Development and Initial Outcomes of an NSF RIEF Project in Understanding Teamwork Experience and its Linkage to Engineering Identity of Diverse Students

Abstract

Engineering identity is a crucial element in the formation of engineering students. It represents how strongly a student identifies with being an engineer and indicates persistence and retention in engineering. Many factors influence the development of an engineering identity; for example, students from diverse backgrounds (transfer, first-generation, one with a disability, female, or minority students) may face challenges in performance expectations, resource access, and peer interactions. Such experiences can hamper their engineering identity development, retention, and advancement in engineering. These challenges also manifest in engineering teamwork, where students are expected to apply and acquire engineering skills, assert themselves, and navigate unfamiliar team dynamics.

Many engineering education studies have stressed the importance of teamwork training in undergraduate engineering education. They have investigated how teamwork experiences promote learning, technical communication, metacognitive ability, social-technical thinking, and other skills. However, little is known about how teamwork informs or is informed by students' engineering identities. Understanding the connection between teamwork and the engineering identity of diverse students, especially among underrepresented groups, enables instructors to create inclusive teaching and learning environments. Such learning environments improve student performance and promote interest and recognition, which are crucial to a student's professional formation.

Funded by the Research Initiation in Engineering Formation (RIEF) program of the National Science Foundation, our project aims to (1) depict teamwork experience through the behaviors of and disagreements between team members in a highly diverse engineering student population at a four-year Hispanic Serving Institution;. and (2) understand how teamwork experience informs students' engineering identities using a mixed-methods approach. During the first year of the project, the research team designed a survey instrument and an interview protocol to measure students' engineering identity and teamwork experiences. Survey and interview data has been collected from 18 engineering classes. Our mixed-methods approach consisted of quantitative and qualitative methods. This paper summarizes the preliminary results and initial findings of this study.

Introduction

Engineering identity plays a formative role in engineering students' growth and has been shown to influence critical educational outcomes such as retention and persistence (Geisinger & Raman 2013). Broadly defined as a sense of belonging within engineering (Tonso 2006), engineering identity has been shown to be composed of multiple dimensions like performance/competence, interest, and recognition (Hazari et al., 2010; Carlone and Johnson 2007). Like other types of identity, engineering identity is shaped by interactional experiences (Gee 2000). One such experience is teamwork, where students must exercise their engineering knowledge and skills while asserting themselves in unfamiliar team environments. Although its importance is widely recognized, teamwork skill varies greatly among students and is lacking among many engineering graduates, according to employer surveys (Marra et al. 2016; Strong 2011; DePiero and Slivovsky 2007). That begs the question: when students engage in teamwork, what do they experience within those teams and how do those experiences affect their engineering identities?

Exploring this question is key to inclusive team-based teaching and learning activities. Underrepresented students in engineering may face additional barriers during teamwork experiences. For example, women are prone to assume stereotypical tasks in teams (Tonso 2006a), are rated less competent (Aragon, et al., 2023), and struggle to fit in (Wilson & VanAntwerp, 2021). Minority women often face backlash when they speak out against the status quo (Valverde & Dariotis 2019). Other groups (e.g., transfer students) possibly also face impediments to teamwork, although the extent of this is less studied. When confronted with these challenges, some students resist and disagree with their peers, while many choose to ignore or accept the negative behaviors or disengage from the collaboration. Because disagreement can serve as an antidote to unfair treatment, not to mention as a catalyst for innovation (Song et al. 2006), we explore in this study whether it is connected to a student's engineering identity, and whether it can be used to strengthen that identity.

In this research initiation grant, we focused on the central question of how engineering identity shapes or is shaped by teamwork experiences. Teamwork experiences are influenced by the behaviors or skills students bring to their teams and the disagreement they have. Prior research has explored how teamwork experiences connect to learning (Werpetinski 2017), technical communication (Zhu & Meuth 2015), metacognition (Xu et al. 2017), psychological safety (Miller et al. 2019), and socialtechnical thinking (Claussen et al. 2021). However, little is known about how teamwork informs or is informed by engineering identity development.

