Understanding How First-Year Engineering Students Create Effective, Collaborative, and Inclusive Teams

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Tara C. Langus is a Ph.D. student pursuing her degree in STEM Education at the University of Nevada, Reno (UNR). Prior to graduate school, she completed Bachelor's and Master's degrees in Biology in which she studied insect immunology and chemical ecology. She has six years of teaching experience and serves as the instructor for the Women in Science & Engineering Program (WiSE), an academic based resource and professional development program for first-year undergraduates pursuing STEM majors. Her research interests include student attitudes toward diversity, integrating socioscientific and sociopolitical issues in the college STEM classroom, and increasing the representation and retention of underrepresented minorities in STEM.

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Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She has won several awards for her research including the 2016 American Society of Engineering Education Educational Research and Methods Division Best Paper Award and the 2018 Benjamin J. Dasher Best Paper Award for the IEEE Frontiers in Education Conference. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and the Purdue University 2018 recipient of School of Engineering Education Award for Excellence in Undergraduate Teaching and the 2018 College of Engineering Exceptional Early Career Teaching Award.

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Adam Kirn is an Assistant Professor of Engineering Education at University of Nevada, Reno. His research focuses on the interactions between engineering cultures, student motivation, and their learning experiences. His projects involve the study of student perceptions, beliefs and attitudes towards becoming engineers, their problem solving processes, and cultural fit. His education includes a B.S. in Biomedical Engineering from Rose-Hulman Institute of Technology, a M.S. in Bioengineering and Ph.D. in Engineering and Science Education from Clemson University.

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This executive summary describes the recent findings and emerging trends for the mixed methods project Building Supports for Diversity through Engineering Teams (NSF EEC 1531586/1531174). The goal of this project is to investigate first-year engineering students' attitudes, beliefs, and perceptions of diversity before and after working in diverse engineering design teams. The engineering challenges facing our increasingly global society are beyond the capabilities of any single engineer, and thus must be solved utilizing the skills and expertise of a diverse group of engineers working in inclusive and collaborative teams. Previous work has demonstrated that the experience of working on diverse teams leads to both positive and negative experiences for students, especially those from underrepresented groups in engineering (e.g., women, racial minorities, LGBTQ+ students, and students with disabilities) [1]–[5]. For example, a group of diverse problem-solvers will routinely outperform a homogeneous group [6]; however, diversity may lead to increased conflicts in teaming scenarios, resulting in less effective teams and problem solutions [7]. To better understand how the experience of working in a diverse engineering team shapes students' perception of diversity, our guiding research questions are: 1) What changes occur in students' diversity sensitivity, multicultural effectiveness, and engineering practices as a result of working in diverse teams? and 2) How do students' perceptions of diversity, affect, and engineering practice change because of working on diverse teams?

Synopsis of Prior Work

Our previous work has synthesized findings from pre- and post-surveys of students' attitudes about diversity, multicultural openness, and identities as engineers; social network analysis of an open engineering lab; peer and self-ratings of their teaming performance; classroom observations; and semi-structured interviews with students. These data were collected at two public, predominately White-, research-focused institutions in the U.S., one located in the Midwest and the other in the West. The data collected at the Midwest institution were gathered in the academic year 2015-2016, while data was collected during the 2016-2017 academic year at the western institution. Between rounds of data collection, the procedures were updated.

Our work to date indicates that students' attitudes about diversity are difficult to shift towards greater inclusivity within a semester-long experience, even with explicit instruction and instructor support [8]. Furthermore, we have shown that working with diverse peers is an integral part of developing openness towards diversity, reaffirming that the experience of working with diverse peers is a vital step in the process of creating inclusive engineering environments [9]–[13]. However, we have shown that working in diverse engineering teams alone does not ensure an inclusive environment. Together these findings indicate that working in diverse teams is

essential for student development, but the dynamics of these teams is complicated with both positive and negative dimensions. These results indicate the necessity of studying peer-to-peer interactions within teams.

