Crafting Success for Underrepresented Scientists and Engineers

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Final Report
Crafting Success for Underrepresented Scientists and Engineers

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Table of Contents

Introduction 1
Research Questions and Methodology 3
Phase 1: Quantitative Analysis of Institutional Student Data 4
Phase 2a: Mixed-Methods Analysis of Student Experiences 4
Phase 2b: Inventory of Policies, Programs, and Traditions 4
Phase 3: Determination and Prototyping of Interventions 4
Phases 4 and 5: Interventions and Assessments 5
Activities during Funding Period (October 2017 to September 2018) 5
Phase 2a: Engineering 5
Phase 2a: Chemistry 6
Phase 2b: Engineering 6
Phase 3: Engineering 7
Primary Themes from the Findings 7
Theme 1: Preparation for and Awareness of the Rigor of the Engineering Curriculum 8
Theme 2: Confidence in Enrolling in Advanced Courses When Appropriate 9
Theme 3: Resource Utilization (or Lack of Utilization) 12
Theme 4: Sense of (or Lack of) Belonging with the Engineering Community 17
Overlap among Themes 21
Results of the Project and Next Steps 22
Changes Made in Engineering as the Result of Our Work 22
Ideating and Prototyping Interventions 23
Chemistry Department Analysis and Next Steps 24
Extramural Funding and Publications 24
References 26
Appendix A: Student Focus Group Protocols 27
Appendix B: Supporting Diversity in STEM at UVA—Faculty Interview 37
Appendix C: General Chemistry Spring 2018 Focus Group Protocol 39

Introduction

To remain competitive in the global economy and maintain a strong national security program, the United States must educate high numbers of college graduates in science, technology, engineering, and mathematics (STEM). Although STEM fields are the fastest growing occupation, and 65 percent of all jobs in the U.S. will require a post-secondary degree with STEM literacy skills by 2020 (Carnevale, Smith, and Strohl, 2013), fewer than 25 percent of college students are pursuing STEM majors (National Center for Education Statistics, 2012). Because the largest growing sector of STEM occupations requires a college degree, U.S. higher education plays a significant role in contributing to the nation's economy and defense. Yet, there is ample room for growth in the number of STEM graduates.

Four troubling achievement gaps compromise higher education's capacity to educate a strong STEM workforce:

1. A gap between white and other racial groups (National Center for Education Statistics, 2012)
2. Within these racial groups, a gap between men and women (ibid.)
3. Another gap among socioeconomic backgrounds (American Psychological Association, 2017; Reardon, 2011)
4. A gap among first-generation college students (Stephens, Hamedani, and Destin, 2014).

The U.S. can't afford for anyone to be hindered from pursuing a STEM field if it wishes to remain globally competitive and protect its citizens. Thus, it is critical to understand the challenges and barriers to undergraduate study in STEM fields, including historically marginalized students, such as underrepresented minority (URM), women, and first-generation and low-income (FGLI) students. The STEM fields are dominated by a white or Asian male workforce.

The Office of Diversity and Engagement (ODE) in the University of Virginia's (UVA) School of Engineering & Applied Science (SEAS) began a comprehensive, longitudinal research project in 2017 called Crafting Success for Underrepresented Scientists & Engineers (CSUSE) to understand the diversity issues affecting STEM education. Our preliminary data analyses indicate that there are pervasive issues limiting UVA's potential to do its part in supporting the growth of the nation's STEM workforce pipeline. For example, only 35 percent of African American engineers graduated with at least a 3.0 grade point average (GPA), versus an 82 percent average among UVA engineering majors over the past four years. As noted above, similar outcome differentials nationwide severely threaten America's STEM workforce readiness and future economic security. The future STEM workforce pipeline will need to be inclusive of the demographic groups that are growing in representation—primarily today's URMs.

UVA engineering's ODE partnered with the consulting firm LMI and the Commonwealth Center for Advanced Logistics Systems (CCALS) to initiate a multi-phase, longitudinal research study examining the factors contributing to differentials in academic achievement among STEM

students of different demographic groups, including racial/ethnic, gender, low-income, and first-generation status. Because UVA attracts students in the top 10 percent of their high school classes, one hypothesis related not to the academic ability of these students but instead to the psychosocial and behavioral challenges and supports of these students during their time in college. For example, how do students' senses of belonging and community, self-efficacy and resiliency, and perceptions of their institutional climate and culture affect their academic achievement?

ODE formed a team of researchers from across UVA with relevant content and methodological expertise.

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Research Questions and Methodology

Working with the research team, ODE developed a longitudinal mixed-methods, five-phase study designed to address two critically important research questions:

1. What factors influence divergent levels of STEM students' academic achievement and success among different demographic groups at UVA?
2. What interventions can be introduced to address these divergences?

The research design for the study consists of five interrelated phases (Figure 1):

- Phase 1 analyzes UVA student records and extant survey data to uncover patterns that suggest sources of academic achievement disparities among student demographic groups.
- Phase 2a uses conceptual frameworks and empirical literature to study UVA STEM students' college experiences through mixed methods.
- Phase 2b catalogs institutional policies and practices intended to support STEM students at UVA.
- Phase 3 determines possible interventions through prototyping.
- Phases 4 and 5 implement and assess the interventions' effectiveness.

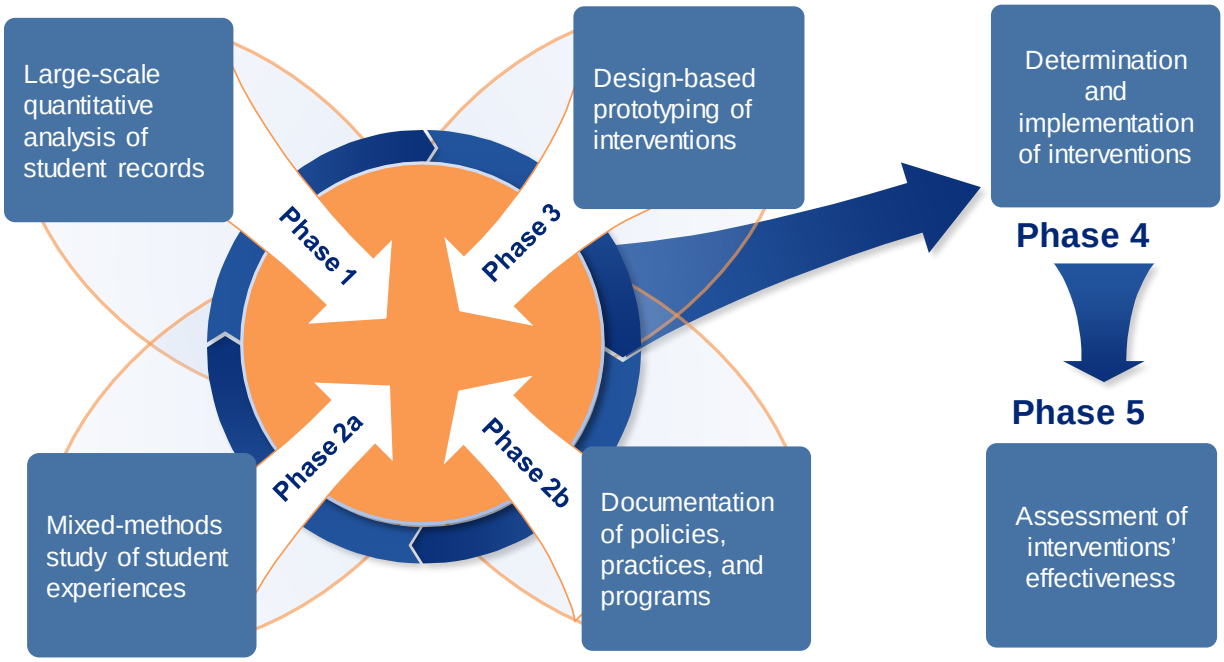

Figure 1. Project five-phase iterative research design

The first three phases occurred concurrently to inform and support the other two in an iterative process.

Phase 1: Quantitative Analysis of Institutional Student Data

In the first step of Phase 1, the team built a data clearinghouse (Student Success Data Mart) of longitudinal student records from 1991 to the present, enabling predictive analytical models for all aspects of educational success while isolating factors that inhibit success. The following data points were included in the clearinghouse: high school achievement records, collegiate semester-by-semester grade reporting, courses taken, and graduation outcomes for all undergraduate students across UVA. Using these data, the team analyzed the demographics of the student body. Next, we searched for course-level inflection points in student progress from matriculation to graduation. Finally, we built a set of predictive models to relate student outcomes with critical input factors.

Phase 2a: Mixed-Methods Analysis of Student Experiences

The second phase included a mixed-methods analysis of the student experience gathered through surveys, focus groups, and interviews. The goal was to assess the psychosocial realities of the student experience, such as STEM identification, sense of belonging, and self-efficacy. Along with Bean and Eaton's (2000) psychological model of college student retention and Milem, Chang, and Antonio's (2005) campus racial climate conceptual model that frames the Phase 2 inquiry, the research team used data collected in Phases 1 and 2b to inform questions and topics to discuss with students.

Phase 2b: Inventory of Policies, Programs, and Traditions

Each institution has its own policies, programs, and traditions that can affect academic achievement as well as students' respective senses of belonging, self-efficacy, and support. Therefore, it is critical to clearly identify those institutional components in light of Phases 1 and 2a. Examples of these components include ODE's summer bridge program for incoming first-year engineering students, UVA's Office of African American Affairs, the university's honor code, the absence of a formal math selection process for first-year students, and the placement of both the Multicultural Center and the LGBTQ Resource Center in the basement of Newcomb Hall.

Phase 3: Determination and Prototyping of Interventions

In keeping with our research protocol, interventions were empirically driven using data from Phases 1–2b. With data collection completed from Phases 1, 2a, and 2b for the School of Engineering & Applied Science, the researchers working in the intervention phase (Hulleman, Roksa, Trawalter, and Wilson) are now discussing plans for prototyping promising interventions for addressing the themes uncovered. A description of the major themes uncovered in the School of Engineering & Applied Science and initial plans for prototyping interventions can be found later in this report.

Phases 4 and 5: Interventions and Assessments

After the completion of Phase 3, the team will implement the selected interventions while the aforementioned four-member faculty research group will perform the necessary evaluation and assessment with an emphasis on psychosocial-behavioral effects.

