Barriers to Belonging: An Analysis of Student Perceptions of Culture and Inclusivity in a Computer Engineering Program

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Introduction

The department of computer engineering (CPE) at California Polytechnic State University has recently received a grant from the NSF to transform the department into a more inclusive and welcoming environment and to identify and dismantle unnecessary and unjust barriers to student belonging and success and to eliminate achievement gaps among students from all backgrounds. As part of this effort, we have undertaken a study to determine which aspects of existing department and instructional culture students identify as providing the biggest obstacles to their success. We also try to identify areas of strengths that can be leveraged as we complete our transformation. While this study was originally designed to help improve our department, we share the results here in the hopes that it can help other engineering departments better understand their students' needs and experiences.

Background

Significant research exists on barriers to graduation for students in engineering and many different explanations have been proposed for the chronically low retention rates seen in engineering programs across the country [1]. Danowitz and Beddoes, for example, have examined individual mental health and wellness a potential means of explaining low graduation rates in engineering students [2], [3], [4] and have found that engineering students suffer from certain mental health issues at rates much higher than the general population. Given the well-documented links mental health and academic performance [5], this is an area worth studying for any program hoping to improve student success.

While Danowitz and Beddoes looked at mental health as a measure of individual students, several researchers have identified links between engineering and department culture and poor mental health outcomes. Studies by Jensen and Cross have linked engineering to a culture that inherently promotes stress [6]. At the same time, Huff and Secules have explored the role of shame as an inherent part of the formation of many engineers [7], [8]. Many other studies have explored the role of imposter syndrome in creating negative outcomes for engineering students [9], [10]. In total, this research suggests that department and program culture plays a large role in determining student success in engineering education, and must be considered as part of any effort to make engineering programs more inclusive and supportive to their students.

In addition to department culture, student-faculty interaction can also have a large effect on student success; this is perhaps best illustrated by the existence and implementation of "weed-out" classes to determine who can succeed in the major [11]. Even in the absence of weed-out courses, however, subtler forms of negative student-faculty interactions have been shown to have negative consequences for student success and retention [2], [12], [13]. On the other end of the spectrum, countless studies have documented how positive student-faculty interactions can promote student success and retention [14], [15], [16]. Therefore, studying the overall nature of student-faculty interactions is critical in identifying areas of strength and weakness for student success.

Finally, it is important to recognize that many students are impacted by factors outside of their engineering program that may affect their ability to fully participate and succeed. These responsibilities may include on-campus or off-campus jobs that students need to afford their studies. Students may also face food, housing insecurity, and challenges getting to campus [17], [18]. Additionally, students come to college with different levels academic preparedness and study skills. In assessing barriers to student success, these factors must be considered as well.

The causes discussed and likely countless others play role in the challenges faced by engineering programs to recruit, retain, and graduate diverse classes of engineers. To understand the full spectrum of obstacles facing engineering students, it is important to explore a variety of factors.

Instrument Design

To get a broad measure of how students are being served and stifled by our existing department structure, we created a survey from several pre-existing Likert instruments that were designed to measure different aspects of the student experience. Our external program evaluators, Redwood Consulting Collective adapted an existing campus climate survey [19] to capture how students feel about the department and to measure their interactions with and impressions of department faculty. Redwood Consulting also included an adapted version of the Science Identity Scale [20] to measure the extent to which our students identified as computer engineers. Redwood adapted an academic anxiety scale [21] and portions of the Diverse Learning Environments survey [22] focusing on educational challenges to help us understand how courseload and academic preparation were affecting our students. The included scales and selected items from each are summarized in Table 1.

Table 1. Instruments and example questions used in our survey.

Instrument	Scale	Sample item
Campus Climate Survey	1 (strongly disagree)– 5 (strongly agree)	I feel comfortable sharing my own perspectives and experiences in class The professors in CPE try to make everyone in class feel welcome
Science Identity Scale	1 (strongly disagree)– 5 (strongly agree)	I have a strong sense of belonging in Computer Engineering community
Academic Anxiety Scale	1 (not at all typical of me)– 4 (very typical)	I often worry that my best is not as good as expected in school.
Educational challenges (from Diverse Learning Environments)	1 (very easy)–4 (very difficult)	At this college, how has it been to develop effective study skills

In addition to the adapted scales, the survey contained several questions asking about student demographic and background. The survey also includes two free-response questions to give students an opportunity to directly address what they find challenging in CPE and what they

would like to see change. These free response questions are included in Table 2. The final survey consisted of 54 questions, and, with Institutional Review Board Approval, was distributed to all computer engineering majors in Spring of 2024. To ensure student anonymity, survey distribution and data collection and anonymization was conducted by Redwood Consulting Collective.