Background

In stark contrast to the volume of studies devoted to both engineering identity and teamwork, separately, was a lack of knowledge on the connection between engineering identity and teamwork. Understanding that connection would allow a more inclusive design of teamwork experiences in order to support all students. Many studies showed the impediments faced by students whose social or cultural identities did not conform to the dominant population in STEM disciplines. Hoehn et al. (2020) used an epistemological approach to observe a physics study group. They concluded that although a female student raised questions that helped to steer the team, she was viewed as less competent than a question "answerer" by her peers. Weatherton et

al. (2017) studied the systemic and personal barriers students with disabilities had in engineering programs. Ong et al. (2020) noted that minority students had negative self-images because others perceived them as diversity tokens. They emphasized the importance of social and structural support to promote self-efficacy and retention for women of color. The bearings of those identities cut across other interactional experiences, such as teamwork, in which students were expected to assert themselves and navigate unfamiliar team dynamics.

Teamwork was often studied through the lens of student behaviors. Using an educational anthropologist approach, Tonso (2006a) studied how the campus culture (categorized by student types – nerds, Greeks, and academic achievers) influenced teamwork in an engineering college of a state-funded university in the Midwest. By observing team behaviors in situ, Tonso found that non-design engineering classes promote social relations that favor narrowly defined excellence (e.g., GPA, awards, etc.). In contrast, engineering design classes encouraged behaviors aligned with traits favored by employers (e.g., respecting one another and learning key communication and organization skills). The study suggested a need for campus cultures to foster gender equality and cast student excellence in a well-rounded light. The study called for more sophisticated interventions to promote desirable teamwork behaviors and curb undesirable ones. In this study, we controlled for behavioral variables because students' behaviors are reflective of their perceptions, such as their engineering identity, and can impact how instructors evaluate them.

Productive disagreement may bolster team outcomes, as shown in other fields (Leslie 2021). In engineering education, Loignon et al. (2018) investigated how members perceived teamwork disagreement differently (i.e., dispersion) and how dispersion patterns informed the overall effectiveness (proxied by whether they are willing to continue to work together in the future). They used hierarchical clustering to identify the patterns with which team members perceived team disagreement. Using confirmatory factor analyses, they found that the optimal pattern depended on the constructs. For example, “if teams are going to disagree about who should perform which role or how resources are distributed in their group, they would benefit if these disagreements emerge based on one person tactfully challenging the status quo or if there is no dominant position within the group” (Harrison & Klein, 2007). Our research focused on how engineering identity was linked to student behaviors that emerged during teamwork and whether that linkage was modified by whether/how they disagreed.

Data Collection

We collected quantitative and qualitative data over two semesters using a survey instrument and interview protocol in a public, teaching-intensive, Hispanic serving institution in the Western US. The survey instrument was drawn from measures of engineering identity and teamwork developed and tested by prior research. It consisted of four main parts. Part One asked students to rate themselves and their teammates from 1 to 5 on five behavioral measures developed in CATME (Ohland, 2012). The five measures included: contributing to the team’s work, keeping the team on track, expecting quality, having relevant knowledge and skills, and interacting with teammates. Part Two inquired about how much the team disagreed during teamwork (Loignon et al. 2018). Disagreement or conflict generally fell into three categories- task, process, and relationship– all of which were considered in this study. Part Three probed psychological safety,

i.e., how comfortable students felt about working in their teams, through validated survey questions (Beigpourian et al. 2020). Part Four asked questions about engineering identity drawn from the work of Hazari et al (2010), Godwin (2016), and Tonso (2006b). Lastly, the survey included demographic questions to control for their compounding effects on engineering identity. The survey was piloted in an upper-division computer/electrical engineering class in Fall 2021 (n = 14). Subsequently, we collected 268 completed responses over Spring and Fall of 2022 (excluding the pilot survey), with the summary statistics shown in the Appendix.

The interview protocol evolved as we reviewed related work (Matusovich 2010; Danielsson and Berge 2020), the lessons learned from the pilot survey in Fall 2021, and two mock interviews conducted with student volunteers in early Spring 2022. The protocol was further modified to address the recommendations by our advisory board in Summer 2022, primarily adding questions about psychological safety. The interview dived into the survey questions by probing how and why students identified as an engineer (or not as one) and how teamwork and specifically disagreement shaped their engineering identities. Twenty eight follow-up interveiws were completed, based off the students who indicated an interest to be interviewed in the surveys. Ten of those interviews had been transcribed, cleaned, and used for the qualitative analysis. The remaining 18 transcripts, collected towards the end of Fall 2022, are currently being cleaned and analyzed.