Activities during Funding Period (October 2017 to September 2018)

Phase 2a: Engineering[1]

Student Focus Groups. A total of 95 unique engineering students participated in 34 focus groups, across 3 time points during the 2017–2018 academic year (see Table 1). Of these students, 26 participated in more than 1 focus group. Focus groups included between 2 and 8 students and were stratified at each time point as heterogeneous (e.g., mixed race, gender, academic class level) and homogeneous (e.g., female only, first-year only, URM only) to capture the unique perspectives of the targeted subgroups. They lasted approximately 1 hour and were transcribed for analysis. Appendix A contains the focus group protocol for each subgroup and time point.

	Fall 2017 (13 focus groups)			**Winter 2018 (11 focus groups)**			**Spring 2018 (10 focus groups)**			
Year	**1st**	**2nd–4th**	**Tot**	**1st**	**2nd–4th**	**Tot**	**1st**	**2nd–4th**	**Tot**	**Unduplicated Total**
All	17	27	44	14	28	42	11	24	35	95
URM	4	9	13	4	5	9	2	5	7	20
FGLI	5	3	8	4	3	7	3	2	5	15
Female	6	14	20	6	16	22	4	13	17	47

Table 1. Focus group student demographics at each time point

Faculty Interviews. To support the credibility of our interpretation of student focus group responses, 11 faculty members teaching key courses in the SEAS curriculum (e.g., calculus, physics, chemistry, introduction to engineering) were also interviewed using the protocol in Appendix B. These interviews lasted between 30 and 45 minutes and were transcribed for analysis.

Analysis. Data were analyzed inductively using Dedoose qualitative software. First, a subset of the data were read by the research team members who conducted the interviews and focus groups (n = 6), and a list of potential open codes (e.g., science experiences before college, exposure to science, early interest in science, negative perceptions of racial diversity, positive

[1] Note: Phase 1 was completed during the prior funding period of October 2016 to September 2017.

perceptions of racial climate, math) were developed. These initial open codes were informed by the research questions, conceptual framework, research team discussions about common responses, and institutional data.

Next, the research team collapsed this initial set into 21 codes for data set analysis. For example, science experiences before college, exposure to science, and early interest in science were combined with the engineering and math experiences, interest, and exposure to create the two codes "early interest/exposure to science, math, and engineering related activities" and "pre-college academic science, math, engineering background." Positive and negative perceptions of the racial climate at UVA were collapsed into the code "racial climate at UVA."

After the 21 codes were developed, an excerpt from one of the transcripts was coded collectively by the research team with discussion of how and when they should be applied to clarify codes for the team. For example, the "math" code was used for any response that related to a student's math experience in college but excluded references to pre-college mathematics experience. Then, another short excerpt was selected and coded by each research team member. Discrepancies in code application were discussed as a team and consensus reached and code definitions modified as needed. This process was repeated with three excerpts requiring different codes and resulted in 75 percent reliability in code application across all of the researchers for the final excerpt. Four members of the research team then divided the transcripts and individually coded them using the scheme developed. In instances when a team member was unsure of how to code a passage, the response was flagged and discussed as a group until consensus was reached on what codes should be applied.

Phase 2a: Chemistry

During the spring of 2018, a total of 22 students who started the general (CHEM 1410) or honors (CHEM 1810) chemistry sequence participated in seven focus groups. Focus groups had between two and eight students and were stratified by course sequence taken (i.e., five focus groups for CHEM 1410 and two focus groups for CHEM 1810) to capture the unique experiences of these sequences. They lasted approximately 1 hour and were transcribed for analysis. Appendix C contains the focus group protocols for these interviews, which were informed by the analysis of institutional chemistry data, the chemistry faculty focus group, and the conceptual framework.

Phase 2b: Engineering

In the first step for Phase 2b, the team interviewed key informants in ODE to learn of additional important stakeholders to interview. Step 2 (ongoing) is to interview staff members from other service-providing offices who work with historically marginalized students, such as URMs, women, and FGLIs. These offices include the Office of African American Affairs, the Office of the Dean of Students, and the Center for Engineering Career Development. Step 3 involves interviewing URM and women's student groups, such as the National Society of Black Engineers, the Society of Hispanic Professional Engineers (SHPE), the Society of Asian Scientists and Engineers, the Society of Women Engineers, Women in Computing Sciences, and Women in Chemical Engineering. These professional organizations are important information

sources, as several of the engineering students who participated in Phase 2a of the study referenced how their networks in these organizations were critical to their sense of belonging and identity.

Phase 3: Engineering

The Phase 3 researchers are using a typical design thinking process to develop potential interventions to test. The design thinking process is represented in Figure 2.

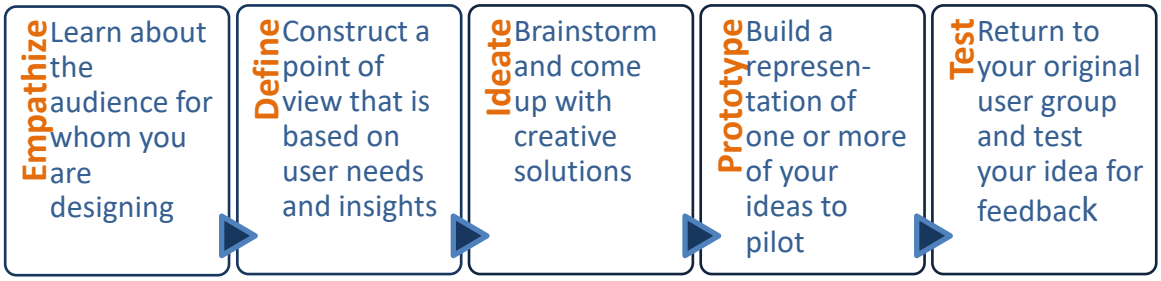

Figure 2. Design thinking process used in Phase 3

For the Emphasize step, Mr. Williams and Dr. Maeng, the leaders of Phases 1 and 2a, respectively, met with the prototyping interventions researchers (Phase 3) to present the major findings from their data collection and analysis in 2017–2018. Those findings were then distilled into primary themes for the Define step. Those primary themes are described in this report in the next section. Given the information presented, the Phase 3 researchers began to ideate potential interventions, and are working toward prototyping a few of their ideas.

Primary Themes from the Findings

As in a convergent parallel mixed-methods design (Creswell and Clark, 2011), results from the quantitative (Phase 1) and qualitative (Phase 2a) findings were triangulated into four key themes:

1. Preparation for and awareness of the rigor of the engineering curriculum
2. Confidence in enrolling in advanced courses (particularly gateway courses, such as calculus) when appropriate
3. Resource utilization (or lack of utilization)
4. Sense of (or lack of) belonging with the engineering community.

Each of these themes are elaborated on below and supported with data from quantitative and qualitative sources. To maintain confidentiality of interviewees, data sources and unique identifiers appear after each quotation instead of names. In addition, potential leverage points that emerge from the data for possible interventions are discussed in detail.

Theme 1: Preparation for and Awareness of the Rigor of the Engineering Curriculum

Engineering students, as a group, have the highest qualifications (GPA and SAT) at admission of any school at the university, yet their GPA is not the highest at graduation—engineering courses are hard, and not everyone is prepared for the rigor required. For example, one student noted,

> I definitely wasn't prepared for the engineering curriculum, but I did a summer program here and then they taught us precalculus. It was a little hard, but I guess that helped a little bit coming into Calc I. But even then as a first-year Calc I, I think I'm behind because everybody else is in Calc II. So, I'm behind a semester and I noticed that a lot of other first year students know how to code and stuff like that already, which I've never done before (URM_2.8.18, URMF60).

This student noted that even with preparation the summer prior to UVA, she perceived herself as being underprepared for engineering compared with other students. Another student similarly indicated that her high school experience did not afford her options to take rigorous coursework to prepare her for engineering, stating, "I came with nothing. I never had the option to take AP, IB. I didn't know IB was a thing before I came here" (1st.UC.URM_106.17, URMF11).

Leverage Point: Be aware of GPA trends and the dip

All engineering students experience a "second semester dip." This is particularly evident for African American and Hispanic students (see Figure 3 below).

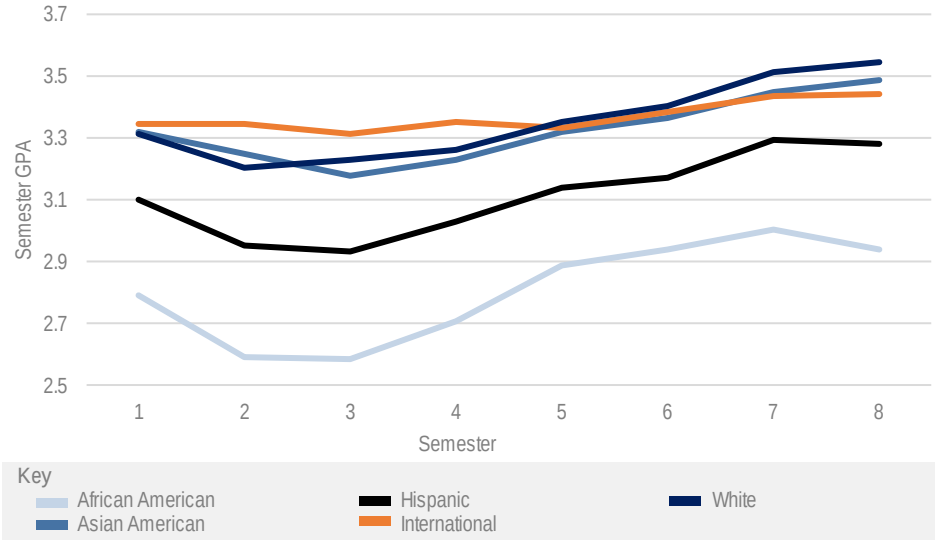

Figure 3. GPA trends and dip in second semester

The dip is, on average, twice as large for African American students as white students. In addition, women, first-generation, and low-income students also experience the dip. Thus, it is important for academic advisors and professors to warn students that they should not "coast" in

the second semester, even if they performed well in the first semester, and that digging out of the GPA hole created by the second semester dip can take several semesters.

Leverage Point: Stress the critical importance of math courses

More than any other subject, math courses are correlated with high graduating GPAs. Of the 15 most common courses for first-year engineering students, 3 of the top 4 that have the highest correlation with graduation GPA are from the core calculus sequence (in red font, Figure 4).