Table 2. Free response questions in survey instrument.

Questions
What would you describe as your challenges or stressors being a CPE student?
What, if anything, do you think is holding you back?
What is one thing that we could do in CPE to make you feel more supported?

Results

The survey resulted in 66 complete responses, representing a 14% response rate for the department overall. The demographics of survey respondents are summarized in Table 3. The respondent pool was overwhelmingly male, in line with the demographics of the CPE department. Most participants listed their ethnicity as either Asian, Latino/a/x, or White. Nearly 40% of respondents reported that they were seniors, with first-year students representing the smallest group of respondents.

Table 3. Demographics of survey respondents

Demographic	Respondents
Gender	
Man	45
Woman	14
Not sure	2
Gender queer/gender non-conforming	1
Decline to state	3
Ethnicity	
Asian	19
Latina/o/x	16
White	17
Southwest Asian or North African (SWANA)	1
Multi-racial or two-or-more races/ethnicities	10
Decline to state	1
Class Standing	
Freshman/first-year	9
Sophomore	17
Junior	13
Senior	26
Other	

Veteran	
First-generation college student	18
Reports a disability	8
Has disability center accommodations	15
Switched into CPE major	21

The results of the survey broken out by subscale area are shown in Figures 1–5. As noted in Table 1 campus and instructor climate survey and the sense of belonging survey are scored on a 5-point Likert scale rating agreement with each statement. The academic anxiety scale is rated on a 4-point Likert scale rating how typical each thought is for the respondent, and the equitable learning environments items are rated on a 4-point Likert scale rating how easy it is for the respondent to face each challenge. In all but the academic anxiety scale and a single reverse coded question in the campus climate survey, higher score values indicate better results for respondents.
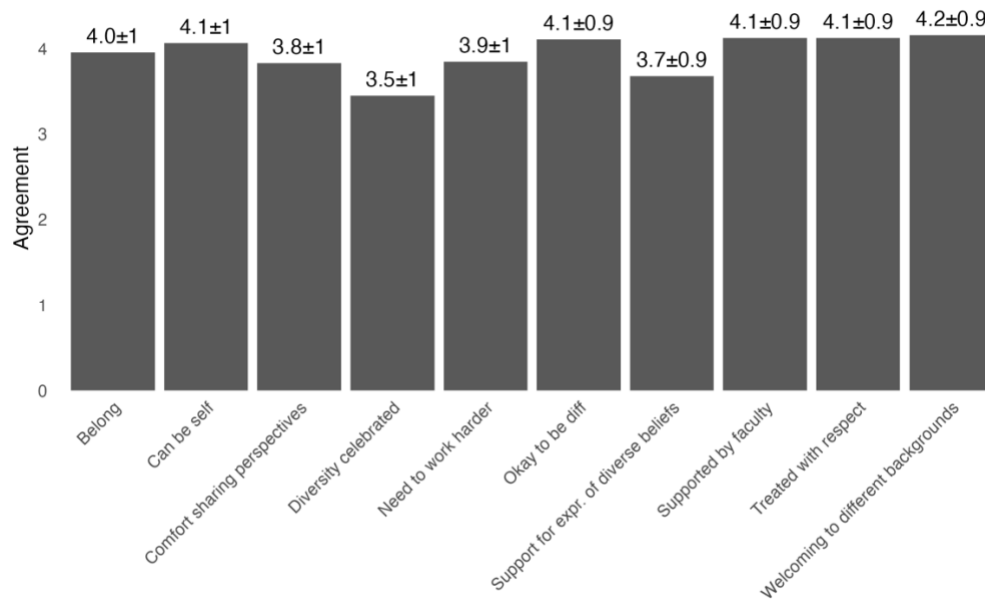