Data Analysis and Results

Our project employed a mixed-methods approach, which combined a quantitative analysis of survey data and a qualitative analysis of interview transcripts. We used the quantitative approach to ascertain the associations among engineering identity, teamwork behavior, and disagreement. That can reveal statistically meaningful connections among the three concepts, thanks to a relatively large sample size. On the other hand, the qualitative analysis helped us understand the reasons behind students' survey responses and potentially gauge the causal direction between teamwork and EI. Preliminary results from the qualitative and the quantitative analysis were summarized in Claussen et al. (2023) and Wang et al. (2023), respectively.

Preliminary results from the quantitative analysis suggested that teamwork conflicts, teamwork behaviors, and engineering identities were all related to varying statistical degree. The correlations were measured by Spearman's coefficients (Knapp 2018). When engineering identity was cast through a multi-dimensional lens, it revealed more nuanced connections with teamwork experience. For example, "contributing to the team's work" (behavior metric 1, B.1) tended to boost virtually all dimensions of engineering identity, but it exerted the strongest connection with the performance/competence dimension of engineering identity (P.1 through P.3 in Table A.1). A similar theme also emerged from qualitative analysis of interview transcripts: several students professed that when they were able to apply themselves in teamwork they felt that their EI grew as a result and that when they were unable to contribute their EI took a hit and for two female students it triggered their imposter syndrome.

Both quantitative and qualitative results showed that disagreement or conflict remained infrequent in engineering students' teamwork, as it did in other studies (Loignon 2022). However, conflict about tasks (e.g., having different ideas about what to do) or processes (e.g.,

disagreeing on who should do what) tended to morph into relationship conflict, as evidenced by practically and statistically significant correlation coefficients. Their strong association was corroborated by the qualitative analysis, where several students mentioned that tension arose when their team members failed to pull their weight (proxied as process conflict). Except a few transcripts, students generally did not identify disagreement as an influencial factor to EI, in part because disagreement they experienced was few and minor during teamwork. In comparison, the quantitative analysis revealed several plausible linkages. For instance, students who were confident about their self-efficacy (construed as the competence dimension of EI) tended to have less relationship conflict during teamwork, with a medium-sized correlation coefficient and a significance level of 0.05. The interplay between disagreement and engineering identity could be refined by considering psychological safety because how comfortable a student felt around their teammates could influenced how they disagreed and how they perceived a disagreement.

Our qualitative analysis provided the contextual information to help us understand how teamwork experience informed engineering identity. Several interviewees expressed that their not contributing to their team's work triggered their imposter syndrome and made them feel less like an engineer, while others did not feel that teamwork had any impact on their engineering identity. One student, Charlotte, found that her engineering identity was strengthened thanks to her senior design project, where she teamed with others to solve an open-ended problem. The interview transcripts also revealed the breadth of engineering identity with which students identify, a breadth that may go beyond the performance/competence, interest, and recognition dimensions. For example, five interviewees emphasized that they generally did not consider it important whether other people saw them as engineers (recognition). They revealed that engineering was just an occupation to them and did not define who they were.

Conclusion

A complex and interconnected web among engineering identity, disagreement, and teamwork behavior is emerging from the preliminary results of our mixed-methods study. In the next stage of this project, we will simultaneously examine these three concepts while controlling for psychological safety and demographic attributes to tell a more complete story of students' teamwork experiences. These stories will illuminate on our central question about how teamwork informs engineering identity, especially for minority students (Davis et al. 2023). We expect that our work will inform future efforts to moderate behaviors and team dynamics through interventions such as conflict management and self-advocacy.

