



Building Diversity in Engineering Competition Teams by Modeling Industry Best-Practice

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Abstract

Each year, thousands of students compete in student, experiential-learning, engineering competition teams (SELECT) to practice and improve their engineering skills. SELECT attract tremendous resources from both industry and academia. Despite considerable efforts over the past decades to recruit and retain women and minorities in engineering, female and minority students still comprise a small portion of SELECT participants.

This paper stems from a multi-year research project to identify and explain which factors contribute to cultures of inclusion or exclusion among various SELECT. We constructed a survey to determine the generalizability of findings obtained from interviews with SELECT teams and enhance our understanding of cultures within SELECT.

Overall, the survey showed most teams have low participation of female and minority students, even when normalized for engineering enrollment. We identified several factors that might be driving the low participation of women and minorities. First, just over half of the respondents were recruited to the team through invitation by a friend who was already on the team, thus limiting membership to those in the network of current or former team members. Second, the more challenging part of diversifying SELECT is the retention of students that choose to initially participate in team activities. In addition, many teams experienced minimal faculty advisor engagement, with little opportunity to offer guidance on team operations.

To open SELECT to broader student audiences, SELECT should follow industry best-practice for equal opportunity. Industry should closely partner with sponsoring professional organizations to guide the development of policies and processes that are aligned with industry practice. Faculty advisors should also be actively engaged in team mentoring to ensure the successful implementation of those procedures. Leveraging academia-industry collaboration is a step towards building a team culture that is inclusive of all students.

Background

Despite considerable efforts made over the past decades to recruit and retain women and minorities in engineering, they still constitute a low proportion of engineering undergraduates. For example, in 2012, of students who received bachelor's degrees in engineering in the US, 4% were African American, 8% were Hispanic, 0.4% were Native American, 0.2% were Pacific Islander and 1% were multi-racial. In addition, only 19% of bachelor's degrees in engineering were awarded to women.¹ The lack of diversity in engineering education persists in spite of early calls for advancing diversity in engineering and industry's demand for a diverse workforce.^{2,3} It is especially visible in student, experiential-learning, engineering competition teams (SELECT). Our initial study with local SELECT teams revealed teams are dominated by white male engineering students with lower than expected participation of women and minorities.^{4,5}

Much research has been conducted on ways to increase diversity in engineering education in general. For example, Klotz et al. suggested that emphasizing and showing students the connection between sustainability and engineering might attract new students to engineering who wouldn't be attracted by traditional engineering demonstrations.⁶ Chesler and Chesler discussed the important role of mentoring in retaining female students in engineering and suggested that some non-traditional mentoring strategies, such as multiple mentoring, peer mentoring and collective mentoring might be more effective than the traditional ways of mentoring such as cross gender mentoring.⁷ May and Chubin summarized a number of factors that affect minority students' performance in engineering, including pre-college experience, intervention strategies, financial support, etc.⁸ Unfortunately, the strategies to increase diversity discussed in previous research haven't trickled down to SELECT.^{4,5}

There is inadequate research into diversity in engineering competition teams. Some of the studies conducted with competition teams focus on discussion of factors and strategies that lead to team success in winning the competitions.^{9, 10, 11} Other studies center around how participating in competition teams enriches student engineering education experience and prepares students for their future careers.^{12, 13} No research has been identified that addresses issues of diversity in SELECT teams.^{4, 5}

Previous research on classroom teams provides us with insight into why teams lack diversity. Studies show that several potential barriers exist that inhibit students from under-represented groups from participating in team activities. For instance, Meadows & Sekaquaptewa show that students' team experience is significantly influenced by their stereotyped gender/racial roles.^{14, 15} For example, females are more likely to be in charge of non-technical work; Asians are more likely to be assigned a mathematical part of the project. Furthermore, Tonso shows that campus culture and student engineering identity shape team construction and social interactions between team members.¹⁶ In addition, Laeser et al. proposed that because engineering has traditionally been a male dominated discipline, students who are used to a masculine culture may not function effectively in gender-diverse teams.¹⁷ These same factors are likely at play in limiting the diversity of engineering competition teams.

