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# Barriers to Broadening Participation in Engineering Competition Teams

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# Barriers to Broadening Participation in Engineering Competition Teams

## Introduction

Despite years of efforts to increase diversity in STEM, engineering continues to be a white male dominated discipline. The low representation of female and minority students is especially visible in Engineering Competition Teams (ECT). Examples of such student teams include the Formula SAE race team sponsored by SAE International, and the Concrete Canoe Competition sponsored by the American Society of Civil Engineers. ECT provide some students opportunities to develop their engineering technical and professional skillset. However, students who are excluded from participation, particularly students from underrepresented groups, do not have access to these advantages. This paper stems from a multi-year mixed-methods research project to investigate factors that contribute to the low diversity in ECT. Using a nationally distributed survey of engineering competition and service learning team members, we show that students' participation in ECT is challenged at multiple phases and the barriers students face create an exclusive team culture which limits the participation of diverse students.

## Literature Review

The lack of diversity in engineering is a challenge at all levels. Between 2000 and 2012, the percentage of women who obtained an engineering bachelor's degree declined (from 21% to 19%).[1] Meanwhile, the percent of bachelor's degrees in science and engineering awarded to Hispanics increased from 7% to 10% and to Asians and Pacific Islanders, from 9% to 10%. The proportion awarded to black and American Indian or Alaska Native students has remained stable (9% and 1%, respectively).[1] Recent data indicate that although the number of workers in science and engineering has been increasing over time, women and most racial/ethnic minorities remain under-represented.[1, 2]

Underrepresentation remains a concern for many reasons, including pragmatic arguments about economics and national prosperity. Our motivation for pursuing this research is based, however, by concerns about the lack of social justice in systematically excluding large groups of people from the process of engineering (and therefore participating in the control of) the future. Strayhorn et al. found that encouraging students to interact with peers from diverse background may lead students to greater perceived gains in engineering education and practical competence, as well as promote personal and social development.[3] In addition, a more diverse student body is related to higher levels of interracial interaction among students and may indirectly lead students to a better understanding of cultural and racial differences.[4, 5]

Although increasing the diversity of engineering has been a long term goal, engineering programs experience difficulty in recruiting and retaining females and minority students. Recruiting efforts that focus on engineering as an adventure or highlight specific artifacts (e.g. fast cars) may not appeal to young women.[6] Even when students from under-represented groups do enroll in engineering, their academic experience can be affected by their race/ethnicity and gender. While many engineering educators look to teamwork and collaborative learning as a mediator of high attrition rates for students from underrepresented minorities (URM), recent

research on engineering teams shows URM and female students can be marginalized in subtle ways leading them to miss the opportunity to develop their engineering skillset. For example, female typical speech acts, such as admitting weakness for strategic purposes, were judged negatively by male students.[7]

Meadows et al. identified four situations where marginalization of underrepresented groups can happen in class-based teams.[8] First, students are affected by stereotyped gender/racial roles and implicit biases, leading to stereotypical task assignments that fail to give members of underrepresented groups an opportunity to develop their full engineering skill set. For example, females are more likely to be in charge of non-technical work and lose the opportunity to gain technical skills.[9] Second, marginalization can occur when the contributions of underrepresented team members are overlooked by instructors or peers. Third, students might feel marginalized when their ideas and input are only accepted when they are proposed or validated by a senior or dominant member from the team.[10] Fourth, students from non-dominant groups may experience marginalization when projects are not relevant to their culture, community, or lived experiences. Several strategies were proposed to improve the experiences of marginalized students on teams, including changing personal beliefs by recognizing biases and how an individual's experience is shaped by factors such as ethnicity, gender and socio-economic status; promoting classroom environments that are welcoming to all students; and adopting new course and assignment designs that incorporate scaffolding strategies and interventions to support all students.[8]

