How Granular is the Problem? A Discipline-specific Focus Group Study of Factors Affecting Underrepresentation in Engineering Undergraduate Programs

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HOW GRANULAR IS THE PROBLEM? A DISCIPLINE-SPECIFIC FOCUS GROUP STUDY OF FACTORS AFFECTING UNDERREPRESENTATION IN ENGINEERING UNDERGRADUATE PROGRAMS

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INTRODUCTION

The underrepresentation of women and several racial minority groups (i.e., Black, Latino, Native American) students in engineering undergraduate programs can be attributed to a multitude of factors, including, but not limited to, insufficient preparation and barriers in recruiting into engineering programs at the K-12 level, low self-efficacy, lack of peer support, inadequate academic advising or faculty support, harmful stereotypes of particular groups that influence interactions in classrooms or in peer groups, and a chilly or unappealing climate [1-9]. These factors may exist at the level of the institution, the engineering college, and/or the engineering-specific department. Given the current accreditation structure for engineering programs, students' experiences may be more influenced by institution and college-level factors in their first two years, when they are taking basic science and breadth courses, and shift to department-level factors in their upperclassmen years as they enter discipline-specific courses. At both the local and national level, engineering disciplines may have widely disparate demographics that affect student experiences. For example, biomedical engineering and environmental engineering are heavily female (40-46%) when compared to electrical engineering, mechanical engineering, and computer science (12-16%) [10].

The potential granularity of the student experience, particularly for women and underrepresented minority groups, provides affordances and constraints in the methods and measures that can be used to characterize the issue and generalize beyond the setting or context at hand. For example, within a given discipline at an institution, there may be too few underrepresented students to gather aggregate, de-identifiable data that would yield generalizable outcomes. Moreover, despite the availability of validated survey instruments, it is difficult to reliably measure the complexity and interrelatedness of potential factors that influence the recruitment and retention of underrepresented groups, especially when combined with small sample sizes. The lack of reliable data within institutions about their students' experiences makes difficult, as faculty and administrators, to develop effective interventions at the appropriate level, e.g., college-wide or departmental or within individual courses, to best support underrepresented students.

The goal of this study was to better understand the experience of women and underrepresented minority groups within our engineering undergraduate program, across all years and disciplines. We were particularly interested in common experiences across departments that could be best addressed at the college or institution level, and those that were localized to individual departments. The majority perspective was concurrently examined in our study to allow us to better understand factors, negative or positive, that are more universal to the student experience in our program. In our study, White and Asian American males are treated as majority groups as they overwhelmingly comprise the majority of the student population in the College of Engineering at our institution. This is not to diminish the experiences of Asian and Asian American students for whom marginalization and stereotyping has been well documented in the literature [2], [11]-[12]. However, as part of the state flagship university, one of the primary goals of the College of Engineering's diversity and inclusion plan is to ensure equitable access to students in the state. A comparison of the state's racial groups is shown in Table 1. As evident from these figures, the composition of the student body at the University and at the College level is not diverse in absolute terms, and the gap between the state's composition and that of the University is among the worst in the nation [13]. As a result

of these racial disparities, our study focused on students who are underrepresented at our institution, and as such are the underrepresented minorities who are the focus of this study.

Table 1. A comparison of racial demographics among state, University and College students

	State[1]	University[2]	College of Engineering[3, 4]
Asian and Pacific Islander	3.7%	4.5%	8.0%
Black	22.0%	5.0%	2.5%
Latinx	8.0%	7.0%	5.0%
Multiracial	2.3%	7.5%	7.0%
White	64.0%	76.0%	75.0%

[1] based on AY17-18 high school seniors in public, private, and charter schools
[2] based on University reported demographics
[3] approximately 2.5% of students are international
[4] based on AY15-16 graduation data from ASEE Engineering Data Management System

Previous institutional research on underrepresentation in engineering has used focus groups or one-on-one interviews, surveys, and ethnography [1, 3, 5-6, 14]. Most recent reviews on the underrepresentation of women and racial minority groups in engineering or STEM have explored 20 years of research studies on these topics, and the majority of the research studies examined underrepresentation in engineering or STEM broadly, but not by specific disciplines [1,7]. However, researchers have found variability in gender in K-12 preparation and self-efficacy by different STEM disciplines, and these differences were most significant in computer science, physics, and general engineering rather than in biology and chemistry [1]. In addition, prior research suggests that distinctive cultures among the engineering disciplines are correlated with different experiences and opportunities among males and females [15]. In light of this previous research, we aimed to study the extent to which these factors and others influence underrepresentation in engineering at the institution, college, and department levels at our university.

METHODS

Our approach involved multiple focus groups that clustered students by engineering discipline and demographics. Twelve focus groups were assembled from the entire undergraduate engineering population at a single university (ca. 2,400 students in four-year programs), with separate focus groups for women, underrepresented minority groups, and majority (White and Asian male) students by discipline (see Table 2). Students were recruited for the study at random, from major-specific and demographic clusters, pulling from the entire population of academically eligible undergraduates in the college of engineering (GPA >2.0). Focus group size ranged from 2 to 8 participants with an average of 4 participants per group. A comparison of the demographics of the students in each college and the participants in the study is shown in Table 3.

Table 2. Focus groups for our study. "Majority" refers to White or Asian males.

1. Women in Chemical Engineering	2. Majority Students in Chemical Engineering
3. Women in Mechanical & Civil Engineering	4. Majority Students in Mechanical & Civil Engineering
5. Women in Electrical & Computer Engineering & Computer Science	6. Underrepresented minority groups in Chemical, Environmental, & Biomedical
7. Women in Biomedical & Environmental Engineering	8. Underrepresented minority groups in Mechanical, Civil, Electrical, and Computer Engineering & Computer Science
9. Majority Students in Electrical & Computer Engineering & Computer Science	10. Students in the National Society for Black Engineers (NSBE)
11. Majority Students in Biomedical & Environmental Engineering	12. Students in the Society for Hispanic Professional Engineers (SHPE)

Table 3. Student participant demographics compared to those of the entire College of Engineering. The number of participants from each program are shown in parentheses next to the total numbers in each program[1].