Figure 1. Department climate survey. All questions are specific to the computer engineering department.
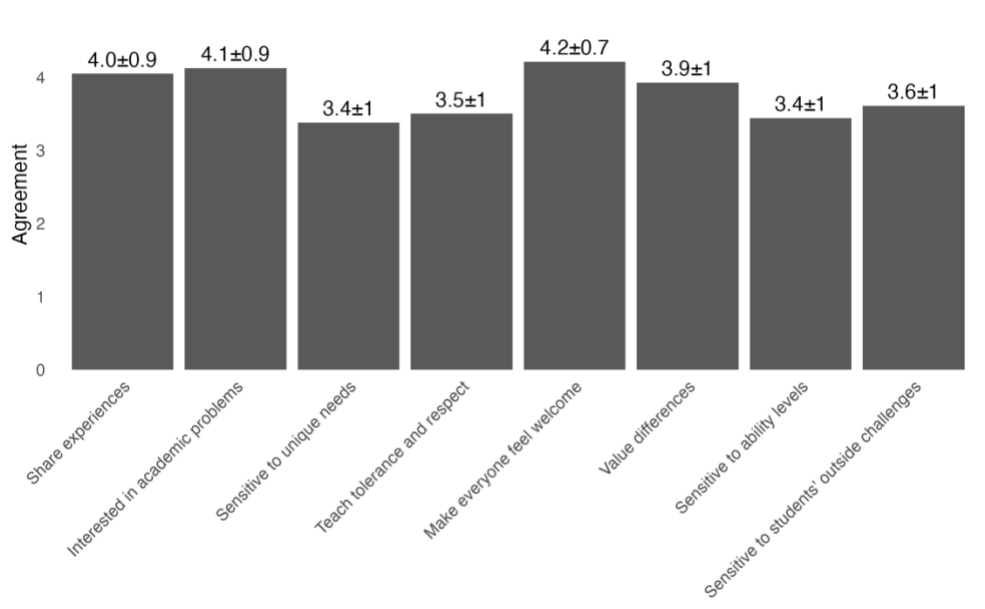
Figure 2. Faculty climate survey. All questions are specific to computer engineering faculty.

A total of 70 responses were provided on our open-ended questions, as summarized in Table 1. While the questions asked two different things, we found that students would often mix their responses—discussing major stressors and suggested solutions in response to both questions. As a result, the responses were analyzed together to determine common themes and areas of feedback. Since each of these questions invited long-form written responses, there were several instances where a single response covered multiple stressors and solutions across different areas; in these cases, the text response was split up and counted towards each of the different common areas.

Table 4. Number of responses to survey's open-ended questions.

Question	Number of responses
What would you describe as your challenges or stressors being a CPE student? What, if anything, do you think is holding you back?	45
What is one thing that we could do in CPE to make you feel more supported?	25

Discussion

The campus climate and computer engineering identity results are largely positive. The measures of these surveys all fall into the category of "agree," indicating a positive culture overall. There are a few caveats to these results, however. First, respondents indicated a strong degree of agreement with the statement "I feel I have to work harder than other students to be perceived as a good student." This result, indicating that the average respondent believes they are less able or viewed less favorably than their classmates suggests that our student population may be affected

by some form of imposter syndrome—the fear that one's success is a fluke and that their peers and colleagues will eventually discover that the individual is not qualified to be there. Given the prevalence of literature addressing imposter syndrome in STEM education [9], [23], [24], this result is perhaps unsurprising.
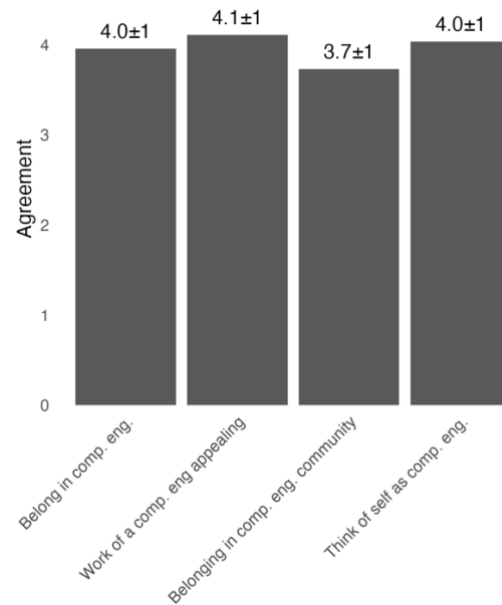