Competition teams are a significant part of the engineering landscape. Competition teams are featured prominently in recruiting engineering students, including pictures on college websites. Competition teams use substantial resources, including funds for parts and travel, faculty time, and academic space. We have identified no research, other than our own, that addresses the absence of diversity in ECT (engineering competition teams). Earlier studies conducted with competition teams focus on either a discussion of the benefits and experience students gain from participation or an exploration of factors that contribute to team success in competitions.[11-15] Our previous research indicates that ECT members tend to be White, male, and middle class and have an extremely low percentage of female and URM student participants.[16]

To investigate what factors contribute to low diversity in ECT, we implemented a multi-year mixed-methods research project (NSF-1068453). In the first phase, we interviewed 29 ECT team members from a single institution and found team cultures that limit students' participation in multiple ways. Characteristics of these exclusive cultures include extreme time commitment requirements for team obligations, stereotyped gender roles, and the presence of homophily (birds of a feather flock together) and transitivity (a friend of a friend is a friend) effects.[17-20] Each one of these characteristics has a direct impact on a group that is underrepresented in engineering. For example, extreme time commitments make it virtually impossible for a student from low socio-economic status to participate since these students typically work long hours for survival.[21, 22] An analysis of team members from two specific competition teams showed that even students from majority groups may miss opportunities to gain leadership, management, and experiences with racial and ethnic diverse others.[20]

To determine the generalizability and transferability of the findings from a single institution to other academic institutions, we developed a survey for nation-wide distribution to ECT team

members. The survey was pilot-tested at a national design competition with 30 students representing 15 teams from different universities. Findings generally supported conclusions drawn from the initial interview data that women and minority students are underrepresented on ECTs. In particular, ECT membership was limited for those students who were not socially connected to current or former team members. Retention of team members was also affected by the expectation for extreme time commitment as well as limited faculty advisor involvement. Limited results from the pilot survey were summarized in a previous publication as they related to corporate best practices.[16]

## Methods

This final survey version includes seventy-one questions organized around topics such as individual and team demographics, team operations, team experiences, team diversity, team leadership and students' perceptions of team participation. These topics parallel those from the interview protocol used in the qualitative portion of the project, with questions and response options driven from the range of replies coded in those interviews. Based on the participant feedback and analysis of the survey pilot test, we deleted questions related to team history, added new questions to differentiate time commitment during and outside of competition season, and revised other questions for clarity and to improve mobile device access. The survey will be available upon request after the research project is completed.

The data presented and summarized in this paper were obtained through online distribution of a survey to ECT team members. The survey was distributed with the cooperation of six national organizations that each sponsor one or more ECT competitions or service learning events. In almost all cases, the organization's contact person agreed to distribute our request for survey participation to their student members. One organization provided us with links to a member email list. For the other organizations, we provided the contact person with the written request for participation and the survey link to distribute to their membership. The surveys were first distributed electronically early in the 2015 academic year. All aspects of this study have been reviewed and approved by an Institutional Review Board.

A total of 116 students responded to the online survey, representing 82 schools and 8 engineering competition or service learning events. Some survey responses were incomplete. Of those surveys with incomplete responses, it appears that students experienced survey fatigue or had difficulty answering some questions on mobile devices. Thus, not all questions have the same response rate (ranging from 77-116 responses per question).

## Results

The results reported here derive from a survey administration that has broader representation than the pilot survey, in number of respondents but also in the representation of specific event types and home institutions of team members (Table 1). These national survey data identify central patterns of team culture that are consistent across this larger sample which represents more types of ECTs and more institutions.

Table 1. Overview of Survey Responses.

| | # of Respondents | # of Institutions | # of Team Events |
|---|---|---|---|
| Pilot Survey | 30 | 15 | 1 |
| National Survey | 116 | 82 | 8 |

Diverse students' participation in ECT is challenged at multiple levels and at all stages of team participation. Through inductive generalization of survey responses, we identify three waves of challenges that arise from team cultures and processes to limit participation of non-majority students. We categorize these waves as entry barriers, persistence barriers, and legacy barriers. Entry barriers limit the ability to join and integrate with a team. Persistence barriers represent sacrifices that must be made for a long term commitment to the team. Legacy barriers limit the ability of team members to rise to a position of leadership. These barriers, in combination with lack of advisor engagement, lead to an exclusive team culture.