Major technology and engineering based companies recognize diversity as beneficial and are committed to building a diverse workforce. To achieve those goals, many companies actively identify and recruit candidates with diverse backgrounds. For example, Boeing holds recruitment activities at minority serving institutions and advertises job opportunities through various media. ExxonMobil reaches out to potential candidates through outreach programs and company partnerships with diversity organizations, such as the Hispanic Heritage Foundation and the National Society of Black Engineers.

Corporations recognize that maintaining a diverse workforce requires a shift in company culture. A variety of corporate initiatives and strategies have been developed and implemented to create a culture that promotes diversity and inclusion. Major corporations, such as General Motors, Caterpillar, ConocoPhillips, Williams, and Chevron, have built employee social groups to encourage people from similar backgrounds or with common interests to build networks, share resources, and provide professional and personal support to each other. Many companies (Dow,

Boeing, Xerox and Raytheon) organize educational programs, training, and workshops to help their employees embrace diversity and inclusion. Boeing's diversity training covers a variety of topics, including "awareness of cultural, gender and international sensitivities, avoiding stereotypes and micro-inequities, understanding generational differences, and how to positively impact culture change".¹⁸ The Department of Defense's strategic plan for diversity and inclusion builds on the government's plan and efforts to promote diversity and inclusion in the federal workforce.¹⁹ In addition, the websites of many companies (NASA, Johnson Controls, Dow, General Motors and 3M) have testimonials and statements from executives demonstrating their support of diversity. Raytheon and Xerox have established diversity councils to define policies and programs to promote diversity in their workplaces.

SELECT are promoted as the hallmark of engineering experiential learning where students gain real world skills in demand by industry. However, it appears that SELECT are not embracing the diversity and inclusion ideals that are promoted by industry. This research uses a national sample of SELECT teams to investigate the status of diversity and inclusion and identify factors that affect team culture.

Methods

This paper stems from a multi-year research project to identify and explain which factors contribute to cultures of inclusion or exclusion among various SELECT. To determine the generalizability of initial findings revealed through semi-structured interviews with SELECT members, we constructed a national survey and distributed it at a major engineering competition event. The survey allowed us to reach out to more SELECT teams and identify common themes and trends among those teams that are related to team culture and diversity, as well as students' team experiences. This survey aims to improve our understanding of cultures within SELECT.

The survey was developed based on findings we obtained from interviews with SELECT members. Through early analyses of 29 one-on-one interviews with local team members and 23 group interviews conducted at national competitions, we found team cultures that were constructed in ways that limit participation of many students. The analysis of these interviews suggested key factors to include in the survey.

In total, fifty-nine questions were included in the survey. Information on team and individual demographics was gathered to help us examine team diversity. Other questions were organized around topics identified from the local and national interviews such as team operations, leadership, team experiences, and perceptions. We expected those questions could help explain reasons why teams might lack/possess diversity.

The survey was distributed at a major engineering competition event in 2014. One of the researchers attended the competition event and invited students from the teams who were present to participate in the survey. The researcher tried to get responses from as many teams as possible. Of particular interest were teams that appeared to have more diversity or teams from institutions that have diverse populations. In order to not interrupt the competition, the researcher approached students who were not actively involved in team activities. An effort was made to

gain input from the few women and minority team members visually identified. Therefore, the data collected are over-represented for diversity.

The survey was taken by 30 students from 15 teams. The pilot sample includes 22 males and 8 females. Of the 30 students, one is American Indian or Alaska Native, four are Hispanic or Latino/Latina, two are Asian American and 23 are white. Of the sample, only two participants majored in non-STEM disciplines; 22 of the team members were from mechanical engineering. These data represent input from almost 25% of the teams participating in the competition. This paper describes the pilot data collected from the survey.

Results

Team Diversity

The survey asked team members to self-report the numbers of female and racial/ethnic minority students on their team. Fourteen teams had more than one member respond to the survey and the reported numbers were averaged by team. Those data are summarized in Table 1. Because these data are based on self-report of perceived race and ethnicity, the numbers may not represent the true team demographics. The average team membership is 31 students, with a high of 45 and low of 17. On average, female students comprise 12% of team membership. Under-represented minority students comprise 10% of team membership. Two teams report no female membership and two other teams report no URM team members. These four teams have the lowest diversity among all the teams surveyed.

