An Investigation of Psychological Safety in Student-Led Undergraduate Engineering Design Projects through Student Interviews

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Abstract

To supplement classroom learning and prepare students to transition from school to industry, many undergraduate engineering students participate in team-based design projects, both in design-focused courses and as extracurricular activities. These projects can be largely organized and run by students, and there is a wide range of projects with different team sizes, objectives, and organization. Then, it is not surprising that student expectations and experiences vary significantly across the different projects. In this work, to inform best practices for student-organized design project teams, we investigate students' perspectives on how their team is organized, the relationships among team members, conflict resolution methods, and psychological safety.

We interviewed five students at the University of California, Irvine, about their involvement in undergraduate engineering team projects that are student-organized outside of their regular coursework. We asked each student four background questions regarding their major, years involved in projects, and how their role on the team was chosen or assigned. We asked another fifteen questions related to their team's organization, relationship with other students, conflicts and resolutions, and psychological safety within the team. The students interviewed played different roles within their projects (e.g., project manager, technical lead, general team member, etc.) and participated on teams with different goals; some aimed to participate in international design competitions while others set internal goals, perhaps with a faculty advisor.

From thematic analysis of interview responses, despite no two projects being organized the same way, some patterns surfaced. Students tended to enjoy working in smaller groups compared to bigger ones because they were more efficient at problem-solving. Additionally, to address both technical and personal disagreements, interviewees said they were comfortable speaking openly in meetings and after incidents occurred, indicating good psychological safety with teammates. We hope to use the results of this work to develop recommendations and best practices for student-organized engineering design project teams to provide a welcoming and effective learning environment for all students involved.

Introduction

Engineering design teams are common in the industry, so students need to have experiential design team experiences to learn and develop critical skills needed for their careers. These skills

go beyond the technical content in core engineering courses and include professional and essential skills like communication, teamwork, organization, project management, and conflict management, among others. Courses and extracurricular activities that require teamwork offer important opportunities for students to learn these skills. However, the environment in which students participate plays a significant role in whether these skills can be effectively learned or not. Open-ended student-led and organized projects may vary widely in their environment and team culture. Therefore, it is important to understand the experiences of student-led and organized teams to develop best practices and guidelines for students and faculty advisors to follow when forming and running these team projects.

The importance of teamwork in engineering careers and curriculum is well-known. ABET lists "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" as a student outcome in its outcomes-based assessment of engineering curricula [1]. Early career engineers often describe effective teamwork and interpersonal skills as the most important competencies in their jobs [2, 3]. The formation of teams can significantly affect how well a team works together, and team formation and function have been studied in engineering curriculum for decades [4–6]. Previous research has shown that teams are more effective when instructors create the teams considering students' availability to work together, considering diverse student backgrounds and abilities, and limiting the team size [7]. Having students create a team charter or contract that identifies specific objectives, team roles and work breakdown, deliverables, and procedures for conflict resolution can improve team effectiveness [8]. Moreover, integrating conflict management training into engineering courses has been shown to successfully improve students' leadership skills. Effective examples include implementing conflict resolution training throughout the engineering curriculum [9] and providing conflict management training in an interdisciplinary capstone design course [10]. These newer developments help to address the challenges that students lack explicit training on effective teamwork and often do not share the project work equally [11] and that faculty may have minimal training in mentoring teams and teaching conflict management [12]. Still, these best practices may be challenging to implement in open-ended projects, largely student-led and organized, and have varying goals, such as participating in a competition as compared to performing research.

The effectiveness of a team has also been related to the level of psychological safety that its members feel. Psychological safety encompasses ideas such as feeling comfortable sharing ideas and concerns, making and admitting mistakes, talking with teammates and mentors, asking questions, and asking for help. It refers to the "sense of confidence that the team will not embarrass, reject or punish someone for speaking up," and the presence of psychological safety in teams is characterized by a climate of mutual respect, care, and trust [13]. Therefore, members of teams with high levels of psychological safety feel safe to express ideas and opinions, which encourages taking risks and promotes creativity and innovation. This climate is especially important for complex, knowledge-intensive tasks that require creativity and critical thinking, like engineering design. Recent research has explored psychological safety in engineering student design teams. For example, psychological safety has been shown to effectively predict team conflict and cohesion [14] and peer evaluation outcomes [15]. Changes in psychological safety for the same teams have been tracked over time [16], and the impact of psychological safety on a design team's concept generation and acceptance has been studied [17]. Finally, interventions

have been presented that are successful in improving psychological safety in engineering student design teams [18]. In this work, we aim to provide further qualitative evidence and best practices for understanding and fostering psychological safety in diverse engineering student design teams.

In previous work, we examined engineering student design team experiences at the University of California, Irvine, (UCI) from a diversity perspective through an end-of-course survey and found that students from different demographic backgrounds reported slight differences in their team project experiences [19]. We also performed a more focused study of two aspects of student teams that have been shown to vary for students from different backgrounds: (a) the roles that students play on their project teams, and (b) their psychological safety [20]. This quantitative study showed small differences in broad student teaming experiences and how student roles were determined when comparing different student demographic groups. It also found generally good psychological safety of students interacting with other team members, team leads, and project advisors. To further investigate these broad results, we next aimed to study the more nuanced aspects of team organization/culture and psychological safety through student interviews and qualitative analysis. The interview protocol was proposed in [20], and its implementation and results are described in this work. In particular, we investigate the connection between psychological safety and team organization and culture and how they relate to students' experiences on teams with diverse students and diverse objectives, sizes, and organization. These results may promote awareness of potential concerns related to psychological safety on diverse, student-led design teams, and enable changes to improve inclusion on student-organized teams that can be made both by project advisors and student leaders.

