Interpersonal Interactions that Foster Inclusion: Building Supports for Diversity in Engineering Teams

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Project Motivation

Teaming is a core part of engineering education, especially in the first and last years of engineering when project work is a prevalent focus. There is significant prior literature on engineering teams, but the effects of incorporating diversity into teams are understudied [1]. It is important to understand not only the practical outcomes of working in diverse teams, but also how the experience of working in diverse teams influences whether students see themselves as engineers and whether or not they feel they belong in engineering. Our project, "Building Supports for Diversity through Engineering Teams (NSF EEC-1531586/1531174)," investigates how students' attitudes towards diversity influence how they experience working in diverse teams through addressing two main research questions: 1) What changes occur in students' diversity sensitivity, multicultural effectiveness, and engineering practices as a result of working in diverse teams? 2) How do students' perceptions of diversity, attitudes about diversity and teaming, and engineering practices change because of working on diverse teams? Using a multi-method approach, we examined student's initial attitudes about diversity, how these students worked in diverse teams, and how their first-year engineering course and experience shaped their attitudes about diversity and teaming.

The results of our study can help explain some of the complexity in the conflicting literature on diversity in teams. Ultimately, this research will help us understand how to build inclusive and diverse environments that guide students to learn how to understand their own complex relationship, understanding, and enactment of diversity in engineering. By understanding how students make sense of diversity in engineering spaces, educators and researchers can better understand how to introduce these concepts in relevant ways so that students can inclusively meet the grand challenges in engineering. This curriculum integration, in turn, can improve team interactions and the climate of engineering for underrepresented groups.

Background Literature

Engineering is collaborative and requires students to develop skills in teaming and inclusivity. The new ABET student outcome, Criterion 3, objective 5, requires students be able to "create collaborative and inclusive environments to effectively solve complex problems and meet ethical and professional responsibilities" [2]. The new objective 5 replaces the former outcome d) which only focused on students' abilities to function on interdisciplinary teams [2]. This shift in required student outcomes for accredited engineering programs emphasizes the importance of developing diverse collaboration skills in engineering graduates.

Despite the clear need for inclusive teaming practices, the findings from research on the outcomes of working in diverse teams indicate both positive and negative student experiences. Positive research findings of diverse teams include more divergent thinking, increased productivity, and better quality of end-products [3]-[5]. Some negative research findings include decreased student affect in diverse teams, more frustration in these teams, and more sustained conflict throughout the teaming experience [6],[7]. Together, these findings illustrate that

successfully forming diverse teams that effectively work together, appreciate each other's differences, and develop engineering teaming, communication, and diversity sensitivity within engineering classrooms is a complex issue.

Students are influenced by their prior experiences and bring those experiences and their attitudes about diversity with them into the engineering classroom. Students are often placed into teams without consideration for these incoming attitudes or instruction on how to interact with others who are different from them in engineering. Often, instructors expect students to acquire teaming skills through their experiences without explicit scaffolding and instruction. There is a significant amount of research on how effective teams can be coached and assessed; however, little research has been conducted on how students interact with one another in diverse teams or how those interactions shape their attitudes about diversity or students experiences of belonging or exclusion in teams [8]-[10]. Our project focuses on these interpersonal interactions to better understand how diverse teams can be formed, taught, and monitored to promote inclusion in the engineering classroom.

Project Overview

To investigate how interpersonal interactions in team's shape students attitudes about diversity and influence their experiences of belonging in engineering, we conducted an in-depth multi-methods study at two U.S. institutions. This study was broken into two sequential phases with the first focused on collecting data streams during classroom instruction (including pre- and post-survey measures of attitudes and social networks, team effectiveness ratings, observations of teams working on engineering design, and teaming journals from observed teams). The second phase focused on post-teaming interviews about students' backgrounds and teaming experiences as well as measures of students' implicit bias. Together, these multiple streams of data, shown in Figure 1, begin to paint a rich picture of particular challenges students face in building inclusive teams and opportunities to better support engineering students in team interactions.