Figure 3. Sense of belonging in computer engineering.
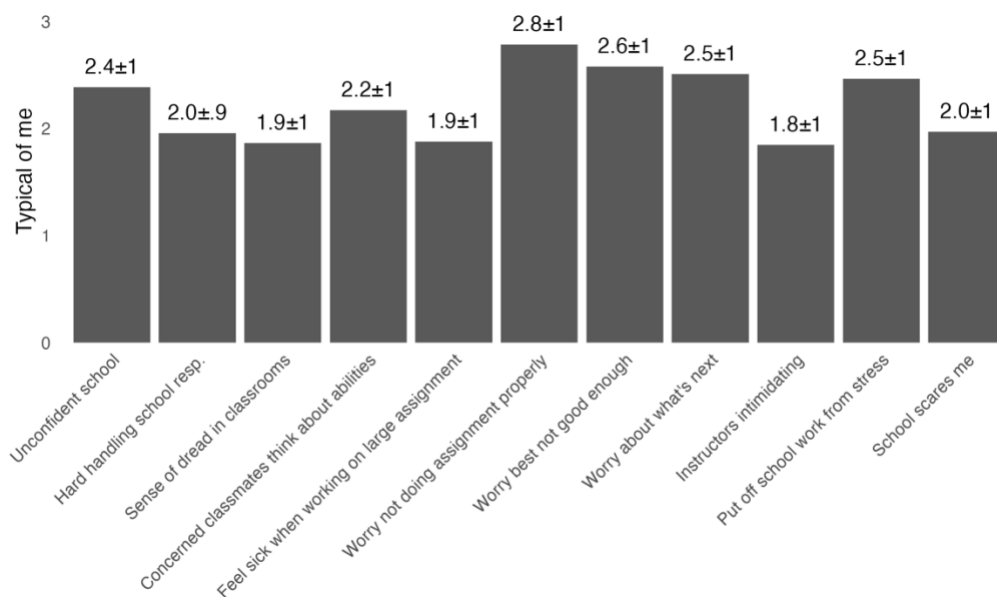

Figure 4. Results of academic anxiety scale for computer engineering students.

From the instructor focused questions of the campus climate subscale, students generally agreed least with statements measuring how closely attuned instructors are to students' individual challenges and situations. These questions are "The professors in CPE are sensitive to students'

unique instructional needs," "The professors in CPE are sensitive to the ability levels of all students," and "The professors in CPE are sensitive to the challenges students face outside the classroom." While relatively large class sizes, and heavy teaching and advising loads likely play a part in this issue, the student responses here suggest that more should be done to ensure that students get the individualized attention and instruction they need to thrive as engineers.
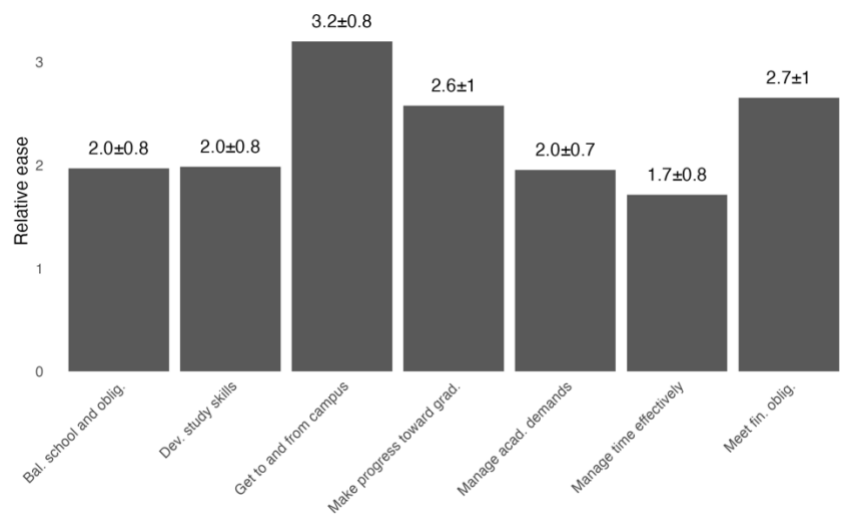

Figure 5. Educational barriers results.

Finally, respondents also expressed lower levels of agreement with the statement "The professors in CPE teach students tolerance and respect for different beliefs." Given that there is higher agreement with the statement "The professors in CPE value individual differences in the classroom", this result likely indicates a lack of proactive teaching of tolerance rather than a perception of intolerance among professors and instructors. Further research would be helpful to clarify this point, however; and the low score here may be indicative of a need for the department to offer more professional development opportunities for faculty in equitable and inclusive teaching.

Moving to CPE identity, the lowest score, and the only question with an average score below 4, is "I have a strong sense of belonging in computer engineering community." This result raises several questions for future research. First, it is unclear whether students are basing their responses on the computer engineering department at California Polytechnic State University or whether the response is influenced by experiences at internships and co-op work experiences. Also, given that students expressed relatively high levels of agreement with the question "I feel like I belong in the field of Computer Engineering," it is unclear whether and to what extent a lower sense of belonging in the community might lead to attrition or other negative outcomes for students in the program. Further research is certainly warranted here, however.