Research Methods

Our work aims to answer the following research question:

R1: How do engineering project teams foster psychological safety for diverse members?

In this section, we describe the local engineering projects ecosystem, data collection, and assessment methods, the interview questions, and brief profiles of the student interviewees.

Projects Ecosystem

The project ecosystem at our institution has multiple identities and has undergone numerous transformations to meet changing academic objectives, career readiness requirements, enrollments, and resources. The first required project courses were put in place in the early 1980s, served 50-60 students per quarter, were student-initiated and managed, and tended to be large and ambitious. In the early 90s, an accident forced projects "inside" onto 3'x8' tables, and over a couple of years, only industry-sponsored projects were offered. By the late 90s students were again initiating and managing their projects and 3 units of open-ended senior projects became required for graduation. When students were able to use up to 8 more units of Senior Projects as technical electives, projects began to be more involved, year-long endeavors. Between 2013 and 2015 non-seniors were then also allowed and encouraged to formally join projects through work-load-credit classes and project enrollments went from 150 to 300 students. The majority of projects had limited or no faculty-advisor involvement and it became obvious that more structure

was needed given both the large numbers of students and the fact that the project work was required for graduation. By the 2017-2018 academic year, project-level documentation and participation in a quarterly design review were required of all teams. With still no formal individual attention to technical engineering work on senior projects, the next iteration in 2018 was to require students to be part of a team that submitted a quarterly design report for a component, assembly, or system that was related to their project and to give brief check-in presentations in 10-person, 50-minute weekly sessions. Despite this high-level organization, at the project level, everything was left to the students. Students managed the teams, including who received an enrollment code, selected team leads, and when applicable, which sub-team each member was on. Before the COVID-19 pandemic, there were 450+ students on 25-30 teams, and teams varied in size from 5 to 40 with about equal numbers of juniors and seniors. Close to half of these projects were participating in national student competitions. A major senior projects curriculum change took place post-pandemic, and now the formal senior design required units are through enrollment in a 2-quarter mechanical engineering design class that emphasizes the design process. The multi-quarter, yearly projects can, through their advisor, submit project ideas to this design course. Large, popular projects, such as the national competition projects, still exist and are still student-managed. Most of their enrollment is through informal courses that do not count for graduation.

Data Collection

Five students who previously participated, or are currently participating, in student-led interdisciplinary engineering design projects were interviewed individually. These students were specifically selected to gather information and perspectives from a diverse group, in terms of the roles they have served on project teams, their degree major, their gender, and their team size, organization, and goals. Profiles for these interviewees are given below. The interviews were completed either in person or via Zoom [21] and lasted anywhere from fifteen to fifty minutes. Participants were asked four background questions and fifteen interview questions, listed below. The audio was recorded via Zoom, and Zoom was used to generate audio transcripts. Following each interview, the audio transcripts were copied into a document and reviewed by the research team to ensure they matched what was said in the recording and to separate what the interviewers asked from the interviewees' responses. All participation in the study was voluntary and uncompensated, and data was collected according to the university's IRB-approved protocol.

Interview Questions

Each student interviewee was asked the following questions: (Note, questions 1-8 are from [22])

IQ1. In general, how well did the people on this team work together?

IQ2. How did you feel about speaking up to other team members?

IQ3. Did you always agree with the decisions taken by this team? If not, would you have openly disagreed with the decision?

IQ4. If you disagreed with someone's opinion in a meeting, were you more likely to say so in the meeting or discuss your concerns with one or two people after the meeting?

IQ5. Did you think everyone's opinion was valued in this team?

IQ6. What do you think could make future team members more comfortable to be their authentic selves/speak up/share their opinions in this team?

IQ7. Can you tell me about one of your experiences speaking up/sharing your opinion on this team?

IQ8. Was there ever a confrontation or conflict within this team? If so, how did the team deal with this?

IQ9. How, if at all, did you feel your gender identity and/or racial/ethnic identity impacted your experience on your team?

IQ10. Could you describe any instances of feeling respected and/or disrespected on the team?

IQ11. If you felt disrespected, what were the reasons for any lack of respect? Personality? Work ethic? Technical Skills? Ethnographic or Economic Background?

IQ12. To what extent did you socialize with any team members outside of the project work?

IQ13. How much did you enjoy being together with the team as a whole?

IQ14. Were the team's stated goals clear from the beginning? How successful do YOU think the team was in achieving its stated goals?

IQ15. Considering all your activities (academic, social, work, family, etc) at the time, what priority was your project work, and why?

Thematic Analysis

To analyze the data for this study, the researchers utilized both deductive and inductive thematic analysis. We performed deductive coding based on existing themes that have been identified in the literature on engineering student teams, such as in [10], and organized keywords based on these themes from the fifteen interview questions to form our initial code book. After reading the interview transcripts, the occurrence of the initial themes was confirmed, and the codebook was updated to include additional key themes that appeared in the data. The inductive and deductive themes and their respective definitions were agreed upon by the authors, and all transcripts were coded by multiple authors and discussed to confirm high inter-rater reliability.

Interviewee Profiles

A summary of the interviewee profiles is given in Table 1, and longer descriptions are below.