Institutional Contexts

This multi-institutional multi-methods investigation included two different institutions. University 1 has a large international student population when compared to United States public universities and universities outside the United States. The large international population makes first-year student teaming experiences interesting due to the increased possibility of interacting and working in teams with students from different backgrounds and cultures. University 2 provides an alternative perspective on diversity that is not as readily prevalent in many other engineering institutions. Nearly 24% of the student population qualifies for Pell Grants and approximately 35% of students have been identified as first-generation college students. These diversity statistics are in addition to above average engineering enrollments of students self-identifying as Hispanic (14%) and multiethnic (5%).
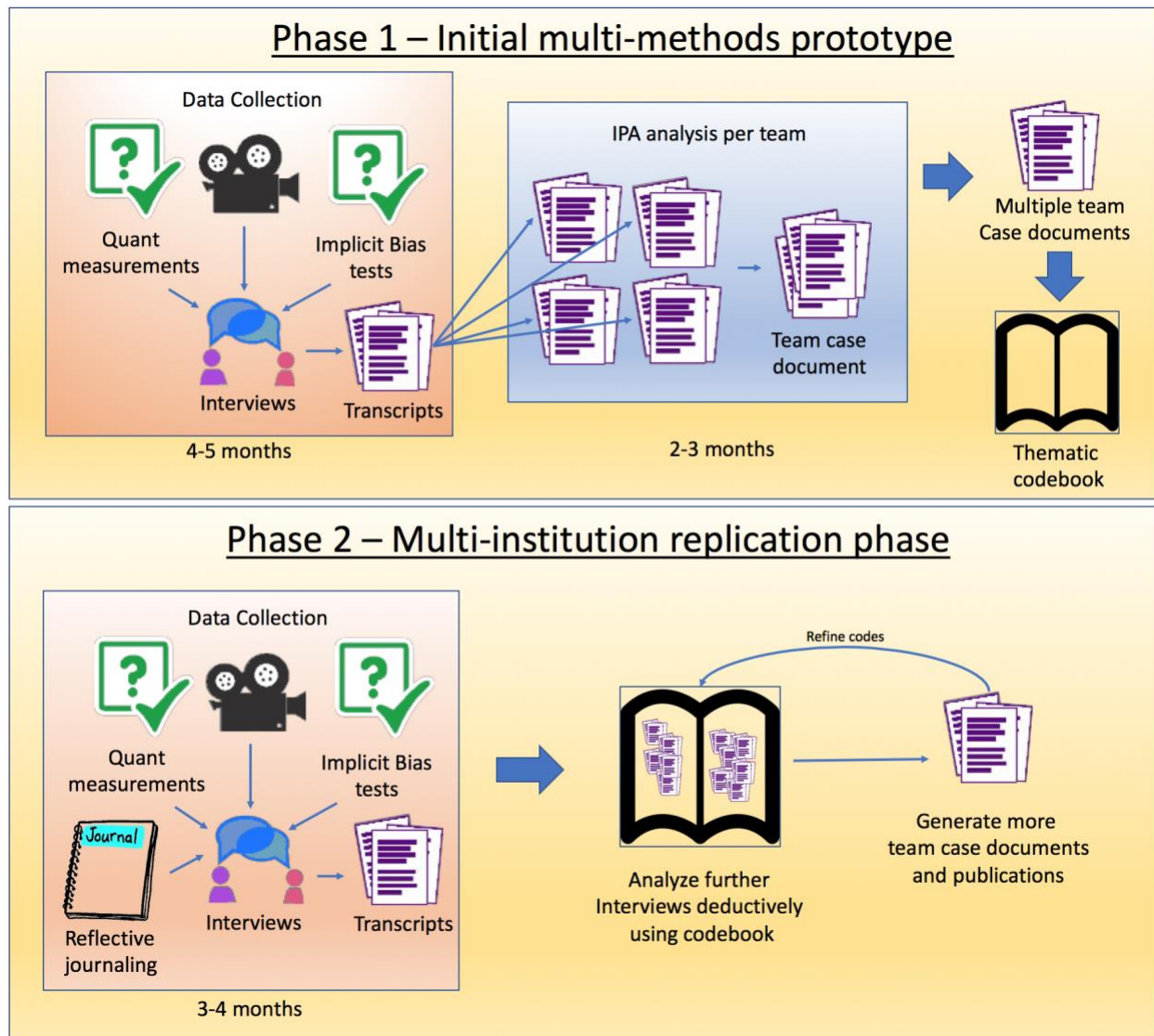
Figure 1. Figure depicting the multiple phases of our research study over the last two years.

Data Collection Procedures

Phase I

We recruited 2,576 participants across both institutions. A pre- and post-semester survey instrument were deployed in Fall 2015 at the first institution and Fall 2016 at the second institution to understand student's shifts in their multicultural openness, teaming effectiveness and diversity sensitivity. Both institutions also used CATME Team-Maker to assign students to teams and to collect peer-ratings of students' teammates.

Additionally, students completed three self-report social network surveys over the course of the semester of who they worked with on engineering tasks. The social network data allowed us to evaluate and characterize the social structure of the engineering learning environment.

Multiple time points allowed us to study how the social structure developed and changed over the course of the semester [11].

