have a strong engineering identity, but that isn’t always the case. My engineering identity has changed throughout the years, based on my academic experience and societal impact.

My first exposure to the engineering profession was through a close relative, who worked as an engineering technologist for a small consulting firm. My initial impression of their work was that they mainly worked individually, performing calculations and creating technical drawings. I initially did not want to be an engineer, based on my lack of interest in architectural drawings and external pressures to choose a more “feminine” profession, like teaching or nursing. A visit to the local university for their yearly Women in Engineering Day introduced me to different sides of engineering, which drew me to a career in electrical engineering. At the time, my ideal engineering career was going to be creating circuits, which aligned with my interest in arts and crafts. However, I still had the impression that engineering was a solo profession, so that I would not have to work with others. This perspective persists with current undergraduate students, who underestimate the professional (soft) skills required to be successful in the engineering profession [12], [14].

Even though most engineering courses in my undergraduate degree involved some form of teamwork (for lab assignments or term projects), the reason for this was never emphasized, so I continued my misconception that engineering work was primarily individual and solely focused on technical expertise, until I started my internship after my third year. When I started my position at an electric utility company, I was surprised by how much of the work that I did involved collaboration, project management and communicating with various contractors and vendors. I did not enjoy most of the work that I did, because it clashed with the type of person I thought I was and what I thought an engineer should be. The authors of [10] also discussed conflicting identities, as your personal identity clashes with how you view yourself as an engineer. Also, as someone who went through postsecondary with traditional pedagogical methods, this concurs with the research conducted in [12], comparing the increase in collaborative identity when comparing different pedagogical methods. Another aspect of working as an engineer that clashed with my personal identity is the level of ableism in industry, where employees are expected to work late, sending out emails at 2am, with no consideration for work-life balance. This exemplified the work done in [19] and [20], discussing that the picture of a stereotypical engineer has no room for disabilities.

This led me to explore other career options, including graduate school, medical school and even law school. I ended up choosing to pursue a graduate degree in engineering, to see if my view of engineering would change while working in a more research-focused role. While working as a graduate student researching topics related to renewable energy, I decided to join various university committees and work as a teaching assistant/sessional instructor to broaden my skillset to hopefully fill in some of the gaps that I found during my undergraduate internship. I originally did not see the benefit of leadership activities in my undergraduate degree, similar to the participants in [14]. These experiences changed my perception of myself, as I found that I enjoyed the teaching and service work that I did more than the technical work that I did for my research. This led me to pursue an academic career as a teaching-focused faculty member. In my teaching, I try to incorporate non-traditional engineering topics, like sustainability, ethics and accessibility, and professional skills, like communication and reflective practices, into the classroom, to introduce them to a different side of engineering and to connect what they are learning with the broader society.

Over my academic experience, my identity has evolved, from wanting to be an individual-focused technical expert, to becoming an academic leader focused on bringing professional skills development into the classroom. The future work for this project hopes to help students discover how their identity fits in with what an engineer is, and how their non-technical skills can help them be successful in their future careers.

4. Current Research Work

As mentioned in the introduction, it seems that students still maintain the perception that technical skills are most important when pursuing an industry-focused career. Based on personal experience, students tend to avoid presentation and communication activities, even those as simple as asking questions during class.

In the aforementioned third-year course, we will be collecting reflection assignments, to help us better understand students' perception of their engineering identity, comparing it to their version of an ideal engineer. We hope to use the comparison of their ideal engineer to the reality of the engineering profession to deconstruct any stereotypes that the students have gained, either through popular media or their own personal experiences. We also want to investigate the impact of the students' personal identity and how potential intersectionality has impacted their engineering identity development. The purpose of this study is to get the students to start thinking about how their skills, attributes, values, goals, etc. align with various career options, so that the students can build more resilience and confidence in themselves, and have a better understanding of what an engineer is to prepare them for their desired career.

The collected data from the reflection assignments will be analyzed using inductive coding to extract common themes from students' responses. The results from the coding process will be compared to the output of an AI tool (e.g., NVivo), to determine if using an AI tool impacts the results and if there is any inherent bias in the output.