Student A had experience on one of the university's larger senior design teams, having thirty people at any time. His team's management consisted of a chief engineer, project manager, and assistant project manager. The design engineers on this team were broken up into sub-teams that performed tasks related to a specific aspect of the project. Before graduating with a bachelor's degree in mechanical engineering, Student A held the role of chief engineer. Student A is the only transfer student in this study.

Table 1: Interviewee Student Profiles

Student	Roles	Team Size	Gender	Major
Student A	Team Technical Lead General Member	30	Male	Mechanical
Student B	Sub-Team Lead Technical Team Member	10-20	Male	Mechanical Aerospace Materials Science
Student C	Assistant Project Manager Design Engineer General Member	40-50	Male	Mechanical
Student D	Project Manager Design Engineer General Member	40	Female	Aerospace
Student E	Sub-team Lead General Member	40-50	Female	Mechanical Aerospace

Student B was part of three different projects ranging in size from less than 5 to approximately 15 students. Due to the smaller size of the teams, there were fewer roles a student could hold, so he served as a structural engineer for all three, and as part of leadership for one. Student B graduated from UCI as a triple major in three engineering disciplines.

Student C served as both a design engineer and assistant project manager for a project with roughly 50 students. He started as an apprentice engineer but opted for a less technical route within the project by gravitating toward assistant project manager in their final year on the project. Similar to Student A's team, Student C's team is led by a chief engineer, project manager, and assistant project manager. All of the design engineers report to one of six sub-team leads. This team also has an apprentice program allowing sophomore-level students to start gaining experience with junior and senior-level students. Student C graduated with a bachelor's degree in mechanical engineering and is currently a graduate student at the same university.

Student D is serving as project manager for a medium-sized team of about 30 students having previously been a design engineer for two years. Her team recently split into two divisions which reduced the size quite a bit. Student D's division is led by a project manager and assistant project manager who manages sub-team leads. The sub-teams are led by two "co-leads" who then direct a team of design engineers.

Student E is currently a sub-team lead for the same large project as Student C, but after starting as an apprentice, chose to take a more technical role on the team. Student E oversees seven students on her sub-team. She has junior standing at UCI and is double majoring in mechanical and aerospace engineering.

Table 2: Themes

Deductive Theme	**Definition**
Communication, Collaboration	Students sharing information and ideas, their thoughts on how well their team worked together, incorporating different perspectives into project work
Conflict Resolution, Problem-Solving	How students overcame disagreements and settled on solutions, and how they dealt with project and personal challenges
Personality	Unique characteristics and traits of teammates, introversion and extroversion, and the nature of interactions
Sense of Community, Social Events	Feeling of belonging, time spent with teammates outside of their projects, strengthening relationships, and building connections
Team Size, Team/Course Structure	How the number of students impacted project outcomes, course requirements and assignments, organization of members (*i.e.* sub-teams and management), and role selection
Team Performance	The outcome of the project experience, efficiency with achieving goals, how well they made decisions, meeting internal and external goals, and the clarity of these goals
Project Management	The structure of leadership on each team
Advisors, Mentors	The level of involvement of faculty members in the projects, communication with advisors, and student role models as sources of information and advice
Interviewee Demographic	Impacts of ethnic background, gender identity, age and seniority, educational and professional background on the project experience
Inductive Theme	**Definition**
Technical Experience	Students seeking engineering expertise from one another, becoming proficient in a specific discipline
Deadlines and Time Management	Students making decisions based on time restrictions and how to effectively satisfy project requirements given time constraints or competition cutoffs

Results

Themes

The thematic analysis resulted in the themes shown in Table 2. For each theme, the definition is given in the table, and example quotes from the interview transcripts are discussed below.

Communication, Collaboration:

The students in this study generally enjoyed working with each other and identified a variety of factors and support systems that aided the communication process. As Student E put it:

> "Yeah, we work together pretty well. We got along... There's a lot of resources. And that's the information that helped me learn more. And that helped me lead this year. So team dynamic-wise, communication was really good."

While Student E felt that having supplementary technical information helped them feel confident in facilitating communication, Student D noted that another necessary resource was lab space:

> "Like the whole COVID thing didn't help the team dynamic. I think for a lot of other teams, the, I guess, involvement sort of fell off. And you can't really blame them when we couldn't have access to the lab very much. But I would say that, let's see, I think over the years, our project specifically, within my experience, has gotten better at working together. Like it really, let's see, I think the roughest time that our project probably had was splitting [into two distinct] teams, mainly because, like the resources that were split wasn't predetermined. And then also figuring out like a new dynamic to share space within lab. I know a lot of other teams struggle with that too.....like the racing team has like three teams packed into one. I think the [computer lab] room has more than three teams sharing lab space."

Student B echoed this sentiment, adding :

> "Having a designated workshop it, or like lab. I'd say it's very beneficial in terms of getting to know and and working well with your teammates."

Student C focused less on the importance of workspace for collaboration and more on how individuals worked together:

> "I felt that generally members did work well together, but I felt that there was a lack of organization. Often when there was a member that did step up and take in and work to help integrate everything together, I felt that members did work together really well, and there was good cohesion. However, in moments of stress such as deadlines imposed by, you know, members of the team or competition deadlines, people did become a lot more stressed. And then there were more difficult opportunities for teamwork."

Student C's emphasis on how deadlines changed the way students interacted also appeared in other interviews and helped to surface one of the inductive themes - deadlines and time management.