Entry barriers

Entry barriers are manifestations of a group's culture and practice that suggest to outsiders that it is not feasible to become a member of the group. These barriers may be either implicit or explicit actions or signs. Even those who find a way to superficially join a team face challenges that must be overcome to be recognized as a team member. Full membership is attained when a newcomer is acknowledged to be a team member by influential existing members.

Survey results from the student team members highlight team recruitment and integration practices that serve as entry barriers for prospective members of ECT. Table 2 shows the various recruitment strategies reported by the respondents. As you can see, most of the teams report using open recruitment (77%) as their primary strategy for recruiting new members. However, when the respondents reported how they had come to join the team, the recruitment mechanisms were more broadly dispersed, including open recruitment as well as social connections and individual initiative.

Table 2. Recruitment – Entry Barriers

| | Open | Social connections | Own Initiative | Other |
|---|---|---|---|---|
| How does your team recruit? (n=116) | 77% (89) | 19% (22) | N/A | 4% (5) |
| How were you recruited? (n=89) | 44% (39) | 25% (22) | 31% (28) | |

Recruiting is further limited by strong disciplinary borders surrounding team membership. Teams are often dominated by students from engineering and a particular engineering discipline. Ninety-two percent (n=71) of our survey respondents are engineering students and 78% (n=55) of those engineering students are majoring in mechanical engineering.

Entry barriers are also built by an inability of teams to effectively provide meaningful ways to welcome interested students into the teams. These issues are addressed in multiple questions each allowing multiple responses, and with varying numbers of respondents. Therefore, the responses shown in Table 3 of strategies for welcoming new members do not add to 100 percent.

The most commonly reported strategy is to encourage new members to participate in team meetings (83%, n=96). Surprisingly, 12% (n=14) respondents report that their team had no strategy for including new members. Students were asked to rate their perception of strategy effectiveness and there are no meaningful differences in the ratings, all which hover above "a little bit" effective.

Table 3. Strategies for Welcoming New Members

| | Responses |
|---|---|
| Encourage new members to actively participate in team meetings | 83% (96) |
| Consider new members' input in decision making | 49% (57) |
| Assign team member mentors to new members | 31% (36) |
| Hold special meetings/social events for new members | 30% (35) |
| We don't have explicit strategies to include new members | 12% (14) |
| Others | 8% (9) |

It appears that many teams rely on the individual to overcome entry barriers. Many teams fail to implement effective recruiting strategies and do not provide sufficient guidance and support to help new members integrate into the team. While respondents cite loss of interest as one of the top three reasons why new members leave the team (53%, n=56), it seems that they fail to recognize the critical role that active recruiting and formal integration strategies may have in mitigating loss of interest.[19, 20] Given that ECT have fairly insular cultures and membership, the belief that open recruiting and passive welcoming strategies are sufficient limits the inclusion of members from more diverse populations.

Persistence barriers

Persistence barriers refer to the challenges faced by newcomers for full participation on a team. These barriers include structural obstacles and extraordinary personal sacrifices. Structural obstacles derive from ineffective team processes for enabling new members to contribute meaningfully to the team.[19] Personal sacrifices result from implicit or explicit team expectations far beyond those of a typical student organization and are required for full inclusion into team culture. Personal sacrifices can exceed the ability of team member to find a balance with other life elements (such as academics, work, and a personal life) and lead to attrition from the team.[18]

Table 4 presents the most common (more than 30%) perceptions of team members as to why other members leave the team. In our survey, the inability to meet the subjective required time commitment is reported by current team members as the top reason why other members drop out (81%, n=86). On average, students spend 16 hours/week on team activities in a non-competition season and this number increases to a staggering 44 hours/week during competition season - the equivalent of holding a full time job. Team members report no restrictions on the maximum amount of time per week members can spend on team activities. The vast majority of respondents (87% or n=75) report that they not only work with their teams during regular school hours but also work on team projects late into the night. When students compare their ideal way of allocating their time to how they actually allocate their time during non-competition and competition seasons, students unanimously express their desire to spend more time on course work, sleep, and other responsibilities.