Table 1

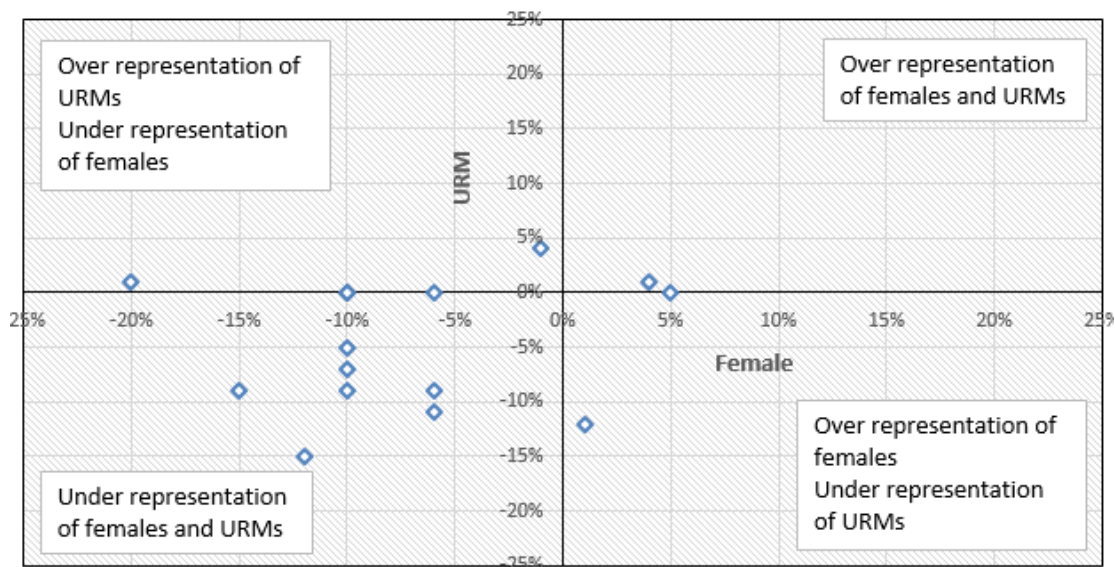
Percentage of Female and Under-Represented Minority Students on FSAE teams

| University | % of Female Students | % of Under-represented Minority Students | Total Team Membership |
|------------|----------------------|--|-----------------------|
| A | 18% | 30% | 17 |
| B | 0% | 2% | 21 |
| C | 4% | 12% | 25 |
| D | 12% | 4% | 25 |
| E | 11% | 20% | 28 |
| F | 21% | 9% | 28 |
| G | 14% | 28% | 29 |
| H | 11% | 5% | 31 |
| I | 12% | 5% | 32 |
| J | 7% | 17% | 32 |
| K | 38% | 13% | 32 |
| L | 0% | 4% | 40 |
| M | 4% | 0% | 40 |
| N | 14% | 6% | 40 |
| O | 7% | 0% | 45 |

| | | | |
|---------|-----|-----|----|
| Average | 12% | 10% | 31 |
|---------|-----|-----|----|