Course	**R^2 for course grade and graduating GPA**
Ordinary Differential Equations	0.52
Intro Sci & Engr of Materials	0.50
Multivariable Calculus	0.49
Single Variable Calculus II	0.45
General Physics I	0.43
Intro Chemistry for Engineers	0.43
Science of Information	0.38
Principles of Econ: Microecon	0.38
General Physics I Workshop	0.34
Introduction to Programming	0.31
Intro to Engineering Lab	0.27
Single Variable Calculus I	0.24
Sci Tech & Contemp Issues	0.24
Intro Chem for Engineers Lab	0.20
Introduction to Engineering	0.13

Figure 4. Percent variance between math course taken and graduating GPA

Because these courses have such a close correlation to graduating GPA, students should be strongly encouraged to seek help for math when they need it, particularly in terms of time management, study groups, tutors, and office hours.

Theme 2: Confidence in Enrolling in Advanced Courses When Appropriate

There is uncertainty about which courses students should take, and the guidance offered through official channels is often not thorough. Many students indicated that they relied on peers, family members, and high school guidance counselors for advice on what math class to enroll in rather than formal advising from School of Engineering & Applied Science faculty and staff. For example, one student discussed how he selected which math course to enroll in his first semester, responding, “I actually posted a question on Reddit about ... UVA has a subreddit and I asked if I

should go in Calc II or Calc III and the unanimous answer was Calc III" (2nd_10.11.17, M27). He then asked his father, who responded that he should "go back to Calc I because it's easy and because I would get an A" (2nd_10.11.17, M27).

Several students indicated that they relied on the templates supplied for their intended major when choosing what math class to take, all of which suggest beginning with Calculus II. Notably, this approach does not take students' individual backgrounds and needs into account. Another student sought advice from outside of the School of Engineering & Applied Science and indicated that he was advised "to start with the foundation of Calc I, and build upon that so that I'm not jumping into something. I was like, 'Hey, I had an A all year long in calculus in high school'" (1st UC URM_10.6.17, URMF3).

As noted above, the first semester math course is critical given math course correlation with graduating GPA. Faculty discussed the importance of math enrollment, too:

> Calc I is typically considered remedial here, as well as [at] other research institutions. Calc II and III is ... I mean, again, you can pretty much look at that spot-on as a predictor of someone's success here. And so, what it comes down to, to me, when you look at that class, those classes, it definitely goes back to what the students were exposed to in high school, and when they got here, and what they're doing when they get here (Interview, Faculty M1).

Both students and faculty responses illuminated the stigma associated with beginning in Calculus I as indicated by this exchange during a focus group:

> Interviewer: Do you think that you would be in a very different place now had you taken your dad's advice and taken Calc I? Do you feel like you would be behind your peers?
> M27: Yes. Very likely.
> Interviewer: Do you think a lot of people who start in Calc I instead of Calc III feel like they're behind their peers?
> M27: The people that I know who've taken Calc I feel ... they told me that they feel like they're behind and that they'd rather taken weed-out Calc II first and not gone back to Calc I (2nd_10.11.17, M27).

Another faculty member reiterated these points as indicated in the following exchange during an interview:

> F5: Personally, I think the students who struggle the most and feel that they are, that they fit in the least are the ones who come in and have to take Calc I.
> Interviewer: Why is that?
> F5: Because there's only a small group of kids who have to take Calc I. And, they know that math is the basis of everything. And, they feel immediately behind. And also, because every curriculum that they get, every curriculum except for [Biomedical Engineering] starts with Calc II. So, every printed curriculum on every department site says, you know, you need to already have Calc II before you can start here (Interview, Faculty F5).

Other students relied on their own confidence, making statements similar to that of M28,

> I took Calc II in high school and I got credit but I decided to take Calc II again 'cause I just thought it was really important. I kind of didn't really know what's going on in high school; I just got good grades, somehow made it through on time. I just wanted a new start. I didn't wanna fall behind in math (2nd_10.11.17, M28).

This lack of confidence resulted in the student selecting a lower math course than the one he was prepared for, a phenomenon known as undermatching.

Leverage Point: Undermatching in calculus

To further investigate the role of appropriate mathematics placement and undermatching, a decision tree model trained with students from 2009 to 2016 (and validated with 25 percent of those students) was used to match students with a predicted first math course. The model correctly placed 75 percent of the students and found 18 percent to be undermatched (enrolled in a math class that is too basic) and 7 percent to be overmatched (enrolled in a math class that is too advanced). Moreover, simply enrolling in a class that may be too basic or too advanced can have long-lasting effects on students' achievement. As shown in Figure 5, students who elected to take Calculus II as their first math course tended to have the highest semester-by-semester GPAs, while students who elected to take Calculus I tended to have the lowest GPAs. However, what is most interesting is that students who overmatched, or placed themselves in a calculus course that was more advanced than their previous achievement would suggest was appropriate, tended to have higher semester GPAs than students who undermatched, or placed themselves in a calculus class below their ability level. Thus, merely undermatching or overmatching appears to be related to overall achievement, even in courses not related to math.

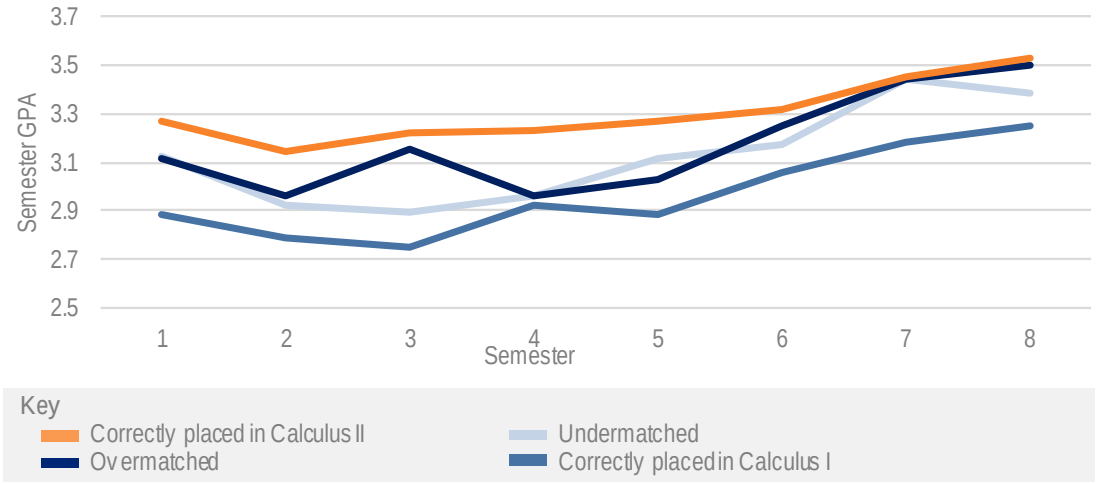

Figure 5. Semester-by-semester GPA among engineering students' placement in their first math course

When we also take into account that students starting in Calculus II (median GPA 3.29, *n* = 1,034) graduate with a significantly higher GPA than those who start in Calculus I (median GPA 3.12, *n* = 572), the dangers of undermatching become more clear (see Figure 6).

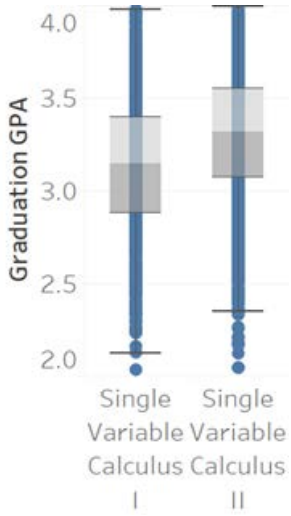

Figure 6. Median, 25th percentile, and 75th percentile graduating GPAs among UVA engineering students who took Calculus I or Calculus II as their first math course

Women and URM students are overrepresented in Calculus I compared with Calculus II, which puts them at particular risk. It is important that students enroll in the appropriate math course for their skill level.

Theme 3: Resource Utilization (or Lack of Utilization)

There were two sets of findings relating to students' use (or lack of use) of university resources.

Reluctance to Seek Help. The first pertained to students' reluctance to seek academic help when they needed it. Seeking help was hindered by some students' perception that School of Engineering & Applied Science professors were not invested in forging relationships with students outside of class:

> This is kind of a bigger change but the one thing I wish were different in the E-school was that, and not to denigrate any professor, but I do think that professors in the E-school don't really put much time into ... positive relationships with their students. Like they're very nice if you put that effort out there. But like versus professors in the Curry School, putting a lot of time into getting to know their students and having activities for students to get to know each other and trying to build a positive classroom community is obviously much more important in the Curry School, 'cause it's the school of education. But I think that that's still important in the E-school and probably even more important because I think so many students in the E-school fall through the cracks and nobody is really looking for that because professors, not that they don't care, but they think that it's the student's responsibility to reach out to them. But I think that even though we're in

> college, it's still your professor's responsibility to try to get to know ... students as people a little bit more (URM_2.8.2018, URMF59).

Indeed, another student felt that the best advice he could give to a new student is to try to forge relationships with professors. While they may not be the most inviting for students to get to know them, once a student makes an effort, there can be rewards:

> I think if I were to advise an incoming first year, try to be best friends with the professor. Seriously. I got an assignment back and I got a 66. I'm just sitting there like, wow, all right. So instead of pouting about it, I went to talk to him and a week later, I checked back at the grade book and the assignment got regraded to an 83. And that was all just by talking to him. Stopped kind of looking at it as a student and teacher kind of relationship, but more like human to human (R.URM.FGLI_4_11_18, URMM42).

However, professors are not the only academic resources available to students in the UVA School of Engineering & Applied Science. The School of Engineering & Applied Science has several full-time academic advisors who are available to meet with students during the week. It also supplies free, on-demand undergraduate tutors to any student requesting one. Finally, the school holds free workshops for individual courses in the following departments and subjects: calculus (multiple sections), biomedical engineering, chemistry, computer science, electrical and computer engineering, mechanical and aerospace engineering, and physics. Yet, students did not mention using these resources. One reason for their underutilization may be related to a fear of being seen as lazy, unworthy, or incompetent:

> [I] did not utilize office hours once because I felt like this should be something that I get. And basically I was fearful, it's like if I go to office hours this deep within the semester, I have this fear that I'm basically giving off the sense of like, "So you haven't done your job correctly for me." And it's like, while I'm hearing about other people's, like, "Oh no, I've got As on this midterm," and everything. It's like, "Okay. So I know it's me, but I don't [want] them to think like, oh, so you're telling me I haven't done my job correctly" (R.URM.FGLI_4_11_18, M21).