We used the results of the pre-survey to select teams to observe. The student teams (4-6 members each) were chosen to maximize the diversity (e.g., race, ethnicity, gender, international status, disability status) in each team as well as to observe teams with low, medium, and high diversity sensitivity measures on the pre-survey measures. We observed five teams at University 1 and three at University 2. Teams were observed three different times during the semester while engaged in engineering teaming activities. We audio and video recorded student interactions and took detailed field notes. Students consented to these observations and were aware of data collection occurring. During observations, we focused on students' communication and associated body language [12]. We collected the work produced in these teams as artifacts of their teaming process. Finally, students in each of these teams completed a journal reflection about their teaming experiences and inclusive or exclusive behaviors in their engineering teams. The journals also served as a source of triangulation for the data.

Phase II

In the second semester of each academic year, we invited individuals from the teams observed in the first phase to participate in one-on-one interviews. These students completed two approximately hour-long interviews with a member of the research team. The first interview focused on students' background and experiences prior to college. This focus allowed us to elicit students incoming attitudes about diversity and teaming. The second interview focused on their experiences within their engineering team. We asked about experiences that we directly observed as well as interactions outside of class. These team members also took an Implicit Association Test to reveal hidden biases that may have manifested in teaming interactions [13].

Results to Date

Phase I

Results from comparing the pre- and post-surveys of students' multicultural openness, teaming effectiveness, and diversity sensitivity show some troubling findings. We found that students' awareness of diversity increased; however, unwillingness to take action to support diverse groups also increased. We also found that students' attitudes towards teaming are "sticky" and difficult to shift over a single-semester experience even when teaming effectiveness and diversity are explicitly taught in the classroom [14]. Our findings indicate the teaming experiences and discussions of diversity need to be deliberate and distributed throughout the engineering curriculum. This work opens the conversation about how we teach and train engineers to work in diverse teams in first-year programs and beyond. Students also showed a decrease in team ratings of their effectiveness over the course of the semester. This decrease may not be an overall reduction in students' effectiveness in teams. In fact, student reflections on teaming activities and cases of conflict in teams decrease over the course of the semester. Instead, we believe that this shift occurs as students learn more about what it means to be a good team member, become more comfortable giving their peers feedback and subsequently deliver ratings that are more realistic.

As part of understanding students' perceptions of working on diverse teams, we have been paying close attention to how students interact in diverse teams. Studying the social network of a multi-section first-year engineering course revealed that students form and maintain social ties that span across various sections of first-year engineering and are inclusive of both race and gender [15]. These results suggest that the often-reported chilly climate in engineering may be warming towards diverse individuals. Together this has reaffirmed the research projects objectives to better understand how students learn to work as a team while being inclusive of diverse team members. This approach allows us to probe the way students work together both inside and outside of the engineering classroom, further expanding our understanding of what constitutes a diverse "team."

In this phase, we have unpacked the attitudes and experiences most influential to successful teaming experiences in diverse teams. We have also begun investigating the social networks students leverage in a first-year engineering course to understand how the underlying social structure affects the inclusion of diverse students [7]. Together, these findings provide valuable points for educators to incorporate explicit and effective instruction on diversity and teaming in their engineering courses.

Phase II

At University 1, we analyzed 10 interviews using Interpretative Phenomenological Analysis (IPA) [16]. IPA seeks to understand the subjective lived experiences of individuals [16]. Here we sought to understand how participants interpreted the phenomenon of working in diverse engineering teams. This process generated rich, deep results, but was extremely time intensive. From the emergent IPA themes found at University 1, we generated a codebook allowing us to implement deductive coding on subsequent interviews at University 2. The codebook included higher order themes such as Teaming, Social Interactions, and Diversity and sub-themes such as Leadership, Team Trust, and Approaches to Social Situations, along with exemplars [17]. The tradeoff in depth by switching to a deductive codebook analysis method allows us to find quickly compelling student interviews and teams and allows us to efficiently find and create new themes of interest as well.

Results from the qualitative portion of this study have uncovered valuable findings. We have learned that student's perceptions of diversity are as diverse as the students themselves. Their perceptions of diversity are based largely on experiences they have had before coming to college, which is consistent with findings from prior literature [18], [19]. Based on our IPA analysis, students defined prime attributes of diversity as gender, socioeconomic class, sexual orientation, race and ethnicity, political views, disability or medical diversity, and religion, to name a few. Other superordinate themes found in the interview data include social interactions, strategizing of possible futures, family, and the dynamics of the space in which engineering teams worked.

We have begun to understand how student's notions of diversity coalesce into a team conception of diversity, and how the alignment among those contributes to differing experiences in diverse teams. We have found that one semester of a diverse first-year engineering course is not long enough to affect a major shift of students' espoused values of diversity. These attitudes are also "sticky" (e.g., difficult to change) and may be harmful to others in the team [6]. At the same

time, one semester of experiences in a diverse engineering team does begin to chip away at narrow viewpoints.