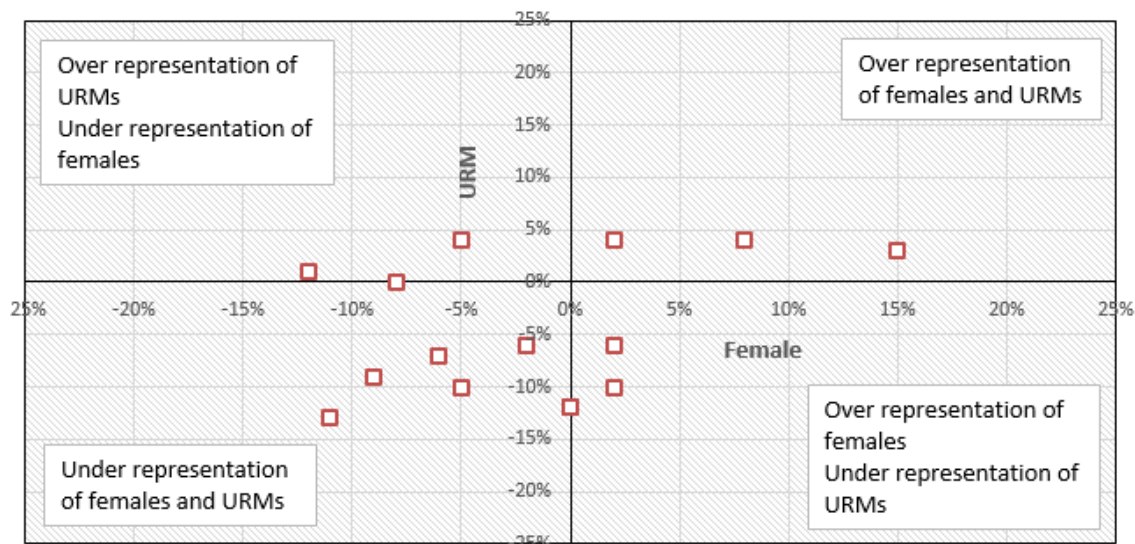
To get an accurate representation of team diversity relative to the population of their home institutions, we compared team diversity to engineering degrees awarded, using data from the 2013 college profiles in the ASEE's online database.²⁰ We calculated the differences between the percentages of females and under-represented minority (URM) students on teams as reported in the survey and the percentages of degrees awarded to females and URM students in colleges of engineering. Figure 1 reveals that 12 of the 15 teams have lower than expected participation of females (note that point (-10%, 0%) represents two separate schools). Eight of the 15 teams lack equitable participation of URM students. Of the 15 teams, 7 teams fail to meet their college-specific percentages of degrees awarded for both female and URM students.

Figure 1
Female and URM SELECT Membership Relative to Engineering Degrees Awarded



We repeated the analysis by narrowing the comparator to the home institutions' departments of mechanical engineering. Figure 2 reveals that 8 of the 15 teams have exceptionally low participation of female students and 9 teams have exceptionally low participation of URM students (note that point (0, -12%) represents two separate schools). Of the 15 teams, 5 lack both gender and racial diversity.

Figure 2
Female and URM SELECT Membership Relative to Mechanical Engineering Degrees Awarded



Given that the departments of mechanical engineering generally have low enrollment of women compared to colleges of engineering (COE), it is not surprising that team diversity looks more favorable relative to mechanical engineering (ME) diversity. This difference is particularly notable for females, who are under-represented 80% of the time vs. COE and 53% of the time vs. ME. In summary, team diversity falls short of student diversity by 50% or more.

Explaining Team Diversity

The survey was constructed to capture team demographics and to examine factors such as team operations, team experiences and perceptions that might limit student participation on teams. Based on the pilot survey results, we conclude that it is an interplay of multiple factors that drives the lack of team diversity. The initial challenge lies with recruiting diverse students to join the team. The recruiting practices described by survey respondents may be part of the challenge in building diversity. However, the more challenging part of diversifying SELECT is the retention of students that choose to initially participate in team activities. Our survey identifies multiple factors that may contribute to loss of membership.

First, we found that team membership is typically achieved through peer networks. Over half (53%) of the survey respondents reported that they joined the team because they were invited to do so by a friend/classmate who was already a team member. Particularly, of the eight female students we surveyed, only one female came to the team through open recruitment. Two of the five URM students joined the team through open recruitment. While peer-networks can be an effective recruitment strategy to increase numbers, they create a homogeneous team of like-minded students whose cliquish nature limits the inclusion of more diverse team members.^{21, 22}

The survey respondents also commented on their perceptions of why team members drop out. Table 2 summarizes the top 6 reasons current team members perceive other members to leave the

team. Overwhelmingly, the most cited reason, by 93% of participants, was that those who left were unable to commit the time necessary to meet team expectations. Each of the other reasons cited was offered by fewer respondents.

