

Building Supports for Diversity through Engineering Teams

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Project Overview

Engineering is a globally focused career with the need to work with people from diverse backgrounds. Significant research and tools have been designed to develop and assess team member's effectiveness¹; however, despite the emphasis on the importance of developing engineering students' teaming skills, little research has been conducted on how students develop sensitivity for students from different cultures and backgrounds within teams in first-year engineering programs. Here we define diversity sensitivity as students' multicultural openness (i.e., openness to other cultures, experiences, and ways of being) and actions taken to incorporate diverse students within students' teams. To address the lack of literature on diversity and teaming this work examines the following research questions: What changes occur in students' diversity sensitivity, multicultural openness, and engineering practices as a result of working in diverse teams? How do students' perceptions of diversity, affect, and engineering practices change as a result of working on diverse teams?

This research addresses these questions through the implementation of three research phases:

- Phase 1: Examination of the development of student diversity sensitivity and multicultural openness of engineering students as a result of working on diverse engineering teams.
- Phase 2: Understanding of the development of social networks in first-year engineering courses
- Phase 3: Replication of Phases 1 and 2 at institutions that are culturally distinct from the institutions of the previous phases.

The focus of this paper is on the first phase of this three phase project, in which students' multicultural openness, diversity sensitivity, and teaming effectiveness were measured at the beginning and end of a first-year engineering experience working in diverse teams. We also present results from qualitative in-depth interviews with selected students to further explain emerging trends from the quantitative results of this work.

Background

In recent decades, engineering has begun to require working with people from a variety of technical and diverse backgrounds. Researchers seeking to improve students' teaming skills have found successful ways to assess team member effectiveness and help develop skills to work in teams¹⁻³. Researchers have also striven to provide support for students in engineering from underrepresented groups for better inclusion in engineering⁴⁻⁶. Despite these efforts, the numbers of underrepresented groups in engineering have not increased proportionately to the effort expended by the community.

Additionally, little research has been conducted on how students develop sensitivity to students from different cultures and backgrounds within engineering teams in first-year engineering programs. In an increasingly global economy, the development of diversity sensitivity and ability to work with a variety of people is of utmost importance. Today, mostly homogeneous engineering teams are no longer able to deal with ever diversifying customer needs. Thus, the issue of underrepresented groups in engineering is achieving more economic and political relevance⁷. Inclusion of underrepresented people can capture a wider variety of ideas and lived experiences^{8,9}, be more representative of customers^{10,11}, lead to more innovation^{12,13}, and meet workforce needs more fully^{14,15}.

Research findings on working in diverse teams are mixed. Some research on professionals working in diverse teams has shown that virtual meeting is better for diverse teams than face-to-face meetings initially to develop teaming skills across cultures^{16,17}. This phenomenon may be true of practicing engineers from across the globe, but in engineering classrooms, students interact in teams within physical spaces. Therefore, understanding how these peer-to-peer interactions occur and what factors can improve understanding of diversity in engineering teams is a needed area of research. Additionally, heterogeneous teams have been shown to outperform their homogeneous counterparts on divergent-thinking and creativity. However, the inclusion of diversity on these heterogeneous teams also decreases affect, possibly due to diverse approaches to problems and a more frustrating experience for diverse individuals to work together¹⁸. 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.

In this research, we use the lens of cultural diversity to understand how students interact and develop diversity sensitivity and multicultural openness within their teams. Cultural diversity refers to the representation of people with distinctly different group affiliations of cultural significance¹⁹. Prior research suggests that there is a seemingly universal human tendency to respond positively to others like us and negatively to dissimilar groups²⁰⁻²¹. Additionally, groups have to work through a number of stages before they can be successful as a team²². Participants usually start in a state of high member uncertainty and search for common goals, work to develop group norms, begin to exchange information, and if effective, stabilize into team roles. Teams are only able to achieve these steps if they develop a common identity within a group²¹. Members of diverse teams come from a variety of social identities based on their backgrounds, cultures, and prior experiences. To develop this group identity, members of diverse groups need to develop diversity sensitivity and multicultural effectiveness which aid in integrating individual cultural identities into a group identity. This integration occurs early on in team formation processes²³ and is vital to team effectiveness.

Data Collection

Data Collection Sites and Population Descriptions

First-year engineering courses at two land-grant institutions were studied to understand the engineering teaming experiences of students. Institution One has a large international student population²⁴. This international population makes first-year student teaming experiences particularly interesting due to the increased possibility of interacting and working in teams with students from different backgrounds and cultures. Additionally, Institution One is on track to graduate 5% of the nation's engineering students in the near future²⁵. Changes at this university in representation can have dramatic impacts on the future of engineering in the U.S.

Institution Two provides an alternative perspective on diversity. Nearly 24% of the student population at Institution Two qualifies for Pell Grants (approximate household income under \$30,000²⁶) and approximately 35% of students are first generation²⁷. These diversity statistics are in addition to above average engineering enrollments of students self-identifying as Hispanic (14%) and multiethnic (5%).