One way students sought help was to instead rely on older peers:

> Yeah building off of that, once I was sort of set in a specific major, I was able to better connect with people older than me in that same path. So now we have a lounge specific to electrical and computer engineering and I'm able to hang out and just chat with my [teaching assistants] from last semester and people like that and also that's really helpful from scheduling courses and just like figuring out how to do well in courses. So it definitely provided a lot of mentorship that I didn't have my first semester (UC_10.13.2017, M29).

Leverage Point: Get students to use academic resources when they need help

Although older peers may be good sources of advice, and perhaps easier to approach than a professor or administrator, they do not always possess the information students may be seeking (or not seeking but should be). It is a missed opportunity not to take advantage of the academic advisors, tutors, and workshops that are all freely available to engineering students.

In addition, for those few students who do speak with their professors outside of class, professors should be fully aware of and recommend these resources to their students. If students are showing signs of having academic difficulty, their professors should make specific reference during office hours to the tutors and workshops, perhaps multiple times, so that any stigma or lack of awareness of them is mitigated.

Lack of Involvement in Co-Curricular Activities. The second issue related to students' use or lack of use of resources is related to their involvement (or lack thereof) in co-curricular activities, such as career development, research experiences, and internships. Students are often unsure of how to make their post-graduation plans happen, including the use of the Career Services Center and the timing of job searches. After all, there is no class that teaches students about when and where to apply for a job. Moreover, for some students, it is difficult enough to choose the right courses and learn the challenging material; co-curricular activities, such as conducting research with a professor or working on an internship are seen as optional or, even worse, as taking time away from hitting the books.

Leverage Point: Timing the job search

Students should not wait until the spring of their fourth year to start their job search. Career Services Center data show that the largest proportion of UVA engineering majors secure employment around November of their fourth year (see Figure 7).

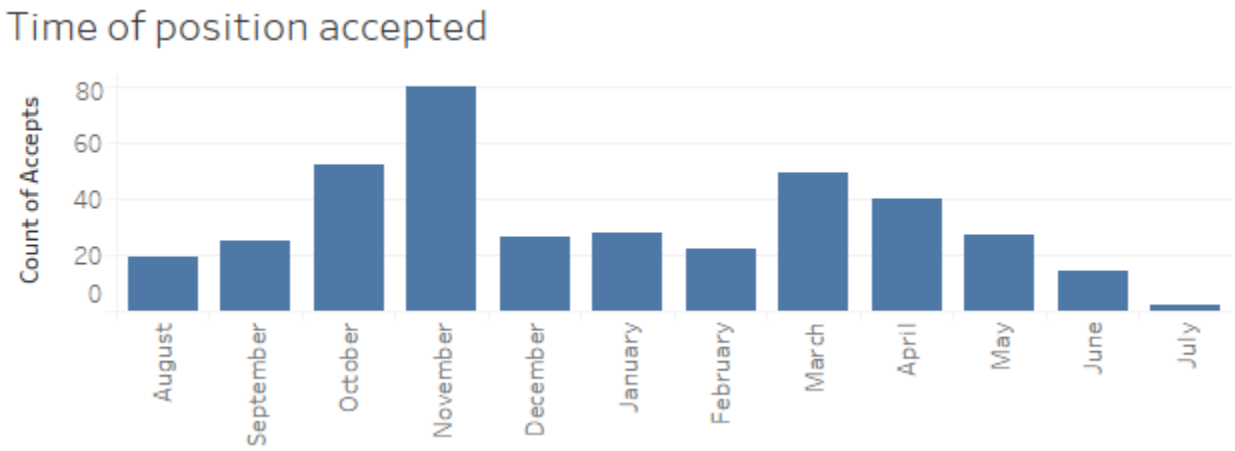

Figure 7. Number of jobs accepted by fourth-year UVA engineering students by month

The data are even more drastic for specific industries, such as computer science (see Figure 8).

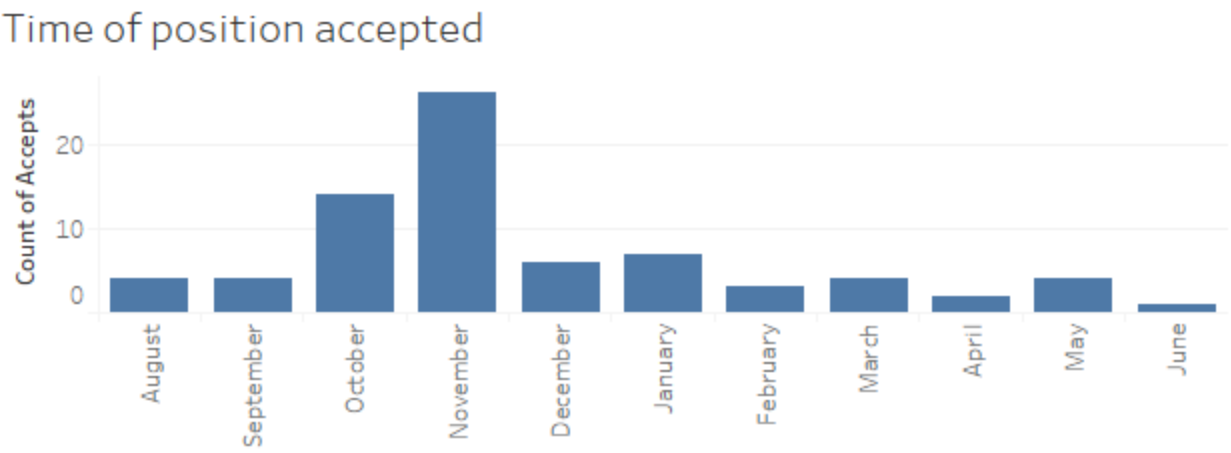

Figure 8. Number of jobs accepted by fourth-year UVA computer science students by month

Students should meet with an advisor as soon as they can (i.e., well before the fourth year) to start the process of preparing résumés, targeting companies, and attending job fairs. Moreover, the Career Services Center should know the idiosyncrasies of the timing of job announcements for different fields (e.g., computer science versus civil engineering) and should create a timeline to reach out to students in certain majors with enough time to work on job-related materials before the high season for that field.

Leverage Point: The importance of research experiences

Not all students go directly into the workforce after obtaining their undergraduate degree, however; others head to graduate school. Prior research experience is the most significant predictor of graduate school success (more than GPA or GRE score), and it is possible to start working on research projects during one's undergraduate years. There is also a trend of graduate programs increasingly valuing letters of recommendation from professors and personal statements from applicants that reference research experiences for graduate admissions in STEM fields. In addition, a number of major research institutions have stopped requiring GRE scores for graduate admissions, making co-curricular experiences even more important for successful admissions.

Relationships students make early can lead to letters of recommendation and research experiences with professors. Students should be encouraged to seek out these opportunities early and often. One way to encourage research participation is through undergraduate research credits: students can earn credit working with professors on research. However, at UVA, only around 10 percent of engineering students obtain credit for research experiences. Although the proportion of URM and women engineers who undertake these experiences is slightly higher, there are still only slightly more than 1 in 10 who take advantage of this opportunity (see Figure 9).

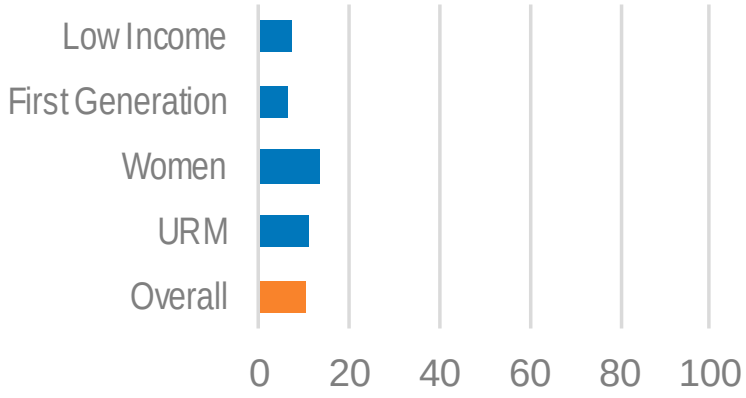

Figure 9. Percent of UVA engineering students engaged in research for credit

Leverage Point: The importance of internships

Internships can have a significant impact on obtaining full-time work after graduation, and even starting salaries. Indeed, the more internships, the better! The internship does not have to have brand recognition, either. In the UVA computer science department, there is a significant relationship between number of internships conducted and starting salary (see Figure 10). These data are not as robust for other departments but match anecdotally.

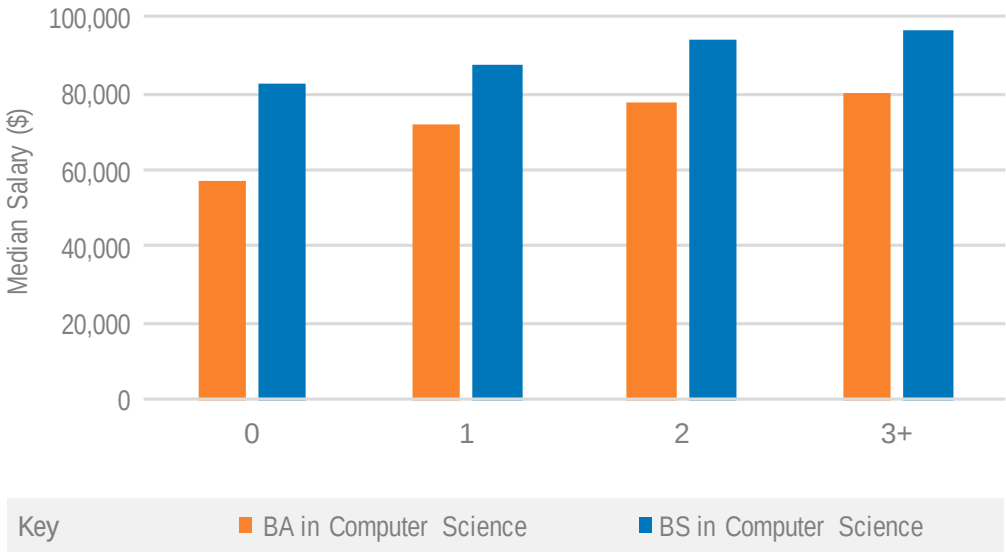

Figure 10. Median salary by number of internships among UVA computer science students

Many students indicated they appreciated the opportunities to engage in internships and research experiences:

> Most positive I guess for me research has been really rewarding. Kind of help me set my career path in terms of which ... I mean for [biomedical engineering] you can either do like more real-time experiments and web lab-related stuff, or you can do more data analysis or like modeling kind of stuff. I think research helped me decide which direction I wanted to head into. Then, also what I wanted to do next in terms of either jobs, or grad school, or med school, or whatever. I think research definitely helped me with that and also in gaining experience with kind of industry level or lab level experiences that you would expect to encounter post-graduation (UC_2.15.18, M48).