Conflict Resolution, Problem Solving:

This section highlights student comments related to how their teams addressed conflict in the context of student engineering projects. There were various approaches from each student's team, ranging from proactive initiatives to hierarchical resolutions. Regardless of what way conflict was addressed, they all mentioned the importance of effective communication, open-mindedness, and leadership in resolving conflicts to ensure project success.

Student A recalls a situation where they disagreed with the design provided by a lead and ultimately took the initiative to change it, leading to consensus among the team that their design was more efficient. This demonstrates a proactive approach to conflict resolution by presenting

alternative solutions. He also discusses another instance of confronting a team member who was not contributing to the team, which ultimately led to the decision to remove them from the project. This highlights the necessity of addressing issues directly and taking appropriate action when needed.

> "I never told [the technical team lead] he had a terrible design. I just told him I don't think this is the most feasible thing we could do. The way you word your arguments has a big impact on how they see your next idea. So it's a good idea to treat everyone with respect and kindness."

Student B mentions arriving at acceptable conclusions through majority rules when encountering conflict, indicating a more democratic decision-making process within the team. Similarly, Student C emphasized the importance of open communication and ensuring that everyone agrees with the decisions made to prevent conflicts professionally and responsibly. He also noted that sometimes conflicts just went unresolved, referencing a time he was disrespected and the issue was never addressed following the incident.

Student D reflects on the constraints of decision-making within certain limitations and acknowledges the importance of working with diverse perspectives. Despite differing decisions, she said her team recognized the value of collective decision-making for the overall success of the project.

Contrary to the other students' approach, Student E describes a time when there was conflict regarding her team members being unable to attend their project competition due to limited funds. The conflict was resolved through management's decision to require members to fund their travel expenses if they wanted to attend, which demonstrated a hierarchical resolution approach. She said:

> "The way it was resolved, [was] that management had the last say in [the decision], and they got to choose who went to competition. Another solution was that the other members that want to go, they have to pay for their own flights and their own accommodations..."

It is challenging to make a definitive judgment for each approach, as they all may be suitable in different contexts. A proactive approach to conflict resolution may be effective in addressing issues promptly, while a hierarchical approach might be necessary for resolving more complex conflicts or making decisions that affect the entire team. Similarly, democratic decision-making can create a sense of inclusivity and ownership among team members, but it may also be time-consuming and challenging to reach a consensus. Ultimately, the effectiveness of a team's approach to conflict resolution depends on various factors such as the team structure, the nature of the conflict, and individual preferences within the team.

Personality:

Personality traits influence how individuals perceive and respond to their work environment. By recognizing these differences, there can be insight learned as to how various personality traits contribute to psychological safety within teams. Effective leadership involves understanding the strengths of team members while addressing potential challenges. By considering personality

traits when assigning tasks, providing feedback, and resolving conflicts, leaders can promote a supportive and safe work environment.

This applies to Student B, as he acknowledges individual differences in motivation levels, suggesting that motivation plays a role in determining the amount of work individuals are willing to do within the team. Similarly, Student C indicates that the frequency of conflicts varies depending on the person or situation, showing how individual differences can affect team environment and work ethic.

Conversely, Student D mentions feeling a sense of imposter syndrome, which affects her confidence in speaking up within the team. She also acknowledges being more comfortable voicing ideas in situations where there is disagreement among the majority or when decisions are still being formulated. She explains:

> "I think that's usually what it comes down to if I feel like I can't speak up. It's probably just because I either feel like a sense of imposter syndrome in the sense that like, 'oh, I might not know what I'm talking about,' or it might not be like, helpful or applicable in a way."

This relates to Student E, as she reflects on feeling more comfortable with the team over time, indicating that personal comfort with team members can affect one's overall experience within the team. This shows how one's comfort in speaking up, and differing levels of comfort may affect work performance and ability to share ideas.

These responses highlight the diversity of personalities within the team and how they impact communication, conflict resolution, and decision-making processes. Understanding these differences is crucial for an inclusive and effective team environment where all members feel valued and comfortable sharing their ideas with others.

Sense of Community, Social Events:

Across the board, all of the students participated in at least one social event with their teammates. Activities varied based on team size. Student B's team was small, so the whole project would go to dinners. Students A and E were on teams with at least thirty people, so they instead highlighted how their sub-teams of approximately seven people did activities together instead. Regardless of size, nearly all the students cited that their teammates became people they saw or sat with in class. Student C's answer was a good model of what most participants mentioned:

> "Oh, I tried to be friends with as many people outside the project as possible, even if that just meant going to the University Mall area or grabbing lunch with them. If the team is about 50 people, I would say that I hung out with about 30 of them outside of class, so that I thought, you know, that's pretty cool. And then we were also classmates and other things. So even if we weren't just... even if we weren't necessarily friends, we were still acquaintances, and we saw each other and other aspects around campus."

While time spent together as a team outside of the projects was not a requirement, all of the interviewees did enjoy it, and it provided both study circles and social circles that students leaned on even after the end of each year.

Team Size, Team/Course Structure:

In examining the dynamics of team size and course structure, multiple students offered valuable insights into the challenges and considerations associated with working within larger teams and navigating course requirements. Student A shares the importance of clear goals and requirements for project success. He emphasizes how it is necessary to have clear expectations and milestones before starting any project to ensure that the effort aligns with the intended outcome. He also elaborates on the process of setting requirements and goals, indicating that both external requirements (competition rules) and internal team goals are considered in project planning. He states:

> "If you don't have clear requirements and clear goals for the team, [our advisor] wouldn't even let us do anything for the car."

