What You Need to Succeed: Examining Culture and Capital in Biomedical Engineering Undergraduate Education

Introduction

The low numbers of women and underrepresented minorities in engineering has often been characterized as a 'pipeline problem,' wherein few members of these groups choose engineering majors or 'leak out' of the engineering education pipeline before graduating [1]. Within this view, the difficulty of diversifying the engineering workforce can be addressed by stocking the pipeline with more diverse applicants.

However, the assumption that adding more underrepresented applicants will solve the complex and persistent issues of diversity and inclusion within engineering has been challenged by recent research. Studies highlight how the persistence of women and minorities is linked to norms and assumptions of engineering cultures (e.g., [2], [3]). For example, some engineering cultures have been characterized as masculine, leading women to feel that they must become 'one of the guys' to fit in and be successful (e.g., [4]). In the U.S., engineering cultures are also predominantly white, which can make people of color feel unwelcome or isolated [5]. When individuals feel unwelcome in engineering cultures, they are likely to leave. Thus, engineering culture plays an important role in shaping who participates and persists in engineering education and practice.

Likewise, disciplinary cultures in engineering education also carry assumptions about what resources students should possess and utilize throughout their professional development. For example, educational cultures may assume students possess certain forms of 'academic capital,' such as rigorous training in STEM subjects prior to college. They might also assume students possess 'navigational capital,' or the ability to locate and access resources in the university system. However, these cultural assumptions have implications for the diversity and inclusivity of educational environments, as they shape what kinds of students are likely to succeed. For instance, first generation college (FGC) students may not possess the same navigational capital as continuing generation students [5]. Under-represented minority (URM) students often receive less pre-college training in STEM than their white counterparts [6]. However, FGC and URM students possess many forms of capital that often are unrecognized by education systems, for example, linguistic capital, or the ability to speak in multiple languages and styles) [7], [8]. Educational cultures that assume everyone possesses the same kinds of capital (i.e. that of white, American, high SES, and continuing generation students) construct barriers for students from diverse backgrounds. Thus, we propose that examining culture is essential for understanding the underlying assumptions and beliefs that *give rise* to the challenging issues surrounding the lack of diversity and inclusion in engineering.

This case study examines the culture of a biomedical engineering (BME) program at Purdue University and identifies underlying assumptions regarding what sources of cultural and social capital undergraduate students need to be successful. By tracing when and how students draw upon these forms of capital during their professional development, we examine the implications for students from diverse backgrounds, particularly FGC and URM students.

Engineering Culture

According to Godfrey [9], culture exists when “a group shares both explicit and tacit knowledge, values and attitudes developed through a history of shared experience” (p. 439). Thus, in order to create cultural change in engineering, Godfrey [9] argues that researchers must go beyond merely identifying surface-level practices and behaviors that constrain inclusion, and seek to unearth the “deeply embedded, often unconscious, cultural knowledge and understandings that are used by participants to interpret experience and generate behavior” (p. 439). Godfrey and Parker [10] identify several dimensions to engineering cultures. In this paper, we examine one dimension, an ‘Engineering Way of Doing,’ defined as the “Shared beliefs and assumptions around how teaching and learning are accomplished” ([9], p. 442). We focus on teaching and learning to highlight the role of engineering educators—whether through pedagogy, assessment, curriculum, teacher-student relationships—in promoting or constraining inclusive disciplinary cultures.

Cultural and Social Capital

To examine how disciplinary cultures carry assumptions about students’ possession of resources or ‘capital’, we draw on Pierre Bourdieu’s theory of cultural and social capital. Cultural capital refers to one’s understanding of the cultural norms of a particular group and the ability to behave in ways befitting these norms [11]. Bourdieu argued that the education system functions according to the cultural norms of the dominant social class, typically the middle and upper classes. Since Bourdieu, other scholars have expanded understandings of the ‘dominant group’ beyond class, arguing that the education system and cultural capital reflect the norms of privileged racial and ethnic groups [12]. Thus, students within the education system are expected to know and operate within this set of cultural norms. However, students from different class, race, or ethnic backgrounds are less likely to know these cultures, and therefore operate at a disadvantage within education settings, such as “predominantly White universities [that] typically reflect White, male, middle-class perspectives” ([12], p. 95). As Dumais [13] explains, these students:

> might not be viewed as favorable by teachers, they might not understand materials or assignments that were based on the dominant culture, and they might opt out of education themselves when seeing the mismatch between their cultural resources and those demanded by the school. (p. 375)

Likewise, students whose parents place them in highly-resourced, high-performing schools often receive better educations. Thus, their resulting ‘academic capital’ is linked to their cultural capital. Students’ ability to navigate education systems, or their ‘navigational capital,’ also stems from their cultural backgrounds. However, in such educational systems, these forms of cultural capital are so pervasive that they are often “unrecognized as capital and recognized as legitimate competence ...” ([11] p. 49). Thus, educators can code as intelligence, self-motivation, or work ethic what actually stems from familiarity with a certain set of cultural norms.