	Biomedical	Chemical	Civil/Environ.	Electrical/CS	Mechanical
Female[2]	99	107	146	92	121
Male	94	290	252	552	445
Asian Am.	27	34	15	81	36
Black	4	9	13	29	17
Latinx	1	8	11	11	12
White	139	271	312	389	417
Multiracial	14	37	27	62	47
International	4	41	15	67	31
Not Specified	4	12	5	5	6
Total	193 (9)	397 (22)	398 (7)	644 (14)	566 (11)

[1] demographic data were collected in aggregate across focus groups (see Table 2); this was done to protect anonymity of participants, especially those from URGs. No international students were included in the sample.
[2] Of the 63 participants in the focus group study, 29 identified as female.

Moderator prompts for the focus groups were based on validated survey instruments from the engineering education literature and focused on common concerns presented by students from underrepresented groups as they pursued degrees in STEM [16-17]. Prompts were centered on: (1) high school preparation; (2) interactions with peers; (3) interactions with faculty and staff; (4) program supports; and (5) family support. This protocol was supplemented by a brief survey to help initiate discussion that was presented to students prior to the start of each focus group. This survey included items on student's program of study, year in the program, student's involvement in engineering and non-engineering activities on campus, and items examining students' feelings of belonging in their program drawn from the literature [16]. Focus groups were conducted by researchers in a center within the university but outside of the college. Interviews were facilitated by one lead facilitator with a second researcher who took notes and assisted with notetaking, collecting surveys and keeping time.

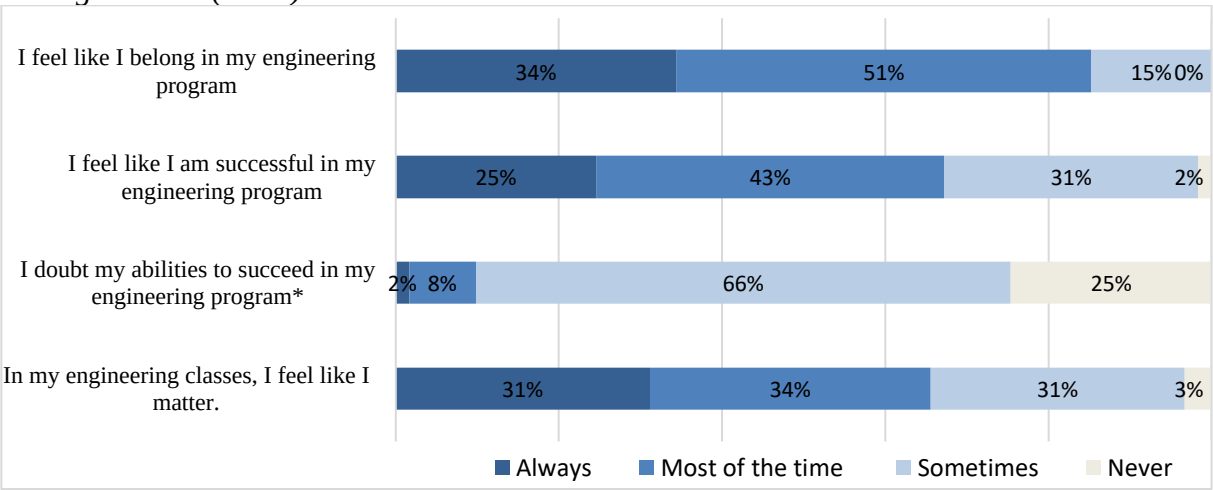
Survey data were analyzed with descriptive statistics (IBM SPSS v24) for the study population as a whole [18]. For the focus groups, audio recordings were made of all focus group sessions, and data were transcribed verbatim and subjected to qualitative analysis to uncover common themes related to recruitment, retention, and achievement. Initial codes were developed based on the protocol questions. Two coders separately reviewed 25% of the focus group transcripts and then met to generate a list of emerging codes that arose across the groups. Both coders then independently coded the chosen transcripts to examine interrater reliability. The percent agreement between the two coders was 97.9% and the Kappa coefficient was $\kappa = 0.75$. The coders then divided and scored the remaining transcripts independently. NVivo qualitative analysis software was used for coding [19].

RESULTS

A total of 63 students participated in the study, with representation from all engineering disciplines within the college (2.6% total undergraduate population). Chemical engineering was overrepresented (35% of all participants) when compared to our program's composition (18% of all undergraduate engineers); however, participation for all other majors was aligned to college composition.

Students represented all years in the program, with 11% first year, 62% middle years (second and third), and 27% fourth and fifth year seniors. The average GPA band for all participants was 3.0-3.5 (on a 4.0 scale); this is similar to the average GPA of all undergraduates in the College. Seventy-six percent (76%) of the students participated in engineering/technology related extracurricular activities. Figure 1 illustrates students' perceptions of their programs.

Figure 1. *Students responses to survey questions about their experiences as engineering undergraduates (n=61).*



Findings from the focus group interviews are presented in order to reflect the major foci of the interviews: (1) high school preparation, (2) peer interactions, (3) faculty/staff interactions, (4) professional identity, (5) program supports, and (6) family supports. Within each focus, we identified themes that represented the range of student perceptions (see Table

4). We present findings related to each theme and discuss differences between perceptions for women, members of URGs, and majority students.