Student B mentions that despite a large team size, only a few actively participated, which ultimately resulted in a smaller effective team size. He also highlights the challenges of unclear or vague project goals, mentioning the importance of clear definitions for effective project design.

> "But out of the 14, maybe only like 6 or 7 actually show up. And it's so small that we just kinda do whatever is needed."

This relates to what Student C discusses, as there were concerns raised by team members about the size of the team, and emphasized the importance of ensuring that there is enough work for everyone to contribute. He suggests that a large team size could potentially lead to reduced motivation if members perceive others to not be contributing. Similarly, Student E indicated that smaller groups may facilitate more efficient collaboration and decision-making- a sentiment that other students shared as well.

The reflections shared by these students show the multifaceted nature of team size and structure within the context of course structure and course requirements. Their insights emphasize the importance of clear communication, equitable workload distribution, and team organization in optimizing team performance and project goals.

Team Performance:

Students' responses concerning team performance contained both internal goals and external goals, and they often felt more successful in accomplishing goals and understanding requirements set by other organizations as opposed to team-wide goals. Student C's team was part of a large professional society's design competition, so they had a rule book they needed to follow and deliverables for an end of the year presentation. However, the team itself set performance metrics and had a timeline for milestones which were not always firmly followed, leading to confusion:

> "The organization has very clear requirements, but I think the internal goals of what we want to reach were always pretty ambiguous, and I feel like they moved or changed or shifted, which I feel like that shouldn't really be what a goal is."

While Student E still recognized the importance of external requirements, they were less opposed to the ambiguity of goals that Student C commented on because other teammates were there to fill

in the gaps. Student E said:

> "The goals that were set were to set [for us to be] ready for competition... And we did achieve the goal. And we did. And we were able to go [...] and compete... If there were some unclear goals, or if someone felt like they didn't know what they were, what they wanted to do like they they could reach out."

Even in the absence of a competition body, Student B's response indicates that having at least one clear set of requirements for design improved the team's feeling of success:

> "Some projects were very vague in terms of goals... [The advisors] basically just said, do whatever you want and hopefully, they will like it. But the projects with clear definitions were very easy to design around."

Project Management:

Effective project management practices contribute to improved team performance by ensuring clarity of goals, efficient resource utilization, strong communication and collaboration, effective leadership, and a focus on continuous team improvement.

Student A mentions that final decisions regarding leadership are made by the chief engineer, who holds authority over who will take over as students continue to graduate.

Student C talks about his experience as the assistant project manager who works closely with the project manager and chief engineer. He mentions feeling intimidated by the project management role but says that regular status reports and team meetings help him connect with other team members and reduce intimidation. This role bridges the technical aspects and timeline management responsibilities. This demonstrates how effective project management practices, such as regular communication and transparent reporting, contribute to psychological safety within the team.

Student D reflects on the influence of differing management styles on team engagement. She recognizes the importance of leadership presence and encouragement to help team comfort and motivation among team members by inspiring them to contribute ideas. She explains the importance of strong leadership, and how it affects team morale:

> "...If the management isn't around a lot or doesn't encourage or meet new members, people don't really feel attached over time. Or if they're not checked in often enough or given enough project work, no one really feels inclined to pursue above and beyond or find new ideas to contribute to the team. So I think it really depends on not only management, but also just how the project is presented to both current and new teammates."

Student E expresses mixed feelings about the differences in management style between her different years on the team. Mentions how there is a more relaxed management, but notes the increased strictness in certain aspects such as assignments and design binders. She also mentions that regular meetings and opportunities for involvement helped her feel more engaged in the project. By providing a structured framework and a positive team environment, project management contributes to overall project success and the well-being of team members.

Advisors and Mentors:

The majority of interviewees had very little to say about the role of faculty advisors and mentors in their projects. In fact, this code was the second least discussed by students after interviewee demographic. Regardless of the theme's frequency, the insight provided on the matter indicates that mentorship is still a critical part of creating psychological safety on a team.

Only Student A's advisor was heavily involved in their project and regulated how the team would operate. The advisors for Student B's projects had weekly check-ins, but the how the teams reached their goals was entirely up to the students.

In a similar vein, Student C found that there was low interaction with their advisor but attributed it to the advisor having a shortage of time for the team:

> "We... communicate with our faculty advisor, and we would try to email him and was happy to be included in the meetings whenever he could. However, he was quite busy, so it was difficult at times."

Perhaps the most interesting finding was that in the absence of a faculty advisor, other students became mentors to each other, especially in regards to leadership. For example, Student A later mentioned:

> "Leadership with something that was kind of taught – not from the professor, but mostly from like the students."

Specifically, having student mentors that were underrepresented, such as women, within engineering gave Student E the guidance and skills needed to lead the following year:

> "Yeah, as a woman. And in the motor sports industry like in STEM and engineering in general... it did feel a bit intimidating... there aren't many girls on the team, especially Middle Eastern girls on the team... I was lucky enough to have 2, 2 mentors that are women... Yeah, that did help a lot. And [they] are like role models as [they] really encourage me. And like, showed me that, yeah, like we can do it. We can lead."

Becoming a mentor gave students the power to contribute to building a more psychologically safe space, like in the case of Student C:

> "I think I wanted to serve as a person on the team that people feel comfortable asking questions to you or coming to."