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Appendix

Table A.1 Summary Statistics of the 5-point Likert Variables (No. Obs. = 268)

Code	Question/Statement	Mean	Std. Dev.	Min.	Max.	Mode
P1	I can understand the concepts I have studied in my engineering classes.	4.135	0.668	2	5	4
P2	I am confident that I can understand engineering subjects in class.	4.132	0.689	2	5	4
P3	I can overcome setbacks in engineering classes.	4.07	0.718	2	5	4
P4	I am confident that I can understand engineering subjects outside of class.	4.113	0.731	2	5	4
P5	I can do well on exams in engineering classes.	3.663	0.908	1	5	4
P6	Others ask me for help in engineering classes.	3.586	0.966	1	5	4
I1	I enjoy learning engineering.	4.357	0.736	2	5	5
I2	I am interested in learning more about engineering	4.427	0.714	2	5	5
R1	Do the following see you as an engineer? - Parents	3.901	1.159	1	5	5
R2	Do the following see you as an engineer? - Relatives	3.805	1.152	1	5	5
R3	Do the following see you as an engineer? - Friends	3.846	1.109	1	5	5
R4	Do the following see you as an engineer? - Professors	3.415	1.087	1	5	3
R5	Do the following see you as an engineer? - Peers	3.759	0.985	1	5	4
Task	We had task-related disagreements [1]	2.651	1.209	1	5	2
Relationship	We had difficulty getting along [2]	1.748	1.031	1	5	1

Process	We had disagreements during the project's process. [3]	2.061	1.079	1	5	2
B1	Behavior 1: Contributing to the team's work	4.343	0.714	2	5	5
B2	Behavior 2: Keeping the team on track	4.27	0.773	2	5	5
B3	Behavior 3: Expecting quality	4.344	0.82	2	5	5
B4	Behavior 4: Having relevant knowledge, skills, & abilities	4.318	0.8002	2	5	5
B5	Behavior 5: Interacting with teammates	4.472	0.742	1	5	5
PS1	If you make a mistake on this team it is often held against you.	3.479	1.377	1	5	4
PS2	Members of this team are able to bring up problems and tough issues.	4.088	1.058	1	5	5
PS3	People on this team sometimes reject others for being different.	3.746	1.087	1	5	4
PS4	It is safe to take a risk on this team.	4.465	0.936	1	5	5
PS5	It is difficult to ask other members of this team for help.	4.089	0.886	1	5	5
PS6	No one on this team would deliberately act in a way that	4	1.086	1	5	4
PS7	Working with members of this team, my unique skills and talents are	3.991	1.101	1	5	4

[1] Task disagreement is defined as having different viewpoints on the task, different ideas about the task, or differing opinions about the work being done.
[2] Relationship disagreement means team's personalities clashed, disagreed about personal matters and non-work things (e.g., social or personal things).
[3] Process disagreement means having different opinions about who should do what in the project, task responsibilities, or resource allocation during the project.

Table A.2 Summary Statistics of the Demographic Variables (No. Obs. = 268)

Category	Type	# of Students	Percentage
Conflict Types	Individual	25	11%
	Dyad	36	17%
	Subgroup	26	12%
	Team	62	29%
	None of the above	66	31%
Gender	Male	185	86%
	Female	29	13%
	Others	1	0.40%
Race	Hispanic	68	32%
	White	34	16%
	Black or African American	13	6%
	Asian	73	34%
	American Indian or Alaska Native	1	0.40%
	Native Hawaiian or Other Pacific	11	5%
	Some other race	15	7.00%
Highest education degree that parents attained	High School (e.g., GED)	53	25%
	Some college credits, no degree	27	13%
	Associate degree (e.g., Associate of	21	10%
	Bachelor's degree (e.g., Bachelor of	52	24%
	Graduate degree (e.g., Master's degree,	35	16%
	Unknown	26	12%
	High school (private or public)	124	58%

Last school attended before enrolled to SFSU	Community college in California	66	31%
	Community college outside of	4	2%
	Another university within the CSU	6	3%
	A university within the UC system	4	2%
	Other institution of higher education in	0	0%
	An institution of high education outside	10	4%
Full-Time or Part-Time Student	Full-Time	198	92%
	Part-Time	17	8%
International Student	Yes	14	7%
	No	201	93%
Pell Recipient	Yes	56	26%
	No	159	74%
Student Status at SFSU	Freshmen	79	37%
	Sophomores	7	3%
	Juniors	18	8%
	Seniors	101	47%
	Graduates	10	5%