This understanding of cultural capital is particularly important when examining the underrepresentation of minority students in engineering education. Although Bourdieu’s theory is often used to describe differences related to class, critical race theorist Yosso [7] argues that every individual possesses *some* kind of cultural capital, as everyone is socialized into certain cultures. When the education system assumes knowledge of a particular culture, it often marginalizes the cultural capital possessed by individuals from different class, race, nationality, or ethnic backgrounds. To promote understandings of all communities as 'culturally wealthy,' scholars have begun tracing the kinds of capital different communities possess (e.g., [12]) such as 'linguistic capital' or 'critical navigational capital,' the ability to maneuver through racially hostile social institutions [7]. Assuming the dominant culture is 'standard,' and other cultures lack 'normative' resources often undergirds a deficit-based view of the underrepresentation of minority groups in fields such as engineering [7].

In addition to cultural capital, we also examine where social capital materializes in ways that benefit engineering students. Social capital is linked to cultural capital, as it refers to social ties that can be leveraged for one's personal benefit [11]. In an education setting, social capital is often conceptualized as contacts that lead to internship or job opportunities, peer relationships that provide emotional or academic support, connections to faculty that can provide opportunities in research labs, letters of recommendation or mentoring regarding graduate school, or similar resources. Previous studies of social capital in engineering education reveal that social capital is linked to increased retention [14], and many other benefits such as "academic achievement, academic performance, and engineering identity" ([15], p. 823).

Cultural and Social Capital in Engineering Education

Research has increasingly demonstrated that the social and cultural capital of first generation college (FGC) students and under-represented minority (URM) students differs from white and continuing generation students. In an education system predicated upon white, U.S., continuing generation students' cultural norms, this can place FGC and URM students at a disadvantage. For instance, studies have demonstrated that FGC students "are less likely to utilize or have more difficulty in recognizing university support resources because they have little practice in doing so" ([15], p. 823). Similarly, FGC and URM FGC students are less likely to receive assistance or support from family in college and career planning [16], [17]. Thus, they often lack family-related social capital important for choosing engineering as a major/career, especially if their family members are not engineers. Educational norms of teaching and learning can either promote or constrain the inclusion and academic success of students from diverse backgrounds. For example, if engineering educators structure curriculum, professional development, or teaching in ways that assume their students possess certain kinds of cultural and social capital, they may unknowingly construct barriers for students of different backgrounds. Thus, we examine how cultural norms of teaching and learning influence students' deployment of cultural and social capital in their professional formation. In this study, we discuss specific forms of cultural capital such as navigational capital, academic capital, as well as the natural confidence and ability to interact with professors and other professionals. We also discuss family related social capital and peer social capital.

The Present Study

Drawing upon Godfrey's dimensions of engineering culture and Bourdieu's theory of cultural and social capital, this study explicates cultural norms related to teaching and learning in an undergraduate program in biomedical engineering (BME) and examines how these norms shape students' deployment of cultural and social capital. We focus on biomedical engineering as few studies have examined its relatively young disciplinary culture, and because the number of undergraduate programs in this field has increased enormously in recent years [18]. Students in biomedical engineering often pursue graduate school and/or work in medical or pharmaceutical fields post-graduation. Given the number of students who complete advanced degrees and work in lucrative industries assigned high class status in U.S. contexts, an examination of cultural and social capital in biomedical engineering education was particularly intriguing. The research questions for this study are:

RQ1: What are the shared beliefs and assumptions about how teaching and learning are accomplished within professional formation in the BME program?
RQ2: How and to what effects do BME students draw on different forms of social and cultural capital in their professional formation?

Methods

This project is part of a larger study funded by the National Science Foundation examining the lack of diversity and inclusion in engineering educational cultures at large, research intensive, university programs. Through in-depth, semi-structured interviews with 18 current or former BME undergraduate students, we collected data and analyzed how this subset of students deploy cultural and social capital within a BME disciplinary culture.