Current team members report the second most common reason other members leave the team is a drop in their GPA (57%, n=60). Only 11% (n=11) of team members indicate that their teams require a minimum GPA for individual members to retain eligibility for team participation. Considering team participation requires extreme time commitment, it is not surprising that students face challenges to balancing their time between course work and team participation.

Table 4. Perceptions of Why Others Drop Out (n=106 responses).

| | Responses |
|---|---|
| Participation takes too much time | 81% (86) |
| Grades or coursework were suffering | 57% (60) |
| Loss of interest | 53% (56) |
| There are not enough tasks to keep all students engaged | 45% (48) |
| Lack of technical knowledge and skills | 39% (41) |

To summarize, our analysis demonstrates that in order to persist on the team and become fully integrated members, students have to show an extraordinary time commitment and must accept various time-related costs such as a lack of sleep, limited or no social life, and even a notable drop in GPA. Those persistence barriers often make it difficult for students who show initial interest in team participation to stay on the team.[18]

Legacy barriers

Legacy barriers are encountered when subordinate team members encounter obstacles to team participation based on the lack of strong interpersonal relationships with more experienced team members. These barriers are similar to the exclusionary academic tradition of admission preferences derived from familial relationships, such as those used by Greek letter organizations. Legacy barriers can also inhibit ascension to leadership roles. Students who do not have close ties to and endorsement from existing leaders are often excluded from team leadership. Personal relationships become a necessary condition for assuming a future leadership role.

Students were asked to select from a list of various methods in which leadership positions are filled. Some of the choices refer to how leadership candidates are identified and other choices refer to how leadership positions are assigned. Respondents were allowed to select more than one option. In total, 96 participants answered this question. The answers indicate that leadership candidates are identified primarily through two ways: leadership/senior members choose (47 out of 96, 49%) or election/voting by the membership (44 out of 96, 46%).

However, the selection of leadership is not nearly as clear as suggested in Table 5. Most respondents selected multiple and seemingly inconsistent response options. For instance, 10% (9) of the respondents selected both options “discussion without voting” and “election/voting”. This pattern of multiple responses suggests that the team members may not have a clear understanding of how one would attain a leadership role.

The lack of a transparent and democratic process for determining leadership on ECT creates a perpetual cycle of tightly knit, socially determined team leadership and makes it difficult for

students who do not have close social relationships with current team leadership to achieve the leadership positions.[16]

Table 5. How are leaders chosen on your team?

| | Responses |
|---|---|
| Team leaders/Senior members choose | 49% (47) |
| Election/voting | 46% (44) |
| Volunteer to serve | 33% (32) |
| Discussion without formal voting | 31% (30) |
| Team advisors choose | 10% (9) |
| Other | 5% (5) |
| I am not sure | 4% (4) |

Lack of advisor involvement

Entry, persistence, and legacy barriers each affect the ability of an individual to gain full status as a member of ECT. While these barriers are put in place by current team members, our data suggest that the lack of advisor involvement and guidance might reinforce those barriers and contribute to the construction of an exclusive team culture.

In the survey, 47% of the respondents indicate that on average, their advisors spend less than 1 hour per week, or no time at all, with the team. Respondents were asked to rate their agreement with various statements about their advisors, using a scale of 1 (strongly disagree) to 6 (strongly agree). Table 6 shows the mean value obtained for the ratings on each statement, along with the standard deviation of the rating and the coefficient of variation. While the scale did not allow for a neutral response, an average value of 3.5 theoretically represents a neutral rating. To gain a clear perspective about the variability in each rating, the coefficient of variation is shown for each rating as a measure of variability normalized about the mean value.