Interviewee Demographic:

When asked about how their ethnic backgrounds and gender identities impacted their project experience, the interviewees felt little to no negativity from their peers. Surprisingly, students had the least to say in this category.

The female students did not mention any instances of being singled out for their gender identities but did recognize that there were fewer of them. As such, they appreciated efforts made by management to bring them all together.

Only Student A recognized how their team included people from diverse backgrounds and the benefits it brought, but maintained that there was no conflict associated with team

demographics:

> "Personally, I don't think it had a huge impact... When I first joined we had about like we had a pretty even split of like racial groups and ethnicities. And we actually ended up getting a sponsorship from [industry], since our team was like about 45 or 43 percent women. So we've - we've we haven't really made like a huge point to do it like our point has just been, hire, whoever the best person is for the job."

Technical Experience:

The students interviewed talked about their experience of respect from their peers as well as disrespect based on their technical knowledge of their projects.

Student A emphasized the importance of hearing out differing opinions respectfully, even if they're ultimately disagreed with. He talked about discussing his ideas without disrespecting anyone, highlighting the impact of respectful communication. Student A also mentions that criticism in engineering is often about focusing on the final product rather than personal feelings, as well as the need to control emotions to focus on improving work. He explains:

> "Like, if your design sucks, I'm going to tell you why I think it sucks. So it's something that, as an engineer, you have to kind of learn how to deal with. Because not everyone's gonna like, I guess, show you the same kindness you would do to them. So something that you have to learn how to control your emotions as well as engineers..."

Student B mentions feeling respected by being approached for help primarily for technical and manufacturing-related subjects but doesn't explicitly mention feeling disrespected.

In contrast, Student C recalls a specific incident at their project competition where he felt disrespected when someone spoke to them inappropriately and told him to leave the area.

> "In addition, at times I didn't feel respected... during those high-pressure situations, including one at competition. Sometimes, it could get pretty high tension, and the pressure cooker turned on. So somebody at comp... because you know my role, it wasn't really engineering-focused after all. So someone at competition, they cussed me out, and they told me to go hold my folder somewhere else."

Both Student D and Student E mentioned feeling respected when their technical decisions were favored by their team. Student D discusses a decision she made being well received by leadership. They attribute this more to the complexities of engineering rather than team dynamics. Similarly, Student E describes feeling respected during a major presentation where her designs were questioned and discussed, indicating that engaging with her work was a sign of respect. These instances demonstrate the importance of recognizing and valuing technical expertise within project teams, which shows mutual respect and appreciation for each member's contributions.

Overall, respect within a team is closely related to the level of technical knowledge one possesses due to the recognition of expertise, problem-solving abilities, and contribution to team success. As students demonstrate their proficiency, which adds value to the team, through their technical knowledge, they earn the respect and admiration of their peers.

Deadlines and Time Management:

Because many of the students' projects involved competitions at the end of the academic year, an inductive code that appeared is Deadlines and Time Management. Meeting deadlines influenced how the teams operated at a given time of the year. For Student E, having deadlines meant that the priority level of project work would move up and down throughout the year. In Student D's case, time shortages meant that they had to accept technical choices inherited from a previous year's team:

> "I sort of had to stick with and continue building whether or not I personally agreed with the viability of the decision, just because of the scope of the project and the deadlines we had set. So I guess, in a way, I didn't really have the opportunity to make a bigger decision for the design from a technical perspective."

Notably, Student C pointed out that internal deadlines could also contribute to the same rushed feeling as deadlines from external bodies. As a result, they became responsible for managing a team-wide timeline to ensure that sub-teams were achieving their design milestones.

Discussion

In this section, we discuss the results presented above in the context of the research question.

R1 (restated): How do engineering project teams foster psychological safety for diverse members?

Teams created safe spaces for all of their members to speak up by facilitating technical and personal conversations, constructively resolving conflict, and using sub-teams to bring structure to the projects, all of which impacted the success of teams in achieving their stated goals.

Each student had different experiences, but some described their team as approachable and easy to talk to, which contributes to an atmosphere where individuals feel at ease expressing their thoughts and opinions. Student D mentions her team's overall open-mindedness creates a space where multiple perspectives are valued. She also reflects on the importance of learning from experiences and how they may influence one's willingness to speak up. This suggests that continuous learning and personal growth help with psychological safety within the team.

Communication and Conflict Resolution

Based on the feedback from the interviewees, design teams can maximize the psychological safety of their members by creating opportunities for members to communicate and interact. This starts with providing an adequate lab space for students to work in. The labs are low-stakes environments where students can begin asking each other questions more privately regardless of their role on the team. As they grow more comfortable, it becomes easier for them to speak up during larger, team-wide meetings, specifically being able to openly disagree while a topic is still being discussed. Not only do these lab spaces help students gain the confidence to speak up, but they can also lead students to feel respected.

Spending time in the lab gives team members the chance to get hands-on experience within the

boundaries of their projects. Having this increased exposure improves students' grasp of technical concepts to the point where some become subject matter experts on specific topics for their teams. When teammates recognize this and seek technical information from these individuals, they make these subject matter experts feel respected and more confident in speaking up if they disagree with a technical decision. For the maximum benefit, students should make an effort to interact outside their lab spaces as well.