In terms of academic anxiety the highest scoring items, indicating items with the highest levels of anxiety, largely had to do with fears over schoolwork and assignment completion. The highest scoring item was "I often worry that I am not doing assignments properly" with a score of 2.8 out of 4. This is followed closely by "I often worry that my best is not as good as expected in school" at 2.6, and "I tend to put off doing schoolwork because it stresses me." This result again

seems to point to the possibility of imposter syndrome among students, and an overall lack of confidence and comfort in approaching assignments. Fortunately, the highest scoring anxiety item among respondents—"I often worry that I am not doing assignments properly"—seems like the easiest to address through traditional academic interventions and increased access to qualified tutors. The fact that this an issue of concern, though, may point to the need for training for faculty focusing on effective ways to work with students through challenging assignments.

Table 5. Scores for seniors versus all respondents on most significant academic barriers. Higher scores indicate the barrier is easier to overcome.

Barrier	All respondent average	Senior respondent average
Develop effective study skills	2.0	1.8
Manage time effectively	1.7	1.5
Manage academic demands	2.0	1.9
Balance school obligations	2.0	1.7

Finally, and perhaps most surprising, the most challenging academic barriers reported by survey respondents had to do with time management and general academic preparation skills: "How has it been to develop effective study skills?", "How has it been to manage your time effectively", "How has it been to manage the academic demands of college," and "How has it been to balance school obligations with personal commitments and obligations." Engineering is well known to be a challenging and time- and project-intensive major [25], [26], [27]. Further, some research has suggested that engineering programs foster a culture of stress [6] that glorifies being busy. Therefore, it is little surprise that lack of time poses a major barrier. It is a bit surprising, however, that students rate their own time management and study skills as a barrier. Looking at respondents who report that they have senior class standing, the scores for each of these measures decreases, as summarized in Table 5. Given that seniors have the most experience and demonstrated success navigating engineering coursework, it is very surprising that they report time management and study skills as significant challenges. This result also demonstrates that traditional approaches targeting incoming students for study skill and academic preparedness interventions or otherwise limiting instruction on these skills to a single course [28], [29], [30] may not go far enough: our results indicate that students throughout the curriculum could benefit from targeted efforts to improve their academic and time management skills.

The qualitative responses highlighted several major sources of stress and potential areas of support for respondents. The most common areas of feedback among respondents in order of number of comments were about program workload, course availability and department resources, department community, faculty interactions, and the tendency to compare their performance against peers.

Perhaps unsurprisingly, respondents overwhelmingly cited department workload as a major stressor. Many respondents reported feeling overwhelmed by the quantity of work, and several reported spending extreme numbers of hours each week working in the academic buildings. As one respondent reported "I am very confident that I have spent more time in the EE building than outside of it in the past 2 school years. I would arrive anytime between 8 AM and 11 AM and not leave until, at the earliest, 11 PM every day (weekdays and weekends). 7 days * 10 hours

(lowballing it) * 10 weeks = 700 hours a quarter. That's assuming a minimum amount of time spent here every day. I think I read somewhere you should be studying something like 35-40 hours a week. Our number is nearly double that." While several respondents imply that the workload is a natural consequence of being in an engineering program "I think the hardest part about being CPE is the magnitude of STEM classes we have to take," others suggest that some of the work is unnecessary with one respondent decrying the use of "busy work assignments that serve no real purpose and are never reviewed by the professor." Others suggest professors put too much emphasis on their own courses: "each professor teaches and expects work to be done like their class is the only class you have when realistically most students have 4 classes of similar difficulty."

Troublingly, however, many students directly link the workload to poor quality of life. Some comments focus on mental health: "I feel like there really is no space to focus on mental health any quarter due to how packed the classes are." Others are focused on issues like sleep, social life, and physical health: "I wish I had time to manage my sleep schedule, spend social time and have a healthy diet/workout routine. If I want at least one of these to be decent, I feel that I need to sacrifice a significant part of my own life." Still others linked the workload to loneliness "I specifically remember leaving my apartments one Saturday and hearing laughter and it made me actually mad. I realized I did not have free time like other students did" and to social isolation "Spring 2024 is the first time I took a 'for-fun' class […] I enjoy it with my friends but also feel a little sad knowing that this is my first and last non-curriculum class I can take with them." Taken together, it is likely that finding ways to help manage student workload would go a significant way in improving student quality of life.