Quantitative Data Collection and Analysis

Survey data were collected from participants enrolled in first semester first-year engineering programs at the described institutions ($n = 1206$) twice during the semester (pre and post) as well as data from the Comprehensive Assessment of Team Member Effectiveness (CATME; $n = 2763$ inclusive of survey participants). We utilized the CATME tool to group students in first-year engineering programs at both institutions into diverse teams²⁸. CATME Team-Maker generates team assignments based on a variety of criteria including sex, race/ethnicity, and English as a first language. Thrice during the semester students were asked to rate themselves and their teammates on their teaming effectiveness using the CATME Peer Evaluation. We used linear modeling, advanced clustering techniques, and pre-post comparisons to understand underlying student attitudes as well as the ways in which students' attitudes may shift over the course of the semester.

Qualitative Data Collection and Analysis

Additionally, five teams were observed throughout the course of the semester. These teams were chosen to maximize the variation of diversity sensitivity as well as the composition of the team by racial/ethnic, gender, nationality, and disability identities. These observations were conducted to understand how students interact in ways both explicit and implicit that may or may not improve belongingness in engineering during teaming activities. Students from teams were interviewed individually two times after the completion of their project to understand their perceptions of diversity.

Addressing how student teaming experiences influence students' diversity sensitivity and multicultural openness can uncover how we can train engineers to work to include diverse

individuals in engineering and potentially warm the chilly climate in engineering. Creating environments and individuals who are fostering of and open to diversity can serve to generate engineers who are capable of designing for diverse needs when addressing the grand challenges in engineering. The next phase of this study will include an expansion at additional institutions.

Results

Awareness without Action

Quantitative results indicate that students' awareness of diversity increased over the semester; however, unwillingness to take action to support diverse groups also increased. We also found that students' attitudes towards teaming are difficult to shift over a single-semester experience even when teaming effectiveness and diversity are explicitly taught in the classroom. Student attitudes about teaming are "sticky," that is, they do not easily change over the course of one semester even with explicit instruction and interventions.

Initial trends indicate that students' value of diversity increased, but their willingness to adapt their behaviors for diverse individuals decreased due to the demands of engineering tasks. Students became more aware of differences and the impact of diversity on working in teams. However, they were more likely to engage in biased behavior as well as be unwilling to take action to support diverse individuals. Analysis of survey results reveal four trends: 1.) Students felt like it was less important to clearly notice and define racial and ethnic differences in their teams; 2). Students reported less discomfort in working with students who do not speak standard English; 3). Students reported less importance of showing diverse engineers in course materials and indicated that it was NOT the responsibility of instructors to teach about diversity; and 4). Students experienced higher levels of frustration working in diverse teams and indicated higher preferences to work with individuals like themselves. These trends indicate a higher awareness of diversity but a lack of agency or motivation to combat bias or to grapple with difficult topics.

Students with the largest positive shifts in teaming attitudes (top quartile) were more often assigned to diverse teams. Diverse teams are defined by having individuals different in race/ethnicity, gender, and nationality than each individual within the team. Students were also less likely to exhibit the largest negative shifts in teaming attitudes (bottom quartile) if they had positive shifts in their multicultural awareness - openness. Results of this quantitative work were used to further refine instruments and data collection protocols for replication in the subsequent phases of the project.

Diversity Orientations

Qualitative results indicate that students consistently described why diversity was important in their teams and in engineering as a field. These descriptions reflected conversations within their

classes and the language used by instructors to discuss why diversity and working in teams were important learning objectives in the courses. However, when talking about their teaming experiences specifically, these students became exclusively task focused and only valued diversity in terms of dividing tasks according to each individual's skills and the ability to accomplish assignments efficiently. Further analysis has also indicated that for students to work with and prioritize diverse individuals they need a coherent connection between three aspects of their “diversity orientation” which includes not only a value for diversity but also a definition of diversity that they connect to teaming and the ability to connect diversity to specific engineering tasks. Without any one of these three components, engineering teams did not integrate diverse individuals and develop their understanding and sensitivity toward diverse individuals.

Conclusions and Discussion

Our results show that students became more aware of diversity over the course of their experiences in working with diverse teams. However, they also became less willing to act to support diverse individuals and often prioritized engineering tasks over incorporating the diverse perspectives and non-engineering skills of individuals in their teams. For individuals and teams to prioritize their development of positive attitudes of diversity, a complex interaction of three factors is needed. The interaction between these factors indicated that teaching about the value of diversity alone is not enough, but that the value of diversity must be attached to the specific engineering tasks that students undertake. Our work emphasizes that teaming must be a deliberate and distributed practice in engineering not only limited to the first and last years of engineering curriculum. The results mirror previous findings in engineering that have displayed dominant cultural valuing of student technical performance over social development²⁹, and that students will not work to understand different concepts unless they can connect it to their careers in the future³⁰.

Future Work

Diversity sensitivity and diversity orientations manifest differently across teams. Further analysis of teaming experiences is ongoing to understand why some teams prioritize diversity and others do not. Additionally, the next phase of this work has begun to explore the social networks that exist within first year engineering classrooms and how these networks incorporate or exclude diverse individuals from participation in engineering. Further development of these findings will allow for the generation of pedagogies and interventions that serve to positively foster students attitudes towards diverse populations and hopefully serve to shift the culture of engineering to one that is more inclusive.

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