Our qualitative data bear out that over the course of the semester some students become more open. Using Peirce's theory of vagueness from the field of semiotics we traced how students expand their understanding of diverse people because of experiences in the classroom, leading to a clearer, or less vague, understanding of diversity [20]. For example, Mohit, an international student entering our American first-year engineering classroom refined and reformed his understanding of how an engineering student dresses. The process of re-forming his understanding of an engineer's dress led to a more flexible understanding, one that fits the context he was now experiencing. Based on the theory of vagueness, this omission or flexibility of what an engineer looks like can lead to more open-mindeness because the student has reduced the recognizable (or visual) characteristics of an engineer, leaving open space for new meaning to be generated [21]. This finding, reflected in our qualitative data, shows that some changes in a direction of more openness are possible.

We found that for students to develop positive attitudes about diversity, their definitions, valuations, and enactments of diversity across the team needed to be aligned. We have named the relationship between these three components "diversity compass" because they guide student's interactions, both positive and negative, in diverse teams. We found students have different conceptions of what diversity is and different thoughts on its usefulness in engineering teams. The more similarly oriented the students are, the easier they are able to come together inclusively, working smoothly towards a common goal. Students' definitions and valuations of diversity guide their enactment of it in engineering, influencing team dynamics, team goals, and ultimately how inclusive and collaborative teams are. This affects the individual experiences of team members, influences the quality of their solutions, and affects their ability to ethically and responsibly solve complex problems. Student's diversity compass affects team interactions and, ultimately, the climate of engineering for underrepresented groups.

Conclusions

The two main research questions we asked initially in this project were 1) What are individual student's perceptions of diversity? and 2) What are student's perceptions of working on diverse teams? We found many different ways first-year students at a large public land grant institution understand and perceive diversity. We have found that these definitions of diversity and the value students place on those definitions translates to how they enact their understanding in diverse engineering teams. While some student teams have very pragmatic ways of leveraging diversity in engineering teams (e.g. to split work up and complete an assignment together) other teams go beyond the pragmatics of solving the problem at hand and invoke social interactions to get to know their team members. Different enactments of diversity in student interactions as negotiated by different teams lead to different levels of inclusivity, and thus different experiences for students.

Across phases of this study, we have refined our research tools and methods, honed in on contextual differences between research sites, and leveraged research results to more deeply probe how students perceive working in diverse teams. This evolution has allowed us to better

understand how students appreciate and define diversity, and how they work in diverse teams. More nuanced answers to these questions provide rich results that help clarify some of the conflicting literature on students in diverse teams. Since students perceptions of diversity are largely based on previous experiences, modifying these 'sticky' attitudes is not a straightforward proposition. These rich results tell us that simply putting students in diverse teams is not enough to create positive teaming experiences. Students develop more awareness of diversity but do not feel any more inclined to take action to create a more inclusive environment. Even in the face of explicit class instruction in purposefully diverse teams, students do not foster an inclusive environment [6], [14]. In our future work, we hope to explore possible interventions that help address this lack of action, such as explicit conversations about cognitive diversity and identity diversity. This may affect how students conceptualize diversity, enabling them to act differently when working with diverse team members.

Future Research

Future research for this project will focus on replicating this study at another institution that is distinct from the current institutions in the study (i.e., not a predominantly white, public, land-grant institution). Replicating this study at another institution will augment and refine our codebook as we continue to understand students' diverse definitions of diversity. This approach will also allow us to understand if the particular discussions of diversity and teaming are consistent across engineering contexts or if there are particular challenges in different regions.

We also plan to explore particular interventions to support students' growth in their understanding of diversity. We found a wide variance in student's enactment of diversity in the engineering classroom. Engineering is a highly technical field and focuses primarily on technical challenges. Effectively integrating diversity and inclusion in engineering curricula can be difficult because as a culture, engineering values technical prowess over social concerns [22]. This issue is exacerbated by the different viewpoints about diversity and meaning-making strategies students show up with to the classroom.

Previously, we found that students in more diverse teams became more aware of diversity over the course of the semester but were less inclined to act on that knowledge [23]. We also found that students develop a team understanding of diversity to finish tasks using divide and conquer methods [1]. Those conceptions of diversity affect team members experiences. Through our research, we will continue to investigate students' diversity compasses, which guide students' interactions in diverse teams, so that we may effectively educate students regarding the importance of diversity in engineering. Student's social networks indicate high levels of inclusivity in first-year engineering classes. We will continue to use social network analysis to understand how students occupy their networks and will combine this analysis with our other data sources to investigate social interactions within the network.

Acknowledgments

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