The results indicate that in general, students perceive their advisors as approachable and supportive ($\bar{x}$=4.99) and as having confidence in the team ($\bar{x}$=4.78). However, the interactions between students and advisors seem to be limited to regular working hours ($\bar{x}$=4.72), and students respond neutrally to advisor availability outside of their office hours ($\bar{x}$=3.89). Considering that 87% of our respondents report working with their team at night (6 pm - midnight), advisors have limited opportunity to mentor the team during team activities that take place after business hours. In addition, when it comes to activities that require additional time commitment, such as new member recruitment and retention, advisors are less involved and barely visible ($\bar{x}$=2.78 and $\bar{x}$=2.61, respectively).

Based on the students' ratings on different dimensions of advisor involvement, we can draw a general portrait of a typical team advisor. The advisor expresses confidence, support, and interest about the project, but tends to only get involved in high-level external team issues. Otherwise, the advisor tends to make himself or herself available but does not engage in day-to-day team operations. The advisor, in general, is less involved in interpersonal relationships within the

team and in team activities that are not perceived to directly support the accomplishment of the team project. These activities, while not perceived to impact the team product, are critical to the healthy functioning of an inclusive team and individual team members' professional development.

Table 6. Team Member Ratings of Advisor Involvement

| | Mean | SD | CV |
|---|---|---|---|
| Approachable and supportive | 4.99 | 1.12 | 0.22 |
| Hands-off when it comes to technical issues | 4.94 | 1.21 | 0.24 |
| Confident in our team | 4.78 | 1.17 | 0.24 |
| Available to my team during his/her regular working hours | 4.72 | 1.24 | 0.26 |
| Hands-off approach when it comes to non-technical issues (fund raising, promotion, leadership) | 4.64 | 1.38 | 0.30 |
| Helps us handle issues with the university/administration | 4.44 | 1.62 | 0.37 |
| Knows and understands what my team is doing | 4.31 | 1.54 | 0.36 |
| Helps us get resources we need | 4.22 | 1.57 | 0.37 |
| Passionate about our project | 4.20 | 1.45 | 0.34 |
| Available to my team outside of his/her regular working hours | 3.89 | 1.54 | 0.40 |
| Actively involved in informal interactions | 3.35 | 1.67 | 0.50 |
| Helps resolve interpersonal or behavior disputes | 3.10 | 1.60 | 0.52 |
| Actively involved in formal interactions such as regular team meetings | 3.07 | 1.83 | 0.60 |
| Plays a significant role in new member recruitment | 2.78 | 1.62 | 0.58 |
| Plays a significant role in new member retention | 2.61 | 1.53 | 0.59 |

## Discussion

The key contribution of this study is the framing of ECT membership challenges identified in early publications into waves of barriers. The breadth of survey responses allowed inductive generalizations to reframe what is perceived as merely a loss of interest among new members as three categories of barriers: entry barriers, persistence barriers, and legacy barriers. These barriers may be more of a function of team behavior, specifically related to passive recruiting, excessive expectations placed on "core" team membership, and unclear pathways to leadership.

Entry barriers are experienced by students seeking team membership, primarily through limited mechanisms for learning about membership and feeling welcomed to the team. A disconnect exists between team members' reports of open recruiting as the most common strategy for recruiting and the half who report that they arrived to the team through personal connections. In addition, the welcoming strategies most commonly reported for integrating new members are passive assimilation, at best, or reliance on the prospective member to take initiative to participate. Earlier work identified the fallacy of the open recruiting narrative.[20] Formal recruitment procedures are by-passed in favor of network friendships, excluding those who do not have high levels of cultural and social capital. Even though teams recruited at college of engineering-wide events, they continued to be populated primarily by white male ME students

with pre-existing friendships and other connections. Due to the effects of homophily and transitivity (explained earlier), both team membership and leadership were limited to a cadre of students with high social capital.[19, 20] The survey results presented here reflect the same homogenizing influences.

Persistence barriers exist that limit the ability of newer team members to gain full team member status. Our first case study of a single competition team demonstrated that an ethos of commitment (excessive time commitment) limits team participation to those students who are not encumbered by economic, social or familial obligations.[18] Eighty-one percent of the survey respondents from the 82 teams in this study report team members leave because participation takes too much time. This is similar, although lower, than the 93% of respondents in the pilot survey reporting excessive time commitment.