> Also, getting my stuff together for getting an internship next summer. I had an internship this last summer, I think it's very important and I think an obstacle for not just me but a lot of third-years, or maybe students in general, is realizing how important those experiences are. Work experience, research, whatever it may be, outside of school. Finding time for them (1st.UC.URM_10.6.17, URMM7).

Theme 4: Sense of (or Lack of) Belonging with the Engineering Community

At UVA overall, URMs, women, and FGLI students have a lower sense of belonging and inclusiveness than majority students and men. In 2016, UVA participated in a national survey, Student Experiences in the Research University (SERU), which measured students' sense of belonging. Figure 11 reveals that 21–30 percent of URM students disagree with the statement, "I feel that I belong at UVA." Similarly, 19 percent of women do not feel that they belong, and most distressingly, 35 percent of (or one in three) FGLI students do not feel that they belong at UVA.

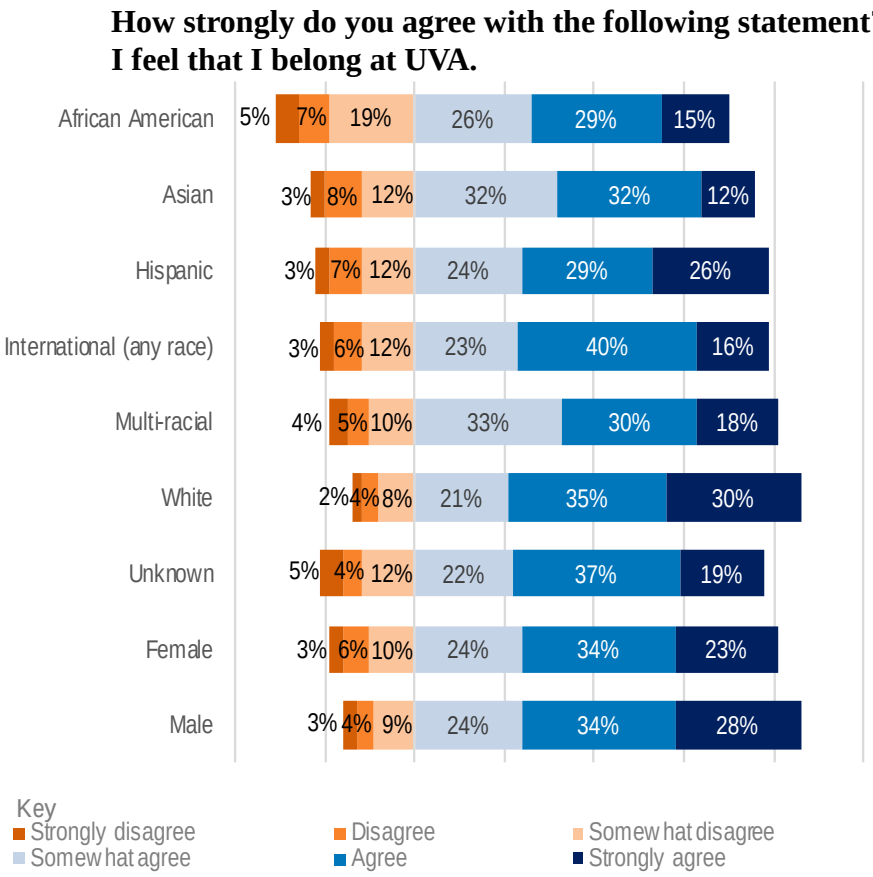

Figure 11. URM and women UVA students' sense of belonging data

Some engineering students who participated in the focus groups saw how finding a niche at the university was important not only for making friends but also feeling like they had some sense of kinship:

> I think just meeting people is probably the most enjoyable experience for me. I don't think I'm really here to like, I don't know, take classes and stuff like that. Obviously, that isn't the point of what college is for, but I think the most enjoyment I've found is meeting people in classes and hanging out with them. Joining clubs, meeting people, things like that (Ret1st_UC_4_19_18, M49).

> I feel like first year, there was definitely a pressure for me to "Okay, I have to be studious, but I also have to have a social life because I don't want to go crazy." But then you learned that the two aren't mutually exclusive. Me and my best friends, we will get together and do homework. We are usually, usually when we're together, someone has their laptop out, she's not listening to my story about this boy because she's doing her work or something. It felt like our relationships sort of center around our school work, but almost. So it's become almost a very normal, "Oh, you want to get together watch some TV, and do work, and then watch TV, and then do work?" (1st.UC.URM_10.06.17, URMF11).

> Like the friends that I've said that I've made, we've definitely bonded over struggling in Calc I together. So, study groups definitely helped. There's times that like we're like, "Oh, you focus on this section. You focus on this. And then we'll teach each other." We'll be like the teacher for 30 minutes and just teach stuff and then there's a quiz or something like that. So, study groups definitely help me. I didn't have study groups in high school, I just did things alone (URM_2.8.2018, URMF60).

Sometimes this niche was not part of the School of Engineering & Applied Science:

> I feel like a lot of my classes are just huge lectures, and I don't like get to know people that much. I just go in and sit, and leave. Yeah, I feel like I haven't really had any opportunities to get to know students in classes in general ... I make most of my friends from activities outside of classes (Ret1st_UC_4_19_18, F18).

Or, in some cases, it took participating in social activities outside of the School of Engineering & Applied Science to meet other engineers socially:

> I meet other engineers not through E-school stuff. I'm in U-Singers and I'm in Chi Alpha, and those are like my two main social groups. I meet a lot of engineers that I wouldn't have contact with. You can't meet every engineer. It's nice meeting those people. Through those groups you might even have more connections since like you're both in engineering and you're in this group (UC_2.15.18, F57).

However, many did make friends with other engineering students, which further deepened their bonds with the school and their peers:

> That's a good point. Definitely, a core part of being ... I'm sorry. Let me erase what I just said. The group of people that you have that are engineers that are your friends, they will help out with a social side and the work side. That's why I think we're saying it's so important is because, same with me, the people I study with are the people I hang out with. That's just because you don't have to coordinate that much stuff, it's easier, and it makes sense. You spend a lot of time with someone, and you create a bond and that goes socially and for work (1st.UC.URM_10.06.17, URMM7).

> One of the things I really feel like I've gotten out of going to E-school is that it's good to be connected to different people, especially people that know what's going on, in terms of what are your options for the future. People who have a genuine interest in your success. I'm pledging the engineering fraternity (1st_10.17.17, M22).

Like the fraternity in the last quote, some students found their communities through engineering social or professional organizations or offices, which is a testament to their importance at the university:

> I didn't like it at all at first. Because I'm from [outside the continental U.S.], and the culture and the environment was just very, very different from what I had experienced back home. I was eager to leave home, but I underestimated the culture shock that one can go through. Especially there not being a very big Latino community here. Because of that, I didn't really like it my first year. But I joined the Society of Hispanic Professional

> Engineers, and we're all Hispanic, or Latino, and engineers, so that was [a] really big thing for me. I also did a bridge program through the Center for Diversity Engineering the summer before coming here. My bestest friends in the whole world I met then and there. So it was nice. I felt kind of alone, because there weren't many other minority students to relate to, but I came in with friends already, who were also engineering, who are awesome minority students. That made it a lot better. I feel like after adapting, sort of adapting to the social and educational culture around here, now that I'm in my fourth year ... My third year was pretty tough but I actually really enjoyed it. Now that I'm in my fourth year, I actually really enjoy being here (1st.UC.URM_10.06.17, URMF11).

But, there were other students, especially URM and FGLI students, who did not necessarily find a niche where they felt valued and supported, as the SERU data indicated:

> I also feel abandoned sometimes. Like when you plan to have a study group and someone, like they don't text you back. Or you want to study with other people and they're like, "Yeah, sure." And then they don't ... and two days later you're like, "Okay, let's have the study group." "I'm busy. Like all the time." "Like, okay, never mind then." Or even when you have, in like my [differential equations] class, we have practice tests that are team based. And my partner is like, "Okay, I got all my work." And leaves me halfway through the quiz. And I'm like, "All right, I guess I'm just getting a D on this." Yeah, so I think that there's definitely some kind of sense of abandonment when people are kind of just looking out for themselves and need help, and we don't really know where to turn to with people in your own class (UC URM 10.5.17, URMF4).

Another noted a sense of lack of belonging, saying, "I'm just glad to be out of dorms next year. Figured there'd be a party scene, pretty big one. But I figured there'd be a few people that wouldn't do it. Yeah, my hall of 30 people, I think I'm one of three that did not rush and then subsequently pledge to a fraternity. So ... there's that… (R1st_2.16.18, M21).

Other engineering students in the focus groups mentioned the level of competitiveness they felt among their peers. After all, UVA is a highly selective institution, and SEAS is considered one of the most difficult curricula in the entire university. However, competitiveness also takes its toll when students feel devalued or excluded. Moreover, when this is experienced by historically marginalized students, it can make them feel as though they are not welcome at the university. Indeed, the student who found her social network through SHPE and the bridge program also admitted that she often felt isolated as an underrepresented minority, and if it were not for programs like SHPE and the bridge program that cater to diverse students, she would still feel lost.

Leverage Point: Encourage students to seek out organizations that match their interests and form a community

In particular, URM, women, and low-income students report lower sense-of-belonging scores than the majority, men, and students from higher socio-economic backgrounds. Yet, as many of the above quotes address, participation in student groups can lead to networking with peers as well as, in the case of the professional societies, industry and academic leaders. This is beneficial for belonging as well as for graduate school and employment.