As the respondents indicated, spending time together outside of the lab became a way for students to feel more comfortable with each other and thus more willing to speak up. Additionally, teammates often became friends and formed study groups, providing a community and contributing to diverse students' sense of belonging as well. While genial interactions certainly play a role in increasing how comfortable students feel, the way conflicts are handled also influences their psychological safety. Avoiding conflict itself is not necessarily desirable because conflict can bring positive change, but what is imperative is how the conflict is managed. Students in this study cited that as deadlines approached, their teams felt more pressure, and in the case of Student C, the pressure drove their teammates to make hurtful comments that never got addressed. Student C lost confidence in their ability to voice their thoughts and the experience diminished their overall psychological safety. By contrast, when conflict arose and was discussed right away, students found themselves effectively reaching a consensus, strengthening the team bond and students' level of comfort in speaking up.

Team size, structure, management

The effects of course structure and team size on team performance are based on multiple aspects, such as team dynamics, clarity of goals, motivation, and leadership. Many acknowledged the impact of team size on their project, as larger teams may face more challenges in ensuring active participation and contributions from all members. Despite having a large team, only a fraction of members actively participated, indicating potential difficulties in coordinating efforts within larger groups. This is mentioned by multiple students who emphasize the benefits of smaller sub-teams within larger teams which is more manageable and conducive to efficient collaboration. This suggests that team size can significantly influence effectiveness in project execution.

Multiple students also mentioned the importance of clear project goals and requirements for project success, as well as the necessity of establishing clear expectations to ensure goals are achieved. Vague or ambiguous project goals can lead to uncertainty and inefficiency in project planning and execution. By providing clear guidelines, teams can plan their goals to ensure everyone is working towards the same objectives, which enhances overall team performance. Defined leadership roles, such as chief engineer or team leader, are mentioned as crucial for decision-making processes and effective communication within the team. This highlights the significance of clear structural organization in promoting cohesion and productivity within the team.

Beyond having clear goals, each student acknowledges the importance of having leadership within the project management structure to drive these goals. Student A highlights the authority of the chief engineer in making leadership decisions, while Student C and Student D emphasize the influence of leadership presence and encouragement on team engagement and motivation. Student C and Student E both discuss the significance of regular status reports, team meetings,

and opportunities for involvement in fostering collaboration and connection among team members. These practices help reduce intimidation and create a sense of engagement within the team. Student E's reflection on experiencing mixed management styles across different years suggests the need for project management approaches to be adaptable and flexible based on the team's needs and circumstances. This highlights the importance of adjusting management strategies to maintain team engagement and effectiveness. Effective project management practices allow for overall increased team performance by promoting continuous learning and adaptation, as well as ensuring that the team is responsive to changing circumstances and conflict.

Overall Team Performance

Ultimately, the ways that teams struck a balance between these subject areas affected how well they satisfied their internal and competition goals.

When understanding team dynamics and performance, personality can play a large role in how the team is affected based on the team member's personality. Introverted individuals may contribute valuable insights and solutions, particularly in problem-solving scenarios that require careful consideration and analysis. However, their reluctance to speak up in group discussions may result in their ideas being overlooked or undervalued if not provided with opportunities to share their thoughts. Extroverted individuals may readily share their ideas with their team members and can positively influence team morale and motivation. However, this may also lead to others being overlooked, or a lack of consideration for those less likely to speak.

In addition, Student B describes feeling at ease and finding his team approachable, an environment where he feels comfortable voicing his opinions. Student E says that there were no instances of feeling unsafe or discomfort in speaking up, though she acknowledges growing confidence over time. Student D expresses feeling valued and comfortable within the team, particularly in her role as a high-level member which emphasizes the importance of approachability and mutual support. These varied experiences demonstrate the significance of psychological safety within the team, where team members feel comfortable expressing their thoughts, ideas, and concerns without fear of judgment. This type of environment allows for open communication, growing trust among team members, and increased collaboration. This ultimately enhances team productivity, and when individuals feel psychologically safe, they are more likely to contribute their unique perspectives, engage in constructive dialogue, and work together to maximize the team's overall performance.

Recommendations

Engineering design teams are an enjoyable part of the student experience, and some general practices can be implemented by the University to ensure these projects continue to provide a psychologically safe space. Based on the student's responses regarding conflict, an effort should be made to build leadership and conflict management into curriculum early in college coursework. Doing so would give students elementary tools for navigating disagreements prior to joining design teams, thus equipping them to prevent some conflicts before they arise and appropriately handle the ones that persist. To address students' concerns that getting ahold of their project advisors was difficult, faculty members can support their teams by having set times for communication - perhaps participating in some form of project office hours, and by making an effort to attend team-wide meetings. Finally, team members themselves can also take steps to help

fellow students feel more comfortable. Firstly, they should prioritize strong team on-boarding for new members so they can ask technical questions, observe the team culture, and simply build friendships in a casual environment. This will also expose them to the lab spaces they will be working in, which students cited as critical to camaraderie and project success. Carrying out the on-boarding in small groups over multiple sessions may help make the process less intimidating for new students.

Limitations

The primary limitation to this study is that there were only five students interviewed. While significant effort was made to capture the perspectives of students with very diverse experiences and backgrounds, the lower quantity makes it difficult to make absolute suggestions about improving these design project experiences.

Positionality

The interviews and thematic analysis were performed by the first two authors, who are current graduate and undergraduate, respectively, engineering students at UCI who participated in these engineering design projects as undergraduate engineering students at UCI. The last two authors are the co-coordinators for the projects and advise multiple projects.