Table 2

Team Members' Perceptions of Why Other Members Drop Out

| Reasons | # of Participants Citing |
|--|--------------------------|
| Can't afford the time commitment | 28 |
| Loss of interest | 16 |
| Personal goals don't match team goals or competition goals | 13 |
| Lack of technical knowledge and skills | 11 |
| Personality doesn't fit in | 10 |
| My team doesn't provide enough guidance to support new members | 8 |

Table 3 shows the time that team members spend on team activities each week. It is clear that time expectations are high. Only 3% of the respondents reported spending less than 10 hours per week with teams. Seventy percent of the team members reported spending more than 20 hours per week on team activities with 30% of the team members working over 40 hours per week on team projects. Time commitment was also strongly suggested as an issue when respondents were asked to describe the costs of team participation. The costs almost exclusively center on time-related costs (Table 4). As previous research indicates, female and URM students might bear more family and financial responsibilities, which in turn may limit the time available to participate in team activities.^{23, 24, 25}

Table 3

Average Time Spent on Team Activities

| Average Time per Week | # of Participants Citing |
|-----------------------|--------------------------|
| Less than 10 hours | 1 |
| 10 -19 hours | 8 |
| 20 -29 hours | 10 |
| 30 - 40 hours | 2 |
| More than 40 hours | 9 |

Table 4

Costs of Being on a Team

| Costs | Average Score (1: strongly agree, 6: strongly disagree) |
|--|---|
| Lack of time for homework or other academic activities | 2.2 |
| Drop in GPA | 2.2 |

| | |
|---|-----|
| Out of pocket expenses related to team activity or travel | 2.4 |
| Loss of time for needed income earning activities | 2.5 |
| Lack of social life | 2.6 |

The second most reported (53%) reason why team members perceive that others leave the team is a loss of interest. In analysis of in-depth interviews of individual students, we have shown how “lack of interest” is often cited as a proxy for exclusionary practices and cultures.⁵ Table 5 shows the variety of strategies teams implement to engage new members into team activities and help them feel welcome. The table shows that the most common strategy is allowing new members to attend meetings, and few teams engage in meaningful mentorship of new members.

Almost half of the participants (43%) believe that members leave the team because their personal goals don't match team or competition goals. Most teams strive for competition achievement and to improve technical skills (Table 6). Students who are motivated by other reasons to join the team, such as having fun and meeting new friends, might not feel a sense of community and might be likely to leave the team.

Table 5
Strategies to Help New Members Feel Welcome on the Team

| Strategies | # of Participants Citing |
|--|--------------------------|
| Include new members in team meetings | 24 |
| Assign team member mentors to new members | 12 |
| Holds special meetings/social events for new members | 10 |
| Include new members in decision making | 8 |
| We don't have explicit strategies to include new members | 4 |

Table 6
Team Goals

| Category | Team Goals | # of Participants Citing |
|----------------------------------|--|--------------------------|
| Competition | Competition Achievement | 27 |
| Engineering Technical Experience | Improve on previous engineering design/product | 26 |
| Engineering Technical Experience | Members gain new experience and knowledge | 25 |
| Engineering Technical Experience | Provide an opportunity to network with potential employers | 22 |
| Social Goals | Pass on knowledge to future teams/successors | 21 |

| | | |
|--------------|---|----|
| Social Goals | Have fun and enjoy work | 19 |
| Social Goals | Provide a social network among team members | 17 |
| | Team doesn't have clear goals | 2 |

Although SELECT is advertised as an experiential learning opportunity for students, 37% of the participants attributed member drop out to lack of technical skills (Table 2). This speculation suggests that students with ready technical expertise are preferred and are most likely to persist on the team. The demand for technical expertise is counter to the expressed goals of the team where the majority of students report gaining new experience and knowledge as a team goal. Formal mentoring or new member training programs would enable more students to persist.

Thirty three percent of the participants reported personality conflict as a reason members leave the team. Given that half of the respondents were recruited to teams by friends and peers, it is likely that the teams are constructed of groups of cliques who share common interests and opinions. For those who enter the group without invitation, it may be challenging to break into this peer network.^{21, 22}

Since only 27% of the participants commented that their teams don't provide enough guidance to support new members, the majority of respondents (73%) believe that their teams provide adequate new member support in spite of significant attrition. The respondents' claim of a lack of technical skills as a reason for new member departure seems in opposition to their purported strategies for teaching new members the needed skills (Table 7). However, only 40% indicate that their teams have formal training programs for new members. Eighty percent of the respondents believe that passive observation constitutes an acceptable strategy for teaching students.