Further, there is a need to develop more effective ways to prepare students to work effectively in diverse teams. Articulating effective teaming practices for diverse teams has the potential to improve the academic and personal experiences of engineering students. We describe findings from our previous data in detail below.

Through a case study of four diverse engineering design teams at the Midwest institution, we examined how diverse first-year engineering teams negotiated personal and team level understandings of diversity [14]. This case study highlighted that first-year engineering students value diversity. For example, one participant, Ezekiel, stated, "[I]f I'm a part of a team, and we all see it from the same perspective, I get really antsy, and I feel like we're missing something." However, some members of Ezekiel's team were unable to see the benefits of diversity within engineering with one voicing, "I don't know if [the diversity in our team] really affected us because I never had a girl in my engineering group, so I wouldn't know." Throughout the semester, this diverse first-year engineering team did not leverage diversity to complete tasks, prioritizing the technical aspects of engineering over the social welfare of their team members. This approach resulted in some team members compromising their learning to fit in with their team:

> I'm going to figure how to do this on my own at some later point, so I'm doing well with the practical. For now, we need to get the good grade so let's figure out how we're going to get that. (Ezekiel)

In this quote, we see how Ezekiel neglected his need for understanding to satisfy the team's needs, ultimately to his detriment. Rather than considering Ezekiel's needs, or the individual needs of team members, this team prioritized the engineering task rather than the engineering students themselves.

Using the case study as a springboard, the study (i.e., both quantitative and qualitative data collection) was replicated at the West coast institution. Engineering students at the West institution were interviewed about their beliefs and attitudes on various diversity-related topics; interviews ranged from general conceptualizations of and experiences with diversity (e.g., experiences with discrimination) to the specifics of their first-year engineering teaming experiences, mirroring the interviews at the Midwestern institution. Through these personal and often uncomfortable conversations about diversity, participants revealed that having an opportunity to talk candidly about diversity may be a catalyst to shifting attitudes about diversity [15]. Students indicated that the opportunity to discuss the topic of diversity was "mind-boggling

(George)" and made them "think about how [they behave] with other people (Claire)." Other students struggled to understand how diversity and engineering are interrelated expressing that engineering "really has nothing to do with diversity (Lacy)." The insight gained through this qualitative portion highlights that students' attitudes and beliefs about diversity develop gradually and there is still a need for improving how students integrate diversity into engineering practice.

In tandem with these qualitative findings, we analyzed pre- and post-semester attitudinal surveys to quantitatively examine how student attitudes, beliefs, and perceptions of diversity changed throughout a semester of working in diverse engineering teams. Our analysis corroborates the more extensive literature base which states that successfully developing diverse engineering teams is a complex issue [16]–[18]. Our work reveals that while students become more aware of diversity and diversity-related issues over the semester, they also become less willing to enact inclusive practices that support their peers. These results suggest that the experience of working in a diverse engineering team increased the progression of students' knowledge of diversity but reduced sensitivity. Simultaneously, the results also revealed the extent to which engineering culture shaped students' expectations about whether or not discussing diversity and inclusion belong in engineering classrooms[19].

Alongside the exploration of student attitudes towards diversity, we developed a new survey to collect self-reported social network data and conducted a preliminary analysis of the social structure at the West institution [20]. Social network analysis examines the patterns of peer-to-peer interactions rather than the content of the interactions which are studied using qualitative methods [21]. By analyzing the social structure, we learned that students created social ties that bridge formal course boundaries (i.e., social ties between students in other course sections as well as students that were not enrolled in the class).

Recent Activity

In the west coast we continued to explore how students respond to working with diverse peers during their first year of engineering. Using social network analysis we discovered that demographic groups (i.e., gender, race, sexual orientation, ability status) have equivalent levels of social engagement [22]. In other words, student demographics did not predict the level of social activity as measured by network degree (e.g., out- and in-degree). This result suggests that the social structure is broadly inclusive. Building upon this finding, we examined how the structure of social interactions changed throughout the semester; analysis revealed that student social networks become smaller during the middle of the semester (week 9 out of 16) than the beginning of the semester (week 3) then increase to a size similar to the beginning of the semester by the end of the term (week 14).