High school preparation

Study participants attended schools in several states and had a range of experiences. A majority of the students engaged in high school coursework that included advanced placement (AP) classes in math and science. Some students also described attending technical schools or schools that focused on STEM, science, or engineering specifically. While some students knew that they were interested in STEM or engineering early on, there were others who did not make a decision to explore engineering in high school. There were also marked differences in exposure to content as illustrated in the two comments below:

"I went to a fairly large high school that had a lot of AP programs as well as some engineering ones. So, my senior year of high school, I took Intro to Engineering, in which we learned AutoCAD; we did a couple different drawing projects and little engineering projects. And then, I took AP Calculus BC and AP Physics C, which both gave me a really good idea of what kind of math and physics I'd be encountering in college. I used some of the credit to get out of some of the courses, which I think prepared me a lot. That's part of the reason why I chose engineering, was those courses."

"My high school was the exact opposite. I don't feel like I was prepared for Engineering courses. A lot of the courses… In my high school, it was the sense of they're spoon feeding you information and then you got to take it all in and then give it all back to them on the test and I wasn't ready for problem solving, and thinking outside the box to solve things, and just being given information and then working with it instead of get to a common goal. I was so used just getting it and then giving it back that I don't think I was prepared barely… Basically, I think I had the bare minimum in terms of my high school experience."

This difference in exposure to content at the high school level resulted in challenges for students once they matriculated to the College. A common challenge faced by students across focus groups was struggling in courses in which they had no prior exposure to the content. Students who participated in AP courses or who attended rigorous high school programs, especially those geared towards engineers, noted that their high school exposure to content supported their success in their program at the University. Those who stated that they did not attend a rigorous high school program or who did not take advanced placement or engineering courses in high school felt that they had a difficult time in learning course material in their first years. An example of a course that several students discussed as particularly challenging without prior high school coursework is Calculus II. For example, a student stated:

"And I second what he said because if I hadn't taken the AP calculus and physics in high school, then I feel like I would not have been prepared to face calculus and physics here because the difficulty is much more substantial here than it was in high school, for obvious reasons. And I feel as though without those AP courses, I probably wouldn't be where I am right now. I probably would have dropped because the level of difficulty, understanding – they seem to overcomplicate the fundamentals in terms of math and physics here"

This sentiment went beyond math and science courses in high school and also included exposure to chemistry, computer programming, and technical writing. While the population of students who are likely to go to under-resourced schools are those living in poverty, a large

proportion of those living in poverty also identify as a member of a URG. As stated by one student:

"I don't know if it stems back to high school. Yes, it does stem back to high school. Under privileged areas. I have this issue with my high school right now. So, you need to take an exam to get in to my high school, and the problem is that to get test prepped for this exam your family needs to have a lot of money or a decent amount of money. And, people like to put the money in to get you in to the high school because junior highs don't offer test prep for it. And, it ends up being that the last 40 years each year only one African-American student has been entered in to a class of like 300 and change, that's the most absurd thing I've ever heard."

Peer interactions

Students felt that peer support was key to success in their various engineering programs. For some, peer interaction was so important that it influenced decisions to change concentrations within their engineering department. Benefits of peer support included studying together, receiving mentoring from upperclassmen, and engaging in enjoyable learning experiences.

Peer mentoring by upperclassmen was highlighted by women and students from URGs as important to their success. Students discussed how mentors provided advice on which courses to take, opinions on professors, where to look for internships, what opportunities to take advantage of, and also provided resources such as course textbooks. Students described peer mentors as individuals who cared about their success in the program.

"Because I was in [Each One Reach One; EORO] and my mentor was electrical engineering and so he saved me... Just with like my advisor to this day doesn't help me at all. I really don't know what he's there for. So, I used to turn to him or his peers that he introduced me to that were also in the major. Like, "What classes should I take? What kinda professor's this?" Those things really make a difference in how your college experience goes about. So, if I didn't do EORO, I don't know what my life would be right now as a third-year student to be honest with you."

In addition to supporting their learning of content, students also felt that working in groups provided opportunities to practice collaboration skills necessary in their future employment. Providing designated student meeting space was presented as one college support that helped students in engaging in study groups.

"Yeah, because in 222, the CPEG room, we were doing the robot project. The room that is going to become I-suite, like we were all – like our entire class was in there like the day before it was due. Everyone was working on it. Everyone was like comparing and helping each other. It was a nice little hangout space."

Table 4. Results of thematic analysis of focus group interviews.

Foci	Student Experiences & Perceptions	Differential Experiences	Level
High School Preparation	- Insufficient prior exposure in basic math & science courses - Differential access to STEM-focused extracurricular activities		Institutional & College Level
Peer Interactions	- "Weed out" culture within certain departments negatively affects peer-to-peer interactions - Chilly climate within informal learning environments, e.g., study work groups & project teams - Formal & informal peer networks seen as highly beneficial	- Microaggressions against women & underrepresented minority groups - Black students, but not Latinx, report lack of cultural awareness & isolation - Peer networks seen as more important for women &	Departmental
Faculty/Staff Interactions	- Mixed reviews on instructional & mentoring experiences, with some faculty seen as highly supportive of student success and others not - Some faculty promote "weed-out" culture & chilly climate - Lack of racial diversity amongst faculty	- Microaggressions by faculty against women & underrepresented minority groups - Underrepresented minority groups more conscious of lack of diversity amongst faculty	Departmental
Professional Identity	- Design projects & internships help students see themselves as engineers - Biomedical & Chemical engineers have more difficult time with professional identity formation	- Mixed perceptions (positive, negative, neutral) of how being a woman and/or student of color impacts engineering identity	College Level & Departmental
Program Supports	- Need for improved articulation with career services, particularly for newer majors (bioengineering) - Importance of affinity groups, like SWE, NSBE, SHPE, in student recruitment & retention - Relatively higher GPA requirement in engineering to maintain merit scholarships	- Women and underrepresented minority groups stress the importance of affinity groups but feel that they are under-funded - Underrepresented minority groups highlighted relatively higher GPA requirement for merit scholarships & feel it leads to students prematurely leaving	College Level & Departmental
Family Supports	- Family seen as a source of emotional support to persist in engineering - Financial stressors related to tuition, completing degree on time, and keeping merit-based scholarships	- First-gen and underrepresented minority groups highlighted financial concerns	Institutional

Concerns surrounding peer interactions included the effect of "weed out" courses on peer interactions. Several students noted that courses that used grade curving resulted in cliques and competition among students. For example, one student contrasted his experience at the beginning of his program with his experience now nearing the end of his coursework:

"*I guess from our program, I felt like in the beginning it was very competitive. Just because your grades – I'm sure you guys are also graded – like your grades aren't A, B. It's more of a curve. So, if a 50 is an average and you got a C plus, then you pass. So, I've just felt like in the beginning, it was – like I have a good relationship with my peers now. But in the*

beginning, I felt like I was working against them. Like you don't want to help them because if they do bad and you do great, you have an A. But if you guys all do average, that's like a C plus. So, I just felt like – I mean, I know why they did it just to drive out everyone who couldn't handle it. But I just felt like in the beginning it was really competitive. Like now, just because everything's projects, we're all in it together because we're at the end."

Examining peer interactions among women and students from URGs suggested that students in these groups face several challenges. Among the challenges are enduring microaggressions from peers. Below are two examples:

"I was the only black female in the room and they had mechanical engineers, chemical engineers, electrical, computer, computer science majors, and everything. I came in. I sat down in a group that was designated for electrical and computer engineers and sat next to this white guy and I can tell he was very uncomfortable, but I don't know if it was because it was hot or what his problem was. So, I looked at him and I was like, "Are you okay?" and he was like, "Are you in the right room?"—Black Female Student

"I think it's more subconscious than anyone actually thinking oh, women in this field don't belong. But it's the kind of situation where you're working in a group and someone comes up [to a male student] and is like, 'Can you help me with No. 4?' And I go, 'I've got No. 4; I can help you.' And they ignore you."—White Female Student

Moreover, students from URGs expressed a lack of connection with classmates with many of these participants stating that they interacted with classmates only when they "needed to" to do well in the class. In further examining the focus group data, it became clear that this perspective was more common among students that identified as Black than it was among students that identified as Hispanic or Latino. In discussions around having classmates you can connect with, students from URGs expressed feeling disadvantaged in this area because they were often the only or one of few which can result in feelings of isolation.

"…last year, in my year, we had another guy, his name is …, but he switched out of my major, so now I'm the only black person in my class. But he and I were really close, we did all of our work together. So, this year has been kind of tough to me trying to assimilate into the class since I'm the only person who…"

Women perceived that their group dynamics were influenced by their gender. Specifically, women noted that in some group interactions men frequently "talked over" women and they noticed women do more work in the groups, as shown in this excerpt:

"I feel it is definitely women doing the most work though, at least trying to hold it to a higher standard. And, I'm not saying, I have worked with guys in my group that do want to hold it to a higher standard, but this might just be because there's been more men in my group than women. But as much as the men are like being lazy or won't show up to groups or things like that, but the women are always, there always trying to do the best work, always taking over the other sections that people forget about."

In interpreting peer microaggressions some Black students noted that for many students in the College, they served as their one "Black friend." One student stated:

"… a lot of our peers haven't been exposed to black people throughout their entire lives. So, when they see you, they make a lot of assumptions, or they're very inquisitive about

things, but not in a manner that is the right way of being inquisitive. So, a lot of the time, they just don't understand black culture. They've never been exposed to it. So, when they come and encounter it – first of all, they either fear it or they… Well, most of the time, it's fear, or they go about it a certain way that offends you, or they just start asking questions. I'm more than open to explaining where I'm coming from, but if you're asking me about it in a sort of defensive way, like, "Oh, that's weird; oh, that's wrong" – come on, now. I'm not going to talk to you about it."

Interactions with faculty and staff

Students discussed interactions with faculty, staff, and teaching assistants (TAs). They discussed both classroom interactions and interactions outside of the classroom in labs, office hours, and via email. They provided mixed reviews on learning experiences in classrooms. Students noted that they had positive experiences in classrooms where instructors presented material in an interactive way:

"There's definitely some professors that honestly can be so boring that you can't even pay attention well enough to ask a question, and then there's professors that are great and it's really interactive."

Specifically, students spoke about professors who incorporated technology by using the course website instead of lectures and those that used class time to allow students to attempt coding or solving problems and would then follow-up with the correct response. One student also discussed a course in which students were asked to learn the material before coming to class and then class time was used to discuss and apply the material. The student felt that this format helped in learning "high-level concepts". In addition, students described positive experiences in which both professors and TAs made themselves available through office hours and this opportunity was helpful to them. This was particularly evident in biomedical, mechanical, and civil engineering. Students provided many examples of positive interactions such as the one below:

"Also, I think that our professors are very personable. So, they'll lecture and stuff like that, but then afterwards, they always have some type of office hours or you're probably always welcome to email them to meet and talk about anything that you don't understand. Most of our professors have office hours, and then I'm sure – well, like I said, if you need a different time, I'm sure they'd be willing to schedule that. And not even just about course material. If you have questions about other things like career goals or applying to different schools and stuff like that, they're always – I feel very comfortable talking to any of our professors about things like that as well."

Students perceived there were opportunities to work with faculty in research labs. Students in chemical, electrical, and computer engineering perceived this information was well-advertised. Students in biomedical and environmental engineering from the majority population felt that they had to seek out the opportunities. Women in the same programs perceived lab environments in these departments provided valuable experiences. One student who is a member of a URG noted that her research experiences have helped the student to build an identity as a budding engineer:

"I feel like I do [response to being asked if (s)he feels like (s)he is becoming an engineer], because I've done research for so long. So, I started my first research project the fall of my sophomore year. And that one was not really my project. I was just mostly doing

data collection for a professor. But I've been doing a project that's mostly self-sufficient on my own for a professor since last summer. And because I've been working on it for so long, I feel like because I have that experience, I do. Just because it's – you're working so heavily on it and you're looked at as an expert. So, say, my research advisor will ask me a question and expect me to know the answer. And the answer I give better be right, because she's not going to fact check me. Given that experience, I do."

Students also discussed challenges they faced in interacting with faculty and staff members in their programs. Central to this discussion were concerns about faculty's willingness and ability to support student learning.

"I have professors that are great with answering questions, just really wonderful. And I've had professors that will say it's in the textbook. Well that's great but if I could learn from a textbook I wouldn't be in this classroom."

"I feel like it's pretty clear that they're experts in their field, not experts in teaching."

"… I'd say about half the professors, I would be able to talk to and, the half that I don't, I just rely through the TAs."

Students expressed concerns about several aspects related to teaching. One was that in some courses professors did not provide clear answers to questions asked by students. Students reported incidents when professors either attempted to respond to the questions but the response did not clarify the material for students, or the professors directed the students to the textbooks as a response. There were also concerns about how certain professors would respond to their questions. Some students reported that professors "made them feel stupid" in class for asking questions. Others reported that in cases where the professor was supportive, they sometimes did not ask questions because there was so much information to process and the students had not yet had the time to process and examine what they did and did not understand about the content. Students also expressed concerns around the presentation of course material. Specifically, they talked about being disengaged in classrooms where the professors read directly from the slides or simply used the slides that came along with the textbook. Additionally, students expressed frustration when there is a lag in feedback from professors on completed assignments. One student in chemical engineering shed some light on this process as s/he tied it to concerns with teaching assistants (TAs):

"And, sometimes the TAs don't even have enough resources themselves to really be proper TAs. They don't have guaranteed solutions and they're just guessing at the problems, too."

A desire expressed by female and unrepresented students was to see more people that look like them among the faculty.

"For me, the main things that I would like to see happen in the college – my ideal situation if I came through: I would like to see a professor that looked like me".

Students felt that having a more diverse faculty means there is a better chance that they will meet someone who has had previous experiences that mirror what they may experience as an engineer from an underrepresented group. To support an inclusive environment, both women and students from URGs presented experiences of being singled out in classes. Women discussed experiences in courses where the professor counted the number of female students during class and followed with comments. Most of the presented comments were not negative in nature but students felt it was unnecessary to draw attention in front of the entire class.

"My one professor did what you said, counted the girls in the class. That was interesting."

Interviewer: Did he say anything after that?

"I forget how many girls he said, but it was like, 'These are the amount of girls. Girls, you should stay in this career path. We need you.' I was like, 'Okay, I don't see why you're doing that right in the middle of this lecture, but okay.'"

Students from URGs also reported several incidents of being singled out. In some cases, it involved the professor calling on them more often because the professor learned who they were quickly since they were one of a few. In other cases, there were comments either said in private or in class that could be viewed as a microaggression. One Black male student talked about his experiences with a professor:

"Early on in my academic career, I had an experience with a professor where he would mention, 'Hey, man, stay out of trouble,' and this, that, and the third. I'm like, 'What trouble am I going to get into?'...I've never heard him say that to any other student when they were in office hours, and then, he would even mention – he would even highlight the fact that I was black, and also make comments on that while we were in office hours. Nothing in front of anybody else, but just on an interpersonal level, I feel like these professors need to be trained more on cultural awareness of the students they are teaching so that they can be more equipped to deal with them, and also more awareness of people's different situations."

A female White student provided another example:

"He was a great professor, I did have one issue with him that first class. You remember when we were doing the problem where he just printed out the picture of a guy shooting a basketball, and was like, figure out what's happening? And, I was working with another student who was one of the males out of the two, and we were talking, and the guy called over the professor, and we were explaining to the professor our thought process. But, the professor wasn't listening to what I was saying and was just listening to what the guy was saying. I was like, 'hi, no my idea'. Like you know, trying to like to say it and after the guy said something wrong, I corrected him then I got the professor's attention. So, that just kinda like really showed me I had to not only be smarter, but call out other people's stupid mistakes, maybe get the attention of some people."

Students also discussed more public displays of microaggression. One such example is presented below by a Black female student:

"And then when we were in class, he tried to explain something and there was images that were white. No, they were images that were black and something white would come up from the front…So in the array, you wanna pick something at the end and bring it to the front of the array, he said like, "The white man is gonna push the black people like they've been doing for centuries." And it was only two black students in the class and the whole class just looks at us."

Several students discussed how the "weed out" nature of the program resulted in negative student-faculty and student-peer interactions (student-peer interactions are discussed under another theme). Some discussed how when faced with difficulty in a course a professor would encourage them to drop the course or even leave the program:

"My biggest problem with …Engineering is that the looming threat of how the professors, even if they want to help you, there's a cutthroat type of thing where they're trying to kick you out."

"One of my professors made a joke about this in one of my …classes. We were talking about separation by boiling things off and he's like, it's kind of like what we're doing with you guys. Boiling off the weak ones."

Professional identity

Students often mentioned that they saw themselves as engineers or would see themselves as engineers when they were involved in activities that allowed them to apply what they'd learned in courses. This included working on a class project (something frequently discussed was the design project some of the students do every semester), doing research and internships, or working in the field, especially when working with a group of other engineering students or engineering professionals. For example, one student mentioned:

"I think I'll feel more like an engineer when I'm actually in the field getting that experience. And finally, maybe, when you apply, something's like, oh yeah, I learned that. I actually know how to solve this problem. That's, to me, I think is when it's more apparent."

In addition to seeing and experiencing what they will actually be doing when they join the engineering workforce, it seems that the sense of accomplishment of actually solving a hands-on problem or creating a tangible thing is important in helping students to connect to their professional identity. For instance, a student commented that when the professor just provided students the essential code to run a microcontroller and showed them how that worked, the student felt less like a budding engineer because the professor had done most of the work and s/he didn't feel as accomplished as s/he may have if s/he had figured it out.

When looking at students within each engineering program or major, there were mixed numbers of students who identified themselves as engineers within each program. In addition, sometimes a focus group included students from multiple majors, and it is therefore difficult to identify exactly which student came from which program. However, for both the female and male chemical engineering student groups, the majority of the students discussed that they did not see themselves as engineers, because they had very few opportunities to actually solve a real-world problem or apply things they'd learned in the classroom to a real engineering setting. For instance, a student mentioned:

"I always feel like mechanical and civil engineers is more like real engineers earlier because their classes are having them build things, versus chemical engineering is a lot of just you're doing problem sets and working out what a real situation would be but it's not until J Lab that you actually are taking a class where you're working with the type of system that you would if you were a chemical engineer in industry."

A senior student in the Chemical Engineering program who identified herself as an engineer, mentioned that it took her a really long time to embrace that engineer identity,

"Like three years of engineering coursework and then three internships. And then finally, I sort of got to the point where I was like oh, I actually can do it and I can complete the coursework."

Additionally, students from the biomedical engineering program mentioned that they felt unprepared because they thought biomedical engineering program was easier than other engineering programs at UD, and since their program is broad, they don't get as many

engineering specific courses that teach them either engineering principles or applied skills, such as CAD or SolidWorks, as students in other programs. One female senior student in the biomedical engineering program mentioned that although she would be graduating soon, she still felt unprepared as a real engineer when applying to certain jobs in her field.

Women and students from URGs shared some similar comments about how being a member of an underrepresented groups influenced their professional identities. Women and students from URGs often discussed how they could be the only female student or the only student from a URG in the classroom which makes them feel challenged and intimidated, especially when working in groups because it's difficult for them to find someone that shares similar backgrounds to work with. For example, a female student mentioned:

"*Sometimes, being a female in my engineering classes definitely is a little intimidating, guys all around. And I feel like, sometimes when I'm put in a group, they kind of look at you like you don't know what you're talking about. And it's annoying. But I find also, in my classes, that I tend to go towards the other minority students. And I always like working with other minorities. And that may be because I'm in programs like RISE and SHPE and SWE. So, I do find that I tend to lean towards working with other minorities*."

Additionally, some students mentioned how being a woman makes them less empowered and less confident about their professional identity, and how they've noticed and perceived the underrepresentation of women engineers in the workforce. Excerpts from three students indicates this trend.

"*I think in general, people don't take us as seriously. Honestly, in our major, I feel like we have a good balance of male to females. I think it's at 50 about for our major, so I've never felt like no one's taking me seriously. But, I mean, I know in some of my other classes like I had a physics lab where I was the only girl. And that was a little intimidating. And I've heard from some of my other friends in other majors that there is such a low population of females. And it should be."*

"I feel like the one thing about myself that would make people question whether I would be an engineer, are probably me being a woman. But, I never thought about that really until college when I started my internships, and I went into the workplace and saw that I was the only one. When like I wanted to know what I should wear, and they went to look around and there were no good examples."

"*Out of 100 people in the research lab there was one woman. I was able to sit down in a conference room and talk to her about what it's like, and she's like: they're going to try to make you the note takers and things like that, and you need to be like: no, your handwriting sucks but you need to take the notes anyway because I'm working on this problem****."***

However, not all female students felt disadvantaged or different from their classmates because of their identity as a woman, as one student shared:

"I never felt like being a female made me any different. I feel like people just took me for my personality of judging what I'm capable of. Since there's a lot less of us than males, we're all very willing to help one another and reach out and try to keep ourselves strong within the program, so that could be beneficial."

Furthermore, several students also mentioned that they viewed being a woman or a member of a URG as a gift that also offers some advantages. Both women and students from URGS mentioned that their identities could sometimes motivate them. For example, a Hispanic student stated:

"I think knowing that Hispanic people are underrepresented in engineering almost makes it more motivating. Like I'm here and I'm Hispanic. And I'm studying engineering. You're increasing the diversity and you don't feel like you don't belong just because you're Hispanic."

Another female student said:

"I always hear this from everyone else that like being a woman in the engineering field will be beneficial for us later on, when we're finding a job. So, I think that aspect is definitely gonna help us."

Program supports

Students discussed a range of supports including tutoring services, designated study spaces for students, mentoring programs, and financial support from the college for extracurricular activities and individual student support. Overall, students described mixed experiences with career services. All participants stated that they received information on a range of opportunities through career services. In regard to internship and career fairs, students in chemical, environmental, and biomedical engineering felt that there were few companies at these events that fit their interests. Students from URGs expressed frustration with the limited opportunities for internships and jobs presented at the campus career fairs. They also felt that opportunities for internships were limited to those who had made connections (likely familial) to the companies:

"Even getting opportunities outside of the curriculum, doing research and internships, but getting back to what … said, hearing about some people who got an internship, but that's through their dad who owns the company, or they know someone… When you don't have those same connections, it puts you down a little bit that you won't have that opportunity to work out there. You only learn so much in the classrooms; you just want to have that fair chance, too. Some people get in through…"

Students from URGs also described how they created their own connections through RISE and NSBE:

"I can speak on RISE – Resources to Insure Successful Engineers. Pretty much, after my freshman year, every internship that I've had after that has been because of RISE and the connections that I established my freshman year through networking, through the workshops, and through the multicultural career fair, whatever it may be, just talking to the recruiters there."

"And then, also through NSBE, the National Conference – even the regional conferences that we go to, we have a lot more opportunities to be seen by companies that aren't within our region like Ford, GM, that are definitely not coming to the University of Delaware, but because we are part of the National Society of Black Engineers, we get exposed to those companies, and also, seeing other engineers doing the same exact thing gives a lot of encouragement as well. And then also, seeing professionals who look like you, who are recruiting for you as well, also gives you a little reassurance."

Challenges included finding tutors for upper classmen particularly those in chemical engineering. Students also suggested the need for a designated grading service to support professors and TAs in efficient grading of assignments that count toward their final grade. With regard to space, students discussed the helpfulness of having designated student space and those in programs without designated student space, expressed a desire to get such space. College and departmental supports that students viewed as needed were funding for conferences and greater diversification of potential industry employers at college career fairs. In addition to a greater range of companies at career fairs, students also discussed concerns related to preparation for their engineering job search. Skills that students felt were needed included interview skills and practice in salary negotiations. Students also expressed a need for greater opportunities for study-abroad, particularly in the chemical engineering program. There were also requests for greater funding/direction for peer mentoring programs. In particular students discussed the RISE mentoring program and noted that not much direction was provided to support peer mentors. Also, women in mechanical engineering noted a new mentoring program that had promise but would benefit from planned mentoring activities. Programmatic changes needed included a move away from "weed-out" courses as students viewed this as negatively affecting student's psychological well-being and the diversity of the student body. One student noted:

"My girlfriend dropped ChemE and I told her about this thing and she said, in CHEG112, … the class is designed, I truly believe it's designed to try and weed people out. She just didn't want to be in an atmosphere like that and I don't know if it's a gender thing, but I know a lot of girls that drop it and it makes them happier, whatever. But, if you're trying to keep diversity and these girls are dropping left and right…"

Women and students from URGs discussed the need for courses or seminars covering ethics, workplace behavior, and the experiences of women and members of URGs in industry, topics that may be incorporated in a course like EGGG. Additionally, students suggested the introduction to each engineering discipline be presented in the first few weeks of course before drop-add has ended to provide students the opportunity to switch disciplines if interested. Students also noted a need for more instruction in MATLAB if the program would then be required in assignments in future courses. This suggestion was presented across several disciplines. Chemical engineering students also noted requirements in the introduction to chemical engineering course that seemed out of sequence and may be better aligned with courses students take in later years. For example:

"Yeah. I took my notes from 305 and walked because the next course was KEG112 of my day and put down my notes and just did the same problem twice which means the Introductory Chemical Engineering class is as hard as the math that you take a year from then and they know it."

In a similar vein, students suggested that majors that require a technical writing course offer the course earlier in the curriculum sequence to support lab report writing in junior and senior year.

Students in NSBE and SHPE also discussed a lack of financial support from the institution for their organization which members felt were organizations that support retention of students from URGs in the college. Specifically, the students felt that they faced many institutional barriers to making progress in growing and funding their organization.

"And then, as far as NSBE and things like that, the college – the department – will be like, 'Oh, we spent $600,000.00 renovating a room.' Great. NSBE asks for a money to go to a conference, and they're like, 'Oh, you're capped at $1000.00.' So, priorities – okay, where exactly do you see me fitting into your picture of, 'Oh, we want to paint diversity.' But, you spend $600,000.00 on a room and $1000.00 on NSBE. So, that's it's kind of a disconnect, and that's where I look forward to being able to work with them, but give back to NSBE and things like that, so other people don't have to figure out, Okay, do I really matter to the college? What exactly is the purpose?"

Family supports

Students generally reported that their families were very supportive. Most of the support was in the form of emotional support, as students mentioned that their family members were always there to listen to their experiences, struggles, and offer them motivation and encouragement. For example, one female chemistry student shared that there were several times that she wanted to drop out, but her parents often encouraged her by stating, *"Yes, you can do it. I know it's awful, but you can get through it and we are here to support you through the process,"* which she thought was very helpful. Students also mentioned that their families did not pressure them, but just want to make sure they did their best. Many students felt that their families did not necessarily push them to pursue engineering as a career, but instead supported them in their pursuit of a career in which the student would be happy and successful.

Other students found helpful having family members with engineering backgrounds helped them. For example, if they had a family member that worked in the engineering field or that had background knowledge about engineering, they could talk to students about engineering concepts or their class content. These family members had a better understanding what the students were going through and offered more targeted advice based on their own past experiences and the students' characteristics. For example, one student shared:

"My uncle's doing, I think it's computer engineering and so I've called to ask him just kinda like what it's like going through it because regardless of your branch of engineering, you have your own difficulties. So obviously, he tells me, he's like, 'I'm not doing what you're doing but in the long run, you just got to be convinced that you're gonna get through it. It's always rough at the beginning but then you get used to how rough it is, and you just battle through to the rest of it and then before you know it, you're out of it.' So, it was encouraging words to hear from somebody who did it, which I definitely could not do computer engineering so him saying that is like motivating like, 'Okay. I can get through whatever I'm trying to get through.'"

Although some students mentioned that their parents offer to pay for tutoring or a summer/winter session, many students mentioned that it's very hard for them financially, especially if they are out-of-state students, transfer students, or international students. Integral to this is the challenge to maintain a high GPA in order keep scholarships. One student shared:

"I also agree that it's really hard to keep that scholarship because of the amount of the load of work that we have to do as engineers is significantly greater than other majors. Because I barely have time for anything fun. And I see all – I don't see all my friends – I see my non-engineering friends going out and just doing whatever."

Similarly, another student shared his/her views about the scholarship standards:

"Yeah. I feel like they (the department) should consider the amount of work that we have, chemical engineers, we also have to start on a higher math course."

It is noteworthy that most of the discussion around financial challenges came from students belonging to URGs suggesting that these students may face greater financial challenges.

DISCUSSION

The results of our study suggest there are elements of the undergraduate engineering experience at our institution that are different for women and underrepresented minority groups than for the majority students. Our results align with and extend prior research. Other studies have pointed towards the feminization of particular engineering fields, such as industrial engineering, which lowers the perceived prestige of one engineering discipline over another and lead to different experiences for males and females [14, 20-21]. Our data similarly point towards normatively gendered borders between programs – the differences in students' perceptions between biomedical engineering and other fields such as mechanical and electrical engineering that could serve as inadvertent gatekeeping for women who are unsure or unclear about which engineering program attends to their interests. Such gatekeeping only serves to reify the underrepresentation of women in particular engineering fields [1, 14, 22-23].

Our work supports research on the intersections of race and class in education, specifically in engineering education. For instance, participants in our study made clear how financial support from family or through academic scholarships is the crucial link in access to educational resources [2]. Some participants raised concerns about both covert stereotyping and microaggressions in their interactions with peers and with faculty. Such microaggressions are harmful to students precisely due to their nature – subtle, innocuous, preconscious or unconscious degradations that seem harmless but collectively contribute to the diminishment of underrepresented minorities [12, 25-27]. Especially prevalent in the data from our study were micro-invalidations – remarks that diminish, dismiss, and negate the realities and histories of people of color [25, 27]. Such findings suggest both students and faculty require professional learning about race and class so they are more aware of cultural dynamics of power and privilege and so they are able to engage in honest discussions about the issues [28]. It is worth reiterating that during focus groups the participants themselves suggested the need for education of faculty and students around workplace ethics and the sociocultural experiences of women and underrepresented groups. Certainly, their insights bear witness to the types of interactions they experience.

In our study, two main issues arose related to professional identity and identity formation. The first, gender politics in identity formation in engineering programs, was evident among the experiences shared by women. Other studies have indicated the association of engineering identity with masculinity and this is heavily manifested in the types of interactions women experience with their male peers and the social networks available to them [15, 21-22, 29]. It has been documented elsewhere the code switching necessary for women engineers to be taken seriously and to be recognized as a 'real engineer' [23]. These interpersonal dynamics in identity positioning, both subtle and overt, have long term consequences for women who attempt to make a stake in engineering as a profession. The other issue related to identity in this study, professional identity, or seeing

oneself as an engineer, was closely connected to the types of opportunities to learn engineering [30-31]. It was clear from the data that heavy emphasis in some programs on disciplinary knowledge rather than the technical skills and competencies left some students feeling uncertain in their journey towards developing a professional identity as an engineer. These findings call into question the curricular structure and content of particular programs such as biomedical and chemical, which heavily emphasize theoretical knowledge over practical skills and/or technical competencies.

It appears from data analysis that students' experiences may differ by department, while others can be attributed to college or institutional policies and culture. Student experiences, both negative and positive, with peers and faculty were highly localized at the department level; whereas issues like criteria for merit-based scholarships, funding for affinity student groups, and lack of diversity amongst the faculty are the result of college and institution-level practices and are best addressed at this level. The results of this study were immensely useful in targeting potential sources and symptoms of underrepresentation within our programs as well as designing focused interventions at the appropriate administrative level. Based on the results of this study, we have proposed several action items (Table 5), which are at present being carried forward in our college's strategic plan for undergraduate diversity.

Table 5. Action items for departmental, college, and institutional level interventions to address issues elucidated by this focus group study.

Department Level	**College Level**	**Institution Level**
- Cultural awareness & sensitivity training for faculty, with particular emphasis on inclusive instructional & mentoring practices - Ensure equal opportunities for women & underrepresented minority groups within departments, e.g., undergraduate TA positions, research assistantships, work study	- Create summer bridge program for women and underrepresented minority groups - Increase college-level funding to students with short-term financial aid needs - Increase funding for affinity groups, such as SWE, NSBE, & SHPE, and conduct a review to ensure equitable funding and faculty advisement across all college & department-sponsored student	- Work closely with local K12 feeder schools to improve rigor of math & science preparation - Revise GPA requirement for merit-based scholarships to reflect GPA concerns in engineering - Continued focus on recruitment of faculty of color across STEM disciplines, but particularly in engineering

In considering how the methodology and conclusions drawn from this work can be extended to other institutions, it is important to consider both the strengths and limitations of this study. From a methodological perspective, we assert that creating separate focus groups by discipline as well as demographics was necessary, and, without disaggregating in this manner, we would not have discovered the microclimate issues related to peer and faculty interactions. This may be an issue of size, however, and smaller institutions may not observe differences in underrepresented group experiences across disciplines. A second methodological strength is that our focus group prompts, and related thematic analysis were grounded in the engineering education literature, which yielded qualitative results that are consistent with prior work [1-2, 5-6, 9, 16-17, 24, 32-33]. Specifically, our underrepresented minority groups unfortunately reported microaggressions by both peers and faculty cite financial stressors in pursuing their

degree, and stress the importance of affinity student groups, like NSBE and SHPE, in providing social support [2, 6, 9, 25, 27-28, 32-33].

One limitation of this study is our lack of attention to intersectionality. Specifically, we had an interest in experiences of women and underrepresented minority groups but did not account for the experiences of individuals who may have identified as women and members of underrepresented minority groups. Moreover, we did not report on separate race/ethnicity groups and instead considered all students who identified as a member of an underrepresented minority group as one unified group in this study. Future research that incorporates intersectionality and that explores perceptions by individual race/ethnicity populations using our presented methodology is needed. Another limitation of our study is that it is localized to our institution, a mid-sized, predominantly white (PWI), public, land and sea grant university in the US Mid-Atlantic Region. While the college and institution-level issues may be relatable to other PWIs, it is likely that the specifics of the department-level concerns result from our institution's subculture and history. Moreover, our use of a small sample and one university setting may mean that our results will not generalize across other university settings. We encourage further research using our methodology to examine its validity across larger samples and across multiple settings.

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