Table 7
Team Strategies to Teach New Member Relevant Skills

| Strategies | # of Participants Citing |
|--|--------------------------|
| Introductory projects/tasks, usually completed as new member groups under the guidance of a more senior member | 24 |
| Observing older team members work | 24 |
| On-the-job training (working alongside/under the guidance of senior members) | 20 |
| Formal/Structured workshops/training | 12 |
| We don't have explicit strategies to teach new members | 3 |

Based on students' responses, we infer that limited advisor involvement and advising might be another reason why teams lack diversity. In the survey, 47% of the participants mentioned that their advisors spent less than one hour per week with the team, with little opportunity to offer

guidance on team operations and dynamics. Mentoring plays an important role in female students' retention in engineering.⁷ Therefore, we suggest that the inadequate interaction between advisor and students might play a part in driving the low numbers of diverse students on teams.

Table 8
Average Number of Hours per Week that the Team Advisor Spent With the Team

| Average Number of Hours per Week | # of Participants Citing |
|----------------------------------|--------------------------|
| Less than 1 hour | 14 |
| 1 - 3 hours | 6 |
| 3 - 5 hours | 2 |
| More than 5 hours | 8 |

The lack of diversity on SELECT remains a concern for engineering educators because by limiting diversity, we are limiting the value of these teams to broad populations of students. Previous studies indicate that competition team experience enriches student engineering education and prepares students for their future careers.^{12, 13} In our survey, students commented on the numerous benefits from team participation, such as hands-on learning, the opportunity to learn things that can't be learned from classroom education, and potential job opportunities.

Recommendations

Through our pilot survey, we confirmed an interplay of multiple factors that contributes to the lack of diversity on SELECT teams. This finding indicates a multifaceted approach must be employed to increase diversity and inclusion. Guided by industry best practices, we propose the following recommendations.

- **Active recruiting:** To create a diverse workforce, many companies actively identify and recruit candidates from under-represented groups. Similarly, SELECT could utilize methods of targeted recruiting by reaching out to student groups, particularly those organized around racial/ethnic or gender identities. Rather than relying on personal networks for member recruiting, SELECT should develop and implement recruitment strategies that are open, informative, and communicate equally to all audiences.
- **Flexible work schedules:** Many companies allow employees to work flexibly to balance their work and family responsibilities. Following this model, SELECT must offer team members flexibility in their time commitment to team activities. Currently, students who can't devote extensive time each week to the team are often marginalized and end up leaving the team. SELECT should seek to accommodate multiple ways of participation such that more students might find ways to achieve work-life balance.
- **Social support:** A number of corporations have built employee social groups to encourage employees to build networks, share resources, and provide professional and personal support to each other. To limit team attrition due to loss of interest or incompatible goals, SELECT should provide a formal structure to enable team members to openly discuss their personal interests and passions, as well as team-related issues. By supporting inter-personal team

interactions, members can start to appreciate the unique contributions that individuals can make to the team.

- Training and mentoring programs: Many companies provide training and workshops to educate employees about diversity and inclusion. In almost all engineering programs, education is solely focused on technical skills and knowledge and little formal training exists to help educate students on issues of diversity. If diversity training was required of SELECT members, SELECT recruitment and retention could be enhanced and team members will be better prepared for a diverse workforce.

Changes start from the top down. Many companies have diversity and inclusion as core corporate values and the message is delivered from top leadership. Similarly, advancing diversity in SELECT will require those in positions of authority to clearly identify diversity as a fundamental goal for competition teams. Competition organizations, sponsor companies, universities, and team advisors should seek opportunities to institutionalize diversity as a core value so that teams are required to thoughtfully consider how to build an inclusive team culture. Competition organizations, sponsor companies, and universities can impose structural requirements on team composition and team training. Advisors should be on the frontline, actively mentoring and guiding the teams, to ensure teams are inclusive and diverse. With a clear message delivered from the leadership, student, experiential-learning, engineering competition teams can become early incubators of the diversity and inclusion ideals that are promoted by industry.

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