Participants

The participants for this study were undergraduate students currently enrolled or were temporarily enrolled in BME at Purdue University. Eighteen students (approximately 6% of total undergraduates in BME) volunteered to be interviewed. Out of 18 participants, ten were women and eight were men. No ethnicity, race, or SES data was formally collected from these participants, although two disclosed that they were international students. Ten of the participants were sophomores; three students were juniors, and five were seniors. Four of the participants transferred from BME to a different engineering major. We included these four students in our sample to examine the perspectives of those who left the program and experienced a second engineering educational culture.

Procedures

We first sent a survey to all undergraduate students in BME about their experiences within the program, and 37 students completed it. We then contacted those who had indicated interest in a follow-up interview and 18 agreed. Semi-structured interviews were conducted in-person during the 2016-2017 academic year. The research team developed an interview protocol according to Godfrey's six dimensions of culture, asking students questions related to engineering ways of thinking, ways of doing, understandings of difference, relationships, and so on. Each interview lasted roughly 45 minutes to an hour. The audio files were then transcribed and the transcripts were de-identified. We received informed consent from each participant, and all surveys, interview protocols, and other data collection materials were approved by IRB. All data was anonymized and stored in secure locations to protect participants' confidentiality.

The first author uploaded the anonymized transcripts into NVivo for thematic analysis [19]. She began with open coding, the unstructured analysis of data by moving through each line of text and developing emergent codes. During the second round of coding, the first author grouped these smaller codes such as 'teaching critiqued' or 'internship experience' into larger categories. At the end of this process, these codes roughly reflected Godfrey's dimensions, such as faculty-student relationships' or 'diversity and inclusion discussed.' In the final round of coding, the first author used the theoretical framework to inform the coding process, tracing where social or cultural capital appeared to emerge in students' descriptions of their experiences. To narrow the analysis further, the research team further analyzed codes related to an 'Engineering Way of Doing'—or those related to teaching and learning—and developed the final themes for this manuscript.

Given the small sample size and qualitative nature of this project, these themes are not generalizable to larger student populations. However, we believe they offer educators insight into students' lived experiences and potential barriers to students' success in engineering programs.

Findings

After analyzing the data, a theme emerged across several aspects of a BME "Way of Doing": students feel that they are 'on their own' in their professional development. From determining their BME specialization to seeking out career development opportunities, the participants revealed how they viewed the educational culture as reinforcing highly independent strategies for professional development. Because students perceived that they are 'on their own,' they drew on resources outside of the program to supplement this development process. These resources are forms of cultural and social capital, and are associated with students with affluent backgrounds. Thus, these findings beg the question of who can be successful in BME without these specific types of capital.

BME Way of Doing: You Are 'On Your Own' to Specialize

Participants described a stereotype of BME students as generalists rather than specialists, as the BME curriculum requires coursework in a range of biological subjects as well as engineering subjects. Thus, they described an unspoken assumption about how to be successful in BME: *to avoid becoming a "jack of all trades, master of none," you must become a "jack of all trades, and specialist at one."* Several students believed that, to be a marketable engineer upon graduation, they must develop in-depth knowledge of a specific content area (e.g. cardiovascular biomechanics) in addition to their coursework. However, further assumptions underlie this main assumption—not only must students know that they *should* specialize, they should know in *what* they should to specialize, and *how* to do so. Acquiring this information required rallying appropriate forms of capital that largely fell outside of the program structure.

As the program requires a heavy course load of multiple subjects, and no specific 'tracks' for specializing, students felt they were left to discover the importance of specializing on their own.

For example, when asked “Is that something that they communicate to you guys, like earlier on that you're going to be exposed to a lot of different things, but you may not necessarily be specialized in one? Or is that just the sense that you guys get?”, Mickey responded: “I think it's just a sense. What would be nice looking back is if they pointed that out.”

Furthermore, after these students discovered the importance of specializing, they were ‘on their own’ to pursue their specific interests, often seeking out additional classes or experiences on top of their heavy BME course load. For example, Melvin describes how he sought out training in mechanical engineering outside of his BME coursework, stating, “either through classes, but most of the time just on my own learned about the mechanical things that BME doesn't necessarily teach you.” To gain further experience in mechanical engineering, he joined an organization that builds Formula 1-type race cars. Similarly, when talking about learning how to use CAD modeling software, Marley said:

> That's stuff that you have to leave the department for