The second most commented area involved course availability and department resources. Respondents cited factors like lack of space to enroll in required courses and difficulty in navigating the enrollment processes for service courses offered by other departments. Many of the comments, however, were requests for more tutoring and department specific advising resources to be made available for students. While our school offers a specialized advising center for the college, as one respondent put it "normal engineering advisors don't fully understand the different weights [difficulty/workload] of each computer engineering class." If nothing else, the department could work directly with the engineering advising center to ensure that they can give department specific insights to our students.

Several respondents also requested that the department do more to offer and advertise extracurricular projects: "Provide academic extracurricular opportunities like research, internships, or major related projects/ work. This would be helpful because one of the most stressful parts of being an engineer is having to compete with other engineers to get the limited number of resume-worthy activities available." While the notion of competing with other students for an increase in workload is problematic, our campus culture has a heavy emphasis on engineering clubs and competitions, and creating more links between the department and clubs could be beneficial for members of our community.

In terms of faculty interactions, student responses were mixed. Many comments under this theme expressed appreciation for department faculty with comments like, "I think the CPE department cares a lot about its students from what I've seen in the professors." Others, however, report a

different experience: "when I ask for help the professor feels that they are wasting their time." Some students suggest "I think a stressor for me is getting the right professors," indicating students have mixed experience with department faculty. These results certainly bear further exploration to ensure that students can have positive experiences with all of their faculty.

The final major theme that came from our analysis of open-ended survey responses is the tendency of students engaging in negative self-talk and comparing themselves negatively to their peers. While countless surveys, including this one, have pointed to impostor syndrome as a problem in engineering, it is still concerning to see student responses like the following: "What is holding me back is burnout, the sting of staring at a screen for 8+ hours a day, and having an echo chamber in my head that makes me feel like I am always falling behind, not performing well enough, and that my teachers think I am the dumbest person in the world." Other responses, though less descriptive, convey similar sentiments: "I often compare myself with other students and feel as though I am not good enough." While, again, the result that students feel imposter syndrome and believe that they are less good than, or have fallen behind their classmates is not new, these comments highlight the continued importance of working with our students on mental health issues and appropriate expectations for themselves and their performance.

Conclusions

This survey represents a baseline of data to determine barriers and challenges faced by students in the computer engineering department at California Polytechnic State University. Overall, respondents reported a strong sense of identity with computer engineering as a field and largely reported a positive climate with regards to department culture and experience with computer engineering instructors.

Despite these positive results, results indicated that respondents were struggling in a few areas. First, respondents reported difficulty with developing effective study skills and effective time management. Surprisingly, computer engineering seniors reported less confidence than the average respondent in their ability to develop these skills. This result indicates both a need for an increased focus on helping students develop good study and time management habits, and suggests that explicit training in these skills should be provided in some form throughout the entirety of the undergraduate degree program.

Other results from the survey indicate that imposter syndrome may be present among our students. Our respondents expressed a high degree of agreement with the statements "I feel I have to work harder than other students to be perceived as a good student," and "I often worry that my best is not as good as expected in school." These indicate that programming meant to address imposter syndrome and promote healthier expectations of personal abilities might be beneficial.

Finally, respondents indicated that faculty could do more to understand the unique learning needs and abilities of their individual students. This is something that could be addressed directly through interventions and trainings directed at faculty.

Limitations

While this research provided several insights into the state of students in our engineering program, and while it has provided several ideas for improving our department as part of our NSF RED grant, this research has several limitations that need to be addressed in future research. First, while the survey instrument covers many topics, it omits peer-peer interactions among students. Given that these interactions can either be the source of support or microaggressions and other negative experiences [31], [32], [33], understanding how students interact with each other as part of our department and institutional culture will provide critical information to improve our department.

The other major limitation of this survey is the response rate of 14%. Additionally, the respondents were overwhelmingly male and that 40% of total respondents were in their final year of the program. These factors mean that many unique perspectives may have been omitted from our data collection, potentially limiting the survey's value guiding the development of a more inclusive department. One the bright side, the respondent population showed strong racial and ethnic diversity, meaning that opinions from at least some historically excluded groups are represented here. Therefore, while not perfect, we believe that the response we were able to obtain still provide valuable insights into our department culture and suggest important areas for improvement. For future, surveys, however, an increased emphasis will be placed on getting responses from women and non-binary individuals, as well as on individuals in their first few years of study.

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