Ninety-one percent of our survey respondents who reported gender at all identify as male. Our earlier work described the barriers met and experiences of female team members and females who attempted to join teams.[17, 19] These papers found that women who are able to persist on teams had strong social-networks with male allies who were established team members. Those with little to no social capital within the team, regardless of their ability to contribute relevant skills, did not persist. The survey respondents do not recognize the role of cultural factors in team member attrition. This absence may be a result of the high representation of male survey respondents.

Legacy barriers underscore the strong interpersonal connections that exist in team subgroups to limit other members' increased participation, and in particular, the ability to secure leadership roles. The survey responses regarding leadership indicate that team members have many different perceptions of how leadership responsibility is assigned or attained. This lack of clarity makes it more challenging for those who do not have the strongest interpersonal connections to understand the processes for becoming a leader. This finding confirms what we described in earlier work where there was little mentorship towards leadership development and other key professional competencies.[20] Similar to recruiting, future leadership was often designated and groomed by outgoing officers. This legacy barrier serves as a means of hoarding and selectively sharing knowledge. The tight social networks that exist make it difficult for students outside the networks to learn about and achieve leadership positions.

One recommendation from our paper on modeling ECT after industry best practice called for advisors to be actively engaged in expressing diversity as a core value for the team.[20, 22]As reported by team member respondents in this survey, ECT advisors give little effort to team mentoring and leadership, particularly in areas that support building a diverse and inclusive culture. Advisors appear to be ancillary to team operations, often engaging only on technical issues as called upon by the team during regular faculty office hours. These findings are also observed in a recent analysis of 17 interviews of ECT faculty advisors.[22]

## Conclusions and Recommendations

Entry barriers often act as a deterrent for potential team members. To overcome entry barriers and open ECT to a broader audience, ECT should explore intentional recruiting practices. Instead of relying on personal networks to recruit new members, ECT should be mindful of recruiting practices and should seek to engage those who are external to the team's personal network. To help new members integrate into the team, introduction and scaffolding activities should be systematically designed and implemented under careful supervision.

Persistence barriers affect initial and long-term retention. These barriers are often associated with the sacrifices students have to make in various aspects of their academic and personal life in order to meet the extreme time commitment of team participation. To overcome those persistence barriers, ECT should create and appreciate multiple ways to participate and should assign tasks to team members that best suit their capability and time schedule.

Legacy barriers make it difficult for team members to break through social and cultural constraints to become a leader. In order to ensure students have equal opportunity to become leaders, ECT must commit to create a fair and transparent leadership selection process. All team members should be given the opportunity to apply for open positions and leaders must be selected through election or broad consensus.

Although team advisors could play a critical role in creating an inclusive team culture, our data indicate that advisors don't actively participate in teams' day-to-day operations and therefore lose the opportunity to provide guidance and support to the teams they advise. It appears that advisors are available to support project-related needs as requested but do very little to understand or affect team dynamics. While we recognize that most advisors are engaged as a nominal service role, a shift in advisor involvement may help move ECT towards a more inclusive culture and diverse membership. Advisors could effectively mentor team members to recognize bias, appreciate difference, and guide team members towards building effective strategies for recruiting and including new team members. However, we cannot assume that such mentorship will come naturally to advisors – there must be arrangement made for advisor training such that their engagement with the team leads to positive outcomes for the team as a whole. All team members could benefit from the opportunity to interact with culturally and racially diverse peers.[4, 5]

Teams operating under a lack of oversight and with practices that create barriers to participation easily build cultures that exclude new members, particularly members from underrepresented groups who might feel isolated or alienated by the team culture. Given that ECT garner institutional resources and respect, it is important that the advantages of membership be available to all members of the academic community. We believe that ECT are missing an important opportunity to extend the advantages of membership to a broader pool of participants and to bring new opportunities to current members.

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