Leverage Point: Help students find study groups, which may blossom into friendship groups

As several of the above quotes suggest, working in study groups was beneficial for help and support on homework assignments and exams. In addition, students found that a common hardship (like calculus) was made more bearable by being with others who were experiencing the same challenges. Finally, some of the quotes spoke to how students who started out studying together eventually became friends. These friendships were easier because they mutually understood what they were going through, and when each had time for fun or when they needed to study. For students who feel isolated or impaired by a heightened sense of competitiveness, perhaps a study group—where the individual students are supportive but also studious—may be a way to find the academic and social networks they need.

Overlap among Themes

In reading through the comments from the students, it is not surprising that there was a significant amount of overlap among the four primary themes. For example, the rigorous curriculum tends to plummet students' self-confidence, especially those who already feel isolated or underprepared (i.e., undermatchers). As their confidence continues to decrease, their isolation may exacerbate their anxiety because they may think that they are the only ones who are struggling, when the evidence shows that *all* students struggle. For example, all students' grades dip in their second semester. Somewhat contradictorily, despite struggling, these students choose not to use academic resources, such as tutoring and workshops, because using such resources would make them appear unprepared and weak. However, the end result is that those who have few peer networks and do not seek help from the school fall further behind. Meanwhile, those with strong peer networks and who do use the resources (including meeting with professors) pull further and further ahead.

What can be done to improve all students' experiences in UVA engineering? And, in particular, what can be done to improve historically marginalized students' experiences? The final section of this report discusses how this project is moving into the intervention phase to address these challenges.

Results of the Project and Next Steps

Changes Made in Engineering as the Result of Our Work

Based upon this project's findings, there have been a number of changes within the School of Engineering & Applied Science:

- **Appropriate math course placement**: Per the findings that undermatching one's initial math course can have deleterious effects on subsequent achievement, students are now advised in the summer prior to their first year to choose their calculus course based on prior experience and achievement, instead of thinking of Calculus I as a refresher or an easy A.
- **Greater emphasis on math**: Due to math grades having such a significant relationship to graduating GPAs, the summer bridge program now places a heavy emphasis on calculus preparation in its programming.
- **Removal of "caps" for majors**: Previously, there were upper limits on the number of new majors a department within the School of Engineering & Applied Science would admit. However, as was described previously, those who begin their first year taking Calculus I are at an extreme disadvantage because nearly all majors require Calculus II. Thus, students who needed to take calculus again or did not take calculus in high school (perhaps because it was not offered at their high school) were often shut out of popular majors because they were a course behind in calculus and all of the spots in coveted majors had been filled by the time they completed Calculus II. ODE convinced the School of Engineering & Applied Science department chairs that this policy was inequitable, and there are now no limits on the number of majors per department.
- **Improved student support**: Finally, the nature of the work of the Center for Diversity in Engineering has changed and now includes improved student support, such as using success plans when engaging with students, emphasizing the importance of a student's first semester math course, and increasing collaboration with organizations supporting students from underserved and marginalized backgrounds.

There are additional changes that the School of Engineering & Applied Science can make in its programming to help diverse students succeed:

- **Warn students of the dip**: Make it more well-known during academic advising sessions that all engineering students' grades dip in the second semester but that prior cohorts have shown a steady increase in GPAs with each subsequent semester. The important point is that no student is alone in this grade dip.
- **Promote help seeking**: Encourage students—whether it be through professors, advisors, counselors, or peers—to seek help when they are struggling academically, especially in their math courses.
- **Make students aware of job search timing**: Orient Career Services Center job search activities based on the timing of recruitment in different fields. For example,

computer science job listings may be most plentiful in the fall, while civil engineering may be available in early spring. Accordingly, computer science students should be preparing their résumés and honing interviewing skills much earlier, because one size does not fit all.

- **Facilitate students' opportunities with internships and research**: Support students through increased opportunities to conduct research with professors and participate in internships. Indeed, encourage students to undertake multiple opportunities in both!
- **Increase sense of belonging with peers**: Help students find study groups with peers who are supportive and willing to socialize as well as study to increase a sense of belonging at UVA.

Ideating and Prototyping Interventions

Based on the themes and leverage points detailed in the previous section, the Phase 3 researchers (Roksa, Hulleman, Trawalter, and Wilson) have met over the summer and will continue to meet in the fall to ideate potential interventions for prototype in the School of Engineering & Applied Science. The Phase 3 team has chosen to focus on two psychological interventions: increasing help-seeking behaviors and promoting sense of belonging.

There are multiple facets to sense of belonging:

- Academic belonging and fit
- Social belonging
- Social identity
- Institutional belonging.

Given the findings from Phase 2a in particular, the researchers are interested in addressing academic belonging and fit, which appears to be a salient issue affecting the academic achievement of URM, women, and FGLI college students. Similarly, the team is focusing on students' reluctance to seek academic assistance when they need it, because a lack of help seeking is relevant to all student populations mentioned in the study.

It is important to note that these two constructs are not mutually exclusive or exhaustive. Potentially, students will feel comfortable seeking help if, and when, they feel as though they belong. Moreover, students not seeking help and feeling as though they do not belong likely have similar issues (e.g., a competitive, zero-sum climate can lead students to avoid help-seeking, lest they look incompetent, and it can lead students to exclude others, to be independent rather than communal, lest they lose out to someone else, which likely undermines belonging).

The qualitative findings from Phase 2 imply that while URM, women, and FGLI students all exhibit a lack of academic belonging or fit and do not seek out academic help, the challenges related to their perceptions and behaviors may differ. For example, some of the students in the focus groups struggled to find peers they could study with, but felt that finding these peer groups was vital to their success. Other students, particularly URM students, felt that they had to "gut through" their struggles alone. Thus, a "one-size-fits-all" intervention that addresses a more generic form of belonging may not be equally effective across the different identity groups. Accordingly, the Phase 3 researchers plan to conduct a brief survey of UVA engineering students

on constructs related to overall belonging, academic belonging, growth and fixed mindset, perceptions of others' mindsets, teachers' perceptions of mindsets, actual behaviors related to help seeking, and beliefs about the utility of seeking help. The survey will help the researchers better pinpoint which interventions may be more or less appropriate for certain student groups.

With the additional knowledge gained through the survey, the Phase 3 researchers can determine potential interventions to pursue with greater granularity. For example, if particular groups exhibit a strong sense of a fixed mindset, potential interventions may include helping students to understand that academic challenges are not indicative of innate intelligence (or a lack thereof) and that improvement is possible with help. Alternatively, if certain groups tend to portray a more communal than autonomous perspective, possible interventions might focus on group encouragement and mutual support. The team intends to survey engineering students in mid-to-late fall 2018, which will help select the interventions to prototype in spring 2019.

Chemistry Department Analysis and Next Steps

Analysis. The chemistry data are being analyzed inductively using Dedoose qualitative software. First, a subset of the data were read by the research team members who conducted the interviews and focus groups, and nine open codes (e.g., career choice, collaboration, course instruction and assignments, high school preparation and experience) were developed. These initial open codes were informed by the research questions, conceptual framework, research team discussions about common responses, and institutional data. Using a process similar to that described for engineering, a subset of the data were coded and consensus reached on definitions of each code and how they should be applied to the data. Two members of the research team then divided the transcripts and individually coded them using the scheme developed. In instances when a team member was unsure of how to code, the response was flagged and discussed as a group until consensus was reached on what codes should be applied.

Next Steps. In the fall of 2018, key faculty members in the chemistry department (e.g., teaching general chemistry, organic chemistry, and gateway lab courses) will be interviewed to triangulate the responses of focus group participants. In addition, focus groups will be held with students who completed various milestones of the chemistry sequence (e.g., both semesters of general chemistry, but no organic chemistry, through organic chemistry) but did not declare a chemistry major to better understand the retention of students as chemistry majors. Particular effort will be made to recruit students from underrepresented populations to specifically understand their experiences in chemistry and rationales for their decisions to major or not in chemistry.

Extramural Funding and Publications

There are several funding sources for which we intend to submit proposals:

- **Accelerating Discovery, National Science Foundation**
  Funds for intervention and assessment of psychosocial interventions designed for the UVA School of Engineering & Applied Science. Proposals have a rolling deadline. Funding is for approximately $200,000–300,000.

- **Improving Undergraduate STEM Education, National Science Foundation**
  Funds to conduct an intervention and assessment with the chemistry department using the data we have collected thus far as a basis for prototyping. Proposals are due on December 11, 2018. Development and Implementation Level I projects have a budget limit of $600,000 and a maximum duration of 3 years.

- **Institute of Educational Sciences 305A, U.S. Department of Education**
  We will apply for this grant in a few years, after we have ideated and prototyped a series of interventions that we then wish to pilot at other institutions, including historically black colleges and universities.

We are also very pleased to have our first publication from this project in print:

Jones, J., Williams, A., Whitaker, S., Yingling, S., Inkelas, K.K., & Gates, J., "Call to Action: Data, Diversity, and STEM Education," *Change Magazine* (July 2018).

This article presents an overview of our research design for this project, as well as what we hope to achieve with the data for future diverse engineering students at UVA.

In addition, we have another paper in review for the annual meeting of the American Educational Research Association, the premiere research conference for pre-K–adult education in the United States:

Inkelas, K. K., Williams, A., Maeng, J., and Jones, J. (in review). "Another Form of Undermatching? A Mixed-Methods Examination of First-Year Engineering Students' Calculus Placement." Submitted to the American Educational Research Association. April 2019. Toronto, Canada.

As we collect more data, as well as implement the interventions, there will be multiple manuscripts generated by this project.

References

American Psychological Association. “Education and Socioeconomic Status.” http://www.apa.org/pi/ses/resources/publications/education.aspx.

Bean, John, and Shevawn Eaton. “A Psychological Model of College Student Retention.” In *Reworking the Student Departure Puzzle: New Theory and Research on College Student Retention*, edited by John Braxton, 48–61. Washington, DC: Vanderbilt University Press, 2000.

Carnevale, Anthony, Nicole Smith, and Jeff Strohl. *Recovery: Job Growth and Education Requirements through 2020*, 2013, available at https://cew.georgetown.edu/cew-reports/recovery-job-growth-and-education-requirements-through-2020/#full-report.