Conclusion and Future Work

Engineering design teams are a unique stepping stone between academics and industry and each one provides its students with a different experience. To learn more about how these teams can serve their diverse members, five students from different projects were interviewed about their team environments. The interviews lasted for about thirty minutes to an hour and their responses were first deductively and then inductively coded. Students generally enjoyed their projects and explained that spending extensive time together, openly addressing conflicts, and working in sub-teams or small groups were all conducive to psychological safety and contributed to meeting their desired goals. In the future, teams can benefit from conflict resolution skills being more deeply integrated into regular engineering coursework, thorough on-boarding processes, and defining clear internal goals at the onset of projects. Additionally, faculty members can assist their teams by reinforcing that they are willing to make time to support their students. Going forward, this study should be expanded to include more student testimonies and more diverse majors.

References

[1] ABET: Criteria for accrediting engineering programs. [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/

[2] M. J. Riemer, "Communication skills for the 21st century engineer," *Global J. of Engng. Educ*, vol. 11, no. 1, pp. 89–100, 2007.

[3] J. A. Donnell, B. M. Aller, M. P. Alley, and A. A. Kedrowicz, "Why industry says that engineering graduates have poor communication skills: What the literature says," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2011.

[4] S. G. Adams, C. R. Zafft, M. C. Molano, and K. Rao, "Development of a protocol to measure team behavior in engineering education," *Journal of STEM Education: Innovations and Research*, vol. 9, no. 1, 2008.

[5] S. Adams and G. Okudan, "A comprehensive model for student design team formation and performance in the engineering classroom," in *Proceedings of International Conference on Engineering Education, July*, 2003, pp. 21–25.

[6] M. Klein, "Capturing design rationale in concurrent engineering teams," *Computer*, vol. 26, no. 1, pp. 39–47, 1993.

[7] R. M. Felder and R. Brent, *Teaching and learning STEM: A practical guide*. John Wiley & Sons, 2016.

[8] M. L. Pertegal-Felices, A. Fuster-Guilló, M. L. Rico-Soliveres, J. Azorín-López, and A. Jimeno-Morenilla, "Practical method of improving the teamwork of engineering students using team contracts to minimize conflict situations," *IEEE Access*, vol. 7, pp. 65 083–65 092, 2019.

[9] D. Novick, M. Realyvasquez, and S. Palacios, "Teaching engineers the leadership skill of conflict resolution," in *2022 ASEE Annual Conference & Exposition*, 2022.

[10] L. Schibelius, O. Ryan, and S. Sajadi, "Student perceptions of teamwork, conflict, and industry preparedness in engineering interdisciplinary capstone design," in *2023 IEEE Frontiers in Education Conference (FIE)*. IEEE, 2023, pp. 1–9.

[11] M. Borrego, J. Karlin, L. D. McNair, and K. Beddoes, "Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review," *Journal of Engineering Education*, vol. 102, no. 4, pp. 472–512, 2013.

[12] M. C. Paretti, J. J. Pembridge, C. Brozina, B. D. Lutz, and J. N. Phanthanousy, "Mentoring team conflicts in capstone design: Problems and solutions," in *2013 ASEE Annual Conference & Exposition*, 2013, pp. 23–899.

[13] A. Edmondson, "Psychological safety and learning behavior in work teams," *Administrative science quarterly*, vol. 44, no. 2, pp. 350–383, 1999.

[14] B. Beigpourian, F. Luchini, M. Ohland, and D. Ferguson, "Psychological safety as an effective measurement in engineering classrooms," in *2019 ASEE Annual Conference and Exposition Proceedings*, 2019.

[15] B. Beigpourian, M. W. Ohland, and D. M. Ferguson, "Effect of psychological safety on the interaction of students in teams," in *2020 ASEE Annual Conference and Exposition Proceedings*, 2020.

[16] S. Miller, J. Marhefka, K. Heininger, K. Jablokow, S. Mohammed, and S. Ritter, "The trajectory of psychological safety in engineering teams: A longitudinal exploration in engineering design education," in *ASME 2019 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers Digital Collection, 2019.

[17] C. Cole, J. Marhefka, K. Jablokow, S. Mohammed, S. Ritter, and S. Miller, "How engineering design students' psychological safety impacts team concept generation and screening practices," in *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, vol. 83976. American Society of Mechanical Engineers, 2020, p. V008T08A026.

[18] S. Scarpinella, C. Cole, S. Ritter, S. Mohammad, K. Jablokow, and S. Miller, "Can we get an intervention, please? the utility of teaming interventions on engineering design student psychological safety," *Journal of Mechanical Design*, vol. 145, no. 8, p. 082301, 2023.

[19] D. Copp, A. Hormaza Mejia, M. Walter, and N. Buswell, "Whom are we serving? an exploration of student demographics in a large engineering design projects ecosystem," in *2020 ASEE Annual Conference & Exposition*, 2020.

[20] D. A. Copp, A. Hormaza Mejia, M. E. Walter, and N. T. Buswell, "Team formation and function decisions and student roles on diverse engineering design teams," in *2021 ASEE Annual Conference & Exposition*, 2021.

[21] Zoom. [Online]. Available: https://zoom.us/

[22] R. O'Donovan and E. McAuliffe, "Exploring psychological safety in healthcare teams to inform the development of interventions: combining observational, survey and interview data," *BMC health services research*, vol. 20, no. 1, pp. 1–16, 2020.