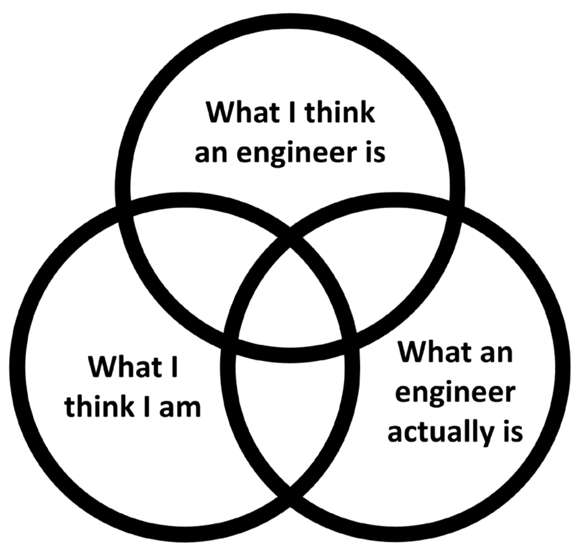

Figure 1: Engineering Identity Framework

The identity framework used for this analysis is based on [8], where the author separated the engineering identity into technical and professional attributes. This study hopes to evaluate engineering identity from a more holistic perspective, combining the technical and professional attributes while comparing the student's perspective of an engineer vs. the reality of the profession. The framework is visualized using the Venn diagram in Figure 1, similar to the Venn diagrams used in [3] and [5].

This project will focus on the redesign of the third-year project course. To address identified gaps, this course will integrate professional skills development through structured activities. Proposed interventions include reflection assignments, in-class discussions and a collaborative team project.

4.1 Reflection Assignments and Course Activities

This project involves collecting student data from five reflection assignments, posted throughout the semester. The questions that will be used are included in Table 1 of the Appendix.

This project aims to integrate engineering identity formation into an existing technical course. Throughout the course, we will incorporate discussion activities into the weekly lectures, focused on different aspects of engineering identity. The results of these discussions will not be collected as part of the research but are aimed at getting the students to start thinking about the topics for the different reflection assignments. Sample discussion questions that have been used in this course include what is an engineer, what is ethical design and what is an entrepreneurial mindset.

The group project for this course focuses on practicing communication and collaboration using project management tools like GitHub. The students must document their contributions and any changes to the project. The students will also have an opportunity later in the semester to practice oral communication, through a video component for the project. This provides the students with a platform to present their project, emphasizing clarity, persuasion, and technical rigor, to practice their ability to explain technical concepts to both experts and non-experts.

5. Conclusion

Engineering identity and professional skills are integral to preparing students for the complexities of modern engineering careers. By integrating these elements into the curriculum, educators can foster a generation of engineers who are not only technically proficient but also resilient, communicative, and socially conscious. The proposed redesign of the third-year project-based course serves as a model for embedding these principles into engineering education, contributing to a more inclusive and holistic approach.

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Appendix: Reflection Questions

Table 1: Sample Reflection Questions

Reflection Topic	Sample Questions

What is an engineer?	1. In your opinion, what does it mean to be an engineer?
	2. What skills/qualities should an engineer have?
	    a. Which of these skills do you have?
	    b. Which skills are you lacking?
	3. How does your image of an engineer fit with your personal identity?

Impact of engineering on society	1. What does being ethical mean to you? Up to this point in your academic journey, have you thought much about the ethical and accessibility concerns surrounding software engineering? 2. Find an example online related to software accessibility and summarize it (include link to source). Why did you pick this example? 3. What does having an entrepreneurial mindset mean to you? Do you think this is important as a software engineer? Why or why not?
Teamwork and Leadership	1. How do you typically assign tasks when working in a team? 2. Do you feel comfortable taking on the role of leader? 3. Have you had any relevant leadership or teamwork experience? If yes, do you feel that these experiences are relevant to your future career? Why or why not? If you haven’t had any relevant leadership or teamwork experience outside the classroom, do you think it is important to have experience with this before going to start engineering work?

Academic Journey	1. Based on our discussions in this course, has your vision of what an engineer is changed? 2. Has your sense of belonging in engineering increased, decreased or stayed the same? 3. Are there any other professional (soft) skills that you would like to learn that you feel are missing from the curriculum?
Final Project	1. What has your experience been working on this project over the entire semester? 2. Any thoughts on the pros and cons of working on a team project compared to working on an individual project? 3. How do you think this project (and this course) will help you in your future career?