Our interpretation of these results is that at the start of the semester students were widely social as they met their peers, figured out study groups, and engineering work teams. As the semester continued and the workload increased, students became increasingly isolated and reliant on their assigned team members. This result mirrors our previous findings from the case study at the Midwest institution where Ezekiel and his team focused on their engineering project rather than fostering social interaction. Finally, late-stage expansion in the social network may result from students seeking additional support and assistance to finalize their semester-long design project. Interviews with students from both institutions corroborate this interpretation of the social networks describes above.

To better understand the relationship between the social structure and a student's attitudes about diversity, we examined students' sense of belonging at the beginning and end of the semester. We found that all students start their engineering education careers with a strong sense of belonging to and in an (M = 4.57, SD = .98, 0-6 scale) engineering environment [23]. While all students start with a strong sense of belonging, female students started their engineering education with a small (Male M = 4.65, SD = .98; Female M = 4.38, SD = .98) yet statistically significant [$F(1,468) = 6.497, p = 0.0111$)], reduced sense of belonging. This small deficit in belongingness at the start of the semester was eliminated by the end of the semester. The initial belonging discrepancy suggests that there is still room for improving the perceptions of female engineers in K-12. While these findings provide insight into the overall climate and student attitudes, we utilized qualitative methods to develop a richer understanding of how students develop an understanding of diversity.

From the results of our earlier work indicating a social-technical divide and through our qualitative exploration of students' diversity, we sought to understand how recent national events (i.e., the 2016 presidential election) impacted the engineering classroom and students' understanding of diversity [19]. This research focused on depoliticization (i.e., the removal of social issues) in engineering spaces and the effect of recent national events on first-year engineering students' attitudes about their political identity, social welfare, and perspectives of diversity. In reflecting on the personal impact of recent national events and how political discussions have or have not been integrated into their STEM courses, two themes emerged: 1) political awareness and 2) future-self impact. Findings revealed that first year engineering students recognized the personal and social impacts current national events imposed on their friends, family, and society. However, students did not sense the significance of political discourse concerning the social impact and ethical practice of engineering. Our research shows that limiting political discourse in the classroom and depoliticizing engineering spaces contributed to students dissociating the relevance of political issues that relate to engineering disciplines but also their future selves as engineering practitioners.

Future Work

In the coming months, we will continue to explore how students develop diversity sensitivity and multicultural effectiveness in diverse engineering teams in a different institutional context. We will gather similar data to the existing data from the Midwest and West institutions at an East Coast, private, faith-related institution. This context will allow us to see if the consistent trends at the prior institutions (both public land-grant institutions) replicate in this new institutional context or if the context changes how students develop attitudes about diversity. In seeking to understand the social environment, we will utilize social network analysis along with student demographics (both expressive and latent diversity [24]) to understand how diversity is integrated into the social structure. Through this line of inquiry, we hope to identify which, if any, student demographics are predictors of social activity. While this alone would be a significant contribution to an expansion of the use of social network analysis within engineering education, we plan on combining the social network data with students' attitudinal profiles to explore if their attitudes about diversity predict their social activity. This first step will lead to a deeper understanding of what diversity characteristics, either expressive or latent, work to predict social activity within an engineering environment.

Simultaneously, as we begin to mix the qualitative and quantitative data streams to understand the inclusivity of the engineering classroom, we will synthesize and combine the qualitative results between the two institutions (Midwest and West). This synthesis will allow us to highlight broader student understandings of how working with diverse peers begins to warm the chilly engineering climate. Through the analysis of the cross-institutional qualitative data, we will develop an understanding of diverse teaming within engineering. The discoveries of the aforementioned studies will allow this project to have a more substantial impact in the engineering education community, allowing us to make recommendations for how to educate and support first-year engineering students' attitudes about diversity and working in diverse teams.

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