Creswell, John, and Vicki Plano Clark. *Designing and Conducting Mixed Methods Research*. 2nd ed. Thousand Oaks, CA: SAGE Publications, 2011.

Milem, Jeffrey, Mitchell Chang, and Anthony Antonio. *Making Diversity Work on Campus: A Research-Based Perspective*. 2005, American Association of Colleges and Universities.

National Center for Education Statistics. “Graduation Rates and Degrees Conferred.” *Higher Education: Gaps in Access and Persistence Study*. https://nces.ed.gov/pubs2012/2012046/chapter6_10.asp.

Reardon, Sean. “The Widening Achievement Gap between the Rich and the Poor: New Evidence and Possible Explanations,” July 2011, https://cepa.stanford.edu/sites/default/files/reardon%20whither%20opportunity%20-%20chapter%205.pdf.

Stephens, Nichole, MarYam Hamedani, and Mesmin Destin. “Closing the Social-Class Achievement Gap: A Difference-Education Intervention Improves First-Generation Students’ Academic Performance and All Students’ College Transition.” *Psychological Science* 25 no. 4 (2014): 943–953.

Appendix A: Student Focus Group Protocols

Focus Group Overview

Before students arrive

1. If needed, rearrange the space so that tables and desks are in a circle or square so everyone can see each other. Try to make these relatively small.
2. Set up plates, cups, napkins, pizza, and sodas.
3. Put paper for the name tent, consent form, and prewriting activity at each seat.
4. Test the audio recorder.

As students arrive

1. Invite students to get pizza and drinks.
2. Have students make a name tent that faces out so others can see it.
3. Make sure the notetaker sits in a location where they can see everyone's name tent.
4. Have students read and sign consent forms and collect them. (They will have received a copy in their email for review and documentation.)

Welcome

Introduce the facilitator and notetaker (e.g., name, program, major, and year). Thank students for coming. *Today we'll be talking about the experiences you've had in the engineering school at UVA.* Go over the ground rules (below) with students. Have students take 10 minutes (max) to complete the prewriting activity. They can keep their answers during the focus group.

Ground rules

- We're on a first name basis.
- Everything said is confidential—don't share outside the group.
- We're recording; one person speaks at a time.
- No right or wrong answers, only differing points of view.
- You don't need to agree with others, but you must listen respectfully as they share their views.
- Turn off your phones. If you cannot and if you must respond to a call, please do so as quietly as possible and rejoin us as quickly as you can.
- Our role as moderators is to guide the discussion. Talk to each other.

Notetaker tasks

1. Writes the name of the person responding and key points and answers for that person in enough detail that, when a member of the research team listens to the recording and reads the transcript, these notes can be used to accurately attribute responses to the correct participant.
2. Sits next to the facilitator so he or she can discretely inform the facilitator when 30 and 50 minutes have elapsed (including the 10-minute prewriting activity)—this person is also the timekeeper.
3. Helps the facilitator return the room to its original state unless there is another focus group immediately after.

First Years—Fall

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Thinking back, what was it about engineering that interested you?
3. What's it like to be a UVA student so far?
4. We asked in the prewrite who you are. Now we'd like you to describe who you are at UVA.
5. What has your first year been like? Probe: What could make the transition better?
6. Now think about yourself as an engineering student. What is being an engineering student at UVA like? Probes: How are the people? What's the vibe? How is the space, atmosphere, or climate?
    a. Do you feel like you fit in? Why or why not? Probes: In what ways are you comfortable? How have you had to change to fit in? What has been uncomfortable about the fitting in process?
    b. *(For women and minority focus groups only)* When people ask you what it feels like to be a woman or student of color in engineering, what do you say?
7. What math course are you taking this year? How did you choose this particular course?
8. What obstacles do you anticipate facing this year in the E-school? Over your career at UVA? To what extent do you think other students will share those obstacles or face different ones? Probe: What obstacles do you think other students may face? What are some ways that these obstacles can be overcome?
9. Everyone has things they're worried about. What do you worry about? To what extent do you think other students share these same worries?
10. What advice would you give to encourage someone who is entering engineering?

Second Years—Fall

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Thinking back, what was it about engineering that interested you?
3. What's it like to be a UVA student so far?
4. We asked in the prewrite who you are. Now we'd like you to describe who you are at UVA.
5. Now think about yourself as an engineering student. What is being an engineering student at UVA like? Probes: How are the people? What's the vibe? How is the space, atmosphere, or climate?
    a. Do you feel like you fit in? Why or why not? Probes: In what ways are you comfortable? How have you had to change to fit in? What has been uncomfortable about the fitting in process?
    b. *(For women and minority focus groups only)* When people ask you what it feels like to be a woman or student of color in engineering, what do you say?
6. What was your first semester like?
7. What was your second semester like? Probes: One thing we noticed is that there's a second semester dip in GPA across all students. What was the biggest challenge you faced in your second semester? What could be done to overcome this challenge?
8. What are the characteristics of students who typically succeed in this department (SEAS/major)? Probes: What does a successful student look like in your department? Where do you fit into this?
9. What are your expectations for your time at UVA and in the E-school? Probes: What are your short-term and long-term goals and how will your experience in the E-school help you to achieve them?
10. Everyone has things they're worried about. What do you worry about? To what extent do you think other students share these same worries?
11. What advice would you give to encourage someone who is entering engineering?

Upper Class—Fall

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Thinking back, what was it about engineering that interested you?
3. What's it like to be a UVA student so far?
4. We asked in the prewrite who you are. Now we'd like you to describe who you are at UVA.
5. Now think about yourself as an engineering student. What is being an engineering student at UVA like? Probes: How are the people? What's the vibe? How is the space, atmosphere, or climate?
    a. Do you feel like you fit in? Why or why not? Probes: In what ways are you comfortable? How have you had to change to fit in? What has been uncomfortable about the fitting in process?
    b. *(For women and minority focus groups only)* When people ask you what it feels like to be a woman or student of color in engineering, what do you say?
6. What was your first year like?
7. What was your second year like?
8. How was the transition into your major? Probe: What was the biggest challenge you faced in transitioning into your major? What could be done to overcome this challenge? Is there anything you would have done differently? If so, what?
9. What are the characteristics of students who typically succeed in this department (SEAS/major)? Probes: What does a successful student look like in your department? Where do you fit into this?
10. What are your expectations for your time at UVA and in the E-school? Probes: What are your short-term and long-term goals and how will your experience in the E-school help you to achieve them?
11. Everyone has things they're worried about. What do you worry about? To what extent do you think other students share these same worries?
12. What advice would you give to encourage someone who is entering engineering?

First Years—Winter

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. What has your first year been like? Probe: What could make the transition better?
3. What are the characteristics of students who typically succeed in this department (SEAS/major)? Probes: What does a successful student look like in your department? Where do you fit into this?
4. Do you feel prepared for UVA engineering? Probes: Why or why not? What factors contributed to your feelings of preparedness? What factors contributed to your not feeling prepared?
5. What has surprised you about the content of the classes you're taking?
6. Are you taking ENGR 1620 (core math)? If so, what is it like? Probes: What do you like or dislike about it? Do you feel you can be successful in it? Why or why not?
7. How would you describe your relationships with other students in this department? Probe: How important are these relationships to your success in the program?
8. Describe a time when a student was being treated differently in one of your SEAS classes.
9. Describe the types of interactions you have with your professors and TAs outside of class. Probe: Have you participated in faculty mentoring? If so, what is it like?
10. Everyone needs help with schooling. Who do you go to when you need help with an academic matter? Social matter? Financial matter?
11. Think back over the past semester.
    a. What was the most positive experience you have had in the program so far?
    b. What are the biggest obstacles that you have encountered so far? Probe: What are some additional obstacles and what made them obstacles?
    c. What could be done to help students get through the program more easily or successfully?
12. What are your expectations for your time at UVA and in the E-school? Probes: What are your short-term and long-term goals and how will your experience in the E-school help you to achieve them?

Second Years/Upper Class—Winter

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Did you feel prepared for UVA engineering?
    a. Why or why not?
    b. What factors contributed to your feelings of preparedness?
    c. What factors contributed to your not feeling prepared?
    d. What has surprised you about the content of the classes you're taking?
3. How would you describe your relationships with other students in this department? Probe: How important are these relationships to your success in the program?
4. Describe a time when a student was being treated differently in one of your SEAS classes.
5. Describe the types of interactions you have with your professors and TAs outside of class. Probe: Have you participated in faculty mentoring? If so, what is it like?
6. How would you describe your level of involvement in SEAS? Probes: What are you involved in? What could be done to make you feel more involved? Are there opportunities for involvement?
7. Everyone needs help with schooling. Who do you go to when you need help with an academic matter? Social matter? Financial matter?
8. Can you talk to me about tutoring available for engineers? Probes: If you have sought tutoring, what was it like? Was it helpful? What would make it more helpful? Do you know of other students who have sought tutoring? Did they find it helpful?
9. What do you think are some of the main reasons students don't seek tutoring in engineering? Are there circumstances under which students would be more likely to seek tutoring?
10. Think back over your engineering program.
    a. What was the most positive experience you have had in the program?
    b. What are the biggest obstacles that you have encountered so far? Probe: What are some additional obstacles and what made them obstacles?
    c. What could be done to help students get through the program more easily or successfully?
11. If you had to pick the biggest obstacle to graduating, what would it be?
    a. You can pick something that you mentioned or something that was said by others.
    b. What are some ways that this obstacle can be overcome?
12. What advice would you give to encourage someone who is entering engineering?

Returning Students—Spring

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Compare your prewriting responses from the previous focus groups you attended to the responses you wrote down now. How are your responses similar and different? Probes: If your thinking has changed in how you described yourself, can you tell me a little about why you think it changed? If your thinking about what it's like to be a UVA student has changed, can you tell me why you think it's changed?
3. Why are you pursuing engineering?
4. What has your time in the E-school been like?
5. *(For non-fourth years)* How did you choose the classes you're taking next fall?
6. How do you deal with stress (generally)? What are the sources of this stress?
7. What helps you thrive in classes?
8. Tell me about how your relationships with other students here are the same as and different from what they were at the beginning of the year. Probes: What factors, if any, do you think played into any changes you reflect on? How did you get acclimated to UVA and SEAS? What do you hope for in the future of your relationships with other students here? How important are these relationships to your success in the program?
9. Describe a time that you thought you needed help in a class. What did you do? Why? Probes: If you were in a class where you thought you might have needed help but you delayed getting it, why did you delay getting help? When you were deciding whether or not to seek help, what factors did you consider? At what point do you seek help?
10. Can you talk to me about tutoring available for engineering students? Probes: If you have sought tutoring, what was it like? Was it helpful? What would make it more helpful? Do you know of other students who have sought tutoring? Did they find it helpful?
11. What do you think are some of the main reasons students don't seek tutoring in engineering? Are there circumstances under which students would be more likely to seek tutoring?
12. Think back over the past semester.
    a. What was the most positive experience you have had in the program so far?
    b. What are the biggest obstacles that you have encountered so far? Probe: What are some additional obstacles and what made them obstacles?
    c. How do obstacles outside of class interact with struggles in classes?
    d. What could be done to help students get through the program more easily or successfully?
13. What advice would you give to encourage someone who is entering engineering? What have you gotten out of these focus groups? Why do you keep coming back?

First Years—Spring

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Why are you pursuing engineering?
3. What has your first year in the E-school been like? Probe: What could make the transition better or easier?
    a. Do you feel like you fit in? Why or why not? Probes: In what ways are you comfortable? How have you had to change to fit in? What has been uncomfortable about the fitting in process?
    b. *(For women and minority focus groups only)* When people ask you what it feels like to be a woman or student of color in engineering, what do you say?
4. How did you choose the classes you're taking next fall?
    a. What math course are you taking next year? How did you choose this particular course?
    b. Are you taking ENGR 1620 (core math)? If so, what is it like? Probes: What do you like or dislike about it? Do you feel you can be successful in it? Why or why not?
5. What experiences prepared you for the E-school? Probe: What has surprised you about the content of the classes you're taking?
6. How do you deal with stress (generally)? What are the sources of this stress?
7. What helps you thrive in classes?
8. How would you describe your level of involvement in SEAS? Probes: What are you involved in? What could be done to make you feel more involved? Are there opportunities for involvement?
9. Tell me about how your relationships with other students here are the same as and different from what they were at the beginning of the year. Probes: What factors, if any, do you think played into any changes you reflect on? How did you get acclimated to UVA and SEAS? What do you hope for in the future of your relationships with other students here? How important are these relationships to your success in the program?
10. Describe a time when a student was being treated differently in one of your SEAS classes.
11. Describe a time that you thought you needed help in a class. What did you do? Why? Probes: If you were in a class where you thought you might have needed help but you delayed getting it, why did you delay getting help? When you were deciding whether or not to seek help, what factors did you consider? At what point do you seek help?
12. Can you talk to me about tutoring available for engineering students? Probes: If you have sought tutoring, what was it like? Was it helpful? What would make it more helpful? Do you know of other students who have sought tutoring? Did they find it helpful?

13. What do you think are some of the main reasons students don't seek tutoring in engineering? Are there circumstances under which students would be more likely to seek tutoring?
14. Think back over the past semester.
    a. What was the most positive experience you have had in the program so far?
    b. What are the biggest obstacles that you have encountered so far? Probe: What are some additional obstacles and what made them obstacles?
    c. How do obstacles outside of class interact with struggles in classes?
    d. What could be done to help students get through the program more easily or successfully?
15. What advice would you give to encourage someone who is entering engineering?

Upper Class Students—Spring

Pre-Survey/Writing Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. Thinking back, what was it about engineering that interested you?
4. What's it like to be a UVA student so far?

Focus Group (~60 min)

1. Please share your first name and major or intended major.
2. Why are you pursuing engineering?
3. What has your time in the E-school been like?
    a. Do you feel like you fit in? Why or why not? Probes: In what ways are you comfortable? How have you had to change to fit in? What has been uncomfortable about the fitting in process?
    b. *(For women and minority focus groups only)* When people ask you what it feels like to be a woman or student of color in engineering, what do you say?
4. *(For non-fourth years)* How did you choose the classes you're taking next fall?
5. How do you deal with stress (generally)? What are the sources of this stress?
6. What helps you thrive in classes?
7. How would you describe your level of involvement in SEAS? Probes: What are you involved in? What could be done to make you feel more involved? Are there opportunities for involvement?
8. Tell me about how your relationships with other students here are the same as and different from what they were at the beginning of the year. Probes: What factors, if any, do you think played into any changes you reflect on? How did you get acclimated to UVA and SEAS? What do you hope for in the future of your relationships with other students here? How important are these relationships to your success in the program?
9. Describe a time that you thought you needed help in a class. What did you do? Why? Probes: If you were in a class where you thought you might have needed help but you delayed getting it, why did you delay getting help? When you were deciding whether or not to seek help, what factors did you consider? At what point do you seek help?
10. Can you talk to me about tutoring available for engineering students? Probe: If you have sought tutoring, what was it like? Was it helpful? What would make it more helpful? Do you know of other students who have sought tutoring? Did they find it helpful?
11. What do you think are some of the main reasons students don't seek tutoring in engineering? Are there circumstances under which students would be more likely to seek tutoring?
12. Think back over the past semester.
    a. What was the most positive experience you have had in the program so far?
    b. What are the biggest obstacles that you have encountered so far? Probe: What are some additional obstacles and what made them obstacles?
    c. How do obstacles outside of class interact with struggles in classes?
    d. What could be done to help students get through the program more easily or successfully?
13. What advice would you give to encourage someone who is entering engineering?

Appendix B: Supporting Diversity in STEM at UVA—Faculty Interview

The goal of this interview is to better understand the experiences of SEAS students at UVA. These interviews will be used to triangulate with student voices from focus groups. The interview is structured to first get faculty perceptions of students in classes and the characteristics that make them successful and then to more broadly focus on what supports student success (e.g., context, who is ignored, points of stress) and belongingness (support and collaboration).

1. Please tell us your name and what STEM courses you teach at UVA.
2. Answer for each class you are teaching this semester:
    a. When thinking about your class, how would you describe your students?
    b. What are your expectations for students in your class? Probe: e.g., studying, skills, and outcomes?
    c. Describe a student who is well-prepared. Are students prepared to take your class? Probes: In general, what proportion of your students is well-prepared? How could they be better prepared?
    d. Describe the characteristics of a student who is successful in your class. Probes: What factors do you perceive contribute to this? To what extent do you perceive math to be relevant to success in your class and engineering?
    e. What are the characteristics of a student who is struggling in your class? Probes: What factors do you perceive contribute to this? Whose responsibility is it to help struggling students? What could be done to better support struggling students? Possible probes: What role do TAs play in this? What are the interactions between students and TAs like?
3. What is your perception of the importance of collaboration for student success in your class (e.g., study groups and in-class projects)? Probes: To what extent do students in your classes collaborate (e.g., work in groups to complete assignments, research projects, and study groups)? How do students form groups in your class? How often do they self-select versus you selecting for them?
4. Describe the types of interactions students have with you outside of class (e.g., advising, mentoring, recommendations, office hours, and research group).
5. *(For faculty in the E-school only)* To what extent do you think there are certain groups of students who struggle with feeling like they belong in the E-school? How and in what ways do you think students perceive themselves as not belonging (e.g., academically, socially)?
6. Every field has underrepresented groups. For example, males are underrepresented in K–12 teaching. What groups do you consider as underrepresented minorities in STEM? To what extent do you think student in these groups struggle with feeling like they belong in STEM? In what ways do you think students perceive themselves as not belonging (e.g., academically, socially)?
7. How would you describe unfair treatment of a student? Describe a time, if ever, when you observed an undergraduate students being treated unfairly. Probe: Provide background about the student. If they respond about a teacher treating a student unfairly, ask what unfair peer-to-peer treatment looks like to them and if they've observed it. If so, have them describe it.

8. What sources of support do students have in your department? Probes: What are sources of financial, academic, and other support? Where do students go when they need help with an academic matter?
9. What do you perceive as the biggest obstacle to students majoring in STEM fields? Why?
10. What could STEM programs at UVA do to help students get through the program more successfully?
11. Is there anything that you would like to add?

Appendix C: General Chemistry Spring 2018 Focus Group Protocol

Prewriting Questions (~10 min)

1. Please tell us your first name and your major or intended major.
2. Who are you? Describe yourself in three to five descriptors.
3. When did you take general chemistry at UVA?
4. What is the most recent chemistry class you took?
5. What do you think your next chemistry class will be, if any, and why?
6. What was taking general chemistry like?
7. Why did you choose to take general chemistry?

Focus Group Questions

1. Please share your first name, major or intended major, when you took general chemistry, and whether you took the 1410 sequence or 1810 sequence.
2. What was taking general chemistry like? Probes: What did you like or dislike? What was the class size? What was the structure of group work in and out of class? What were the most positive and most negative experiences you had in general chemistry?
3. What are the characteristic of students who typically succeed in general chemistry? Probes: What does a successful general chemistry student look like? Where do you fit into this? What do students who are successful do?
4. If you could change one thing about general chemistry (e.g., environment, course structure, instruction approaches used), what would it be?
5. How did your high school experiences in math and science prepare you for general chemistry? Probes: In what ways were you prepared for general chemistry? In what ways could you have been better prepared?
6. What was the biggest challenge you had while taking general chemistry? How did you deal with or overcome that challenge? Probes: When you were successful, what did you do? What about when you were unsuccessful?
7. What helped you be successful in general chemistry?
8. Describe the types of interactions you had with your general chemistry professors and TAs outside of class. Probes: Do you attend office hours? Why or why not?
9. Describe the types of interactions you had with your general chemistry peers outside of class.
10. What types of academic activities would be most helpful for students to succeed in general chemistry (for example, tutoring, study groups conducted by an instructor or students who took the class before, additional class time, peer study groups, or boot camp before enrolling in general chemistry)?
11. Talk to me about tutoring for general chemistry. Probes: Do you know of students who have sought tutoring? Did they find it helpful? If you have sought tutoring, would you like to share what it was like? Was it helpful? What would make it more helpful? What do you think are some of the main reasons students don't seek tutoring in general chemistry? Are there circumstances under which students would be more likely to seek tutoring?
12. If you didn't continue in the chemistry sequence, why not? What advice would you give someone who is entering general chemistry to help them succeed?
13. Is there anything else you wish to share about your experiences or ways to make general chemistry a more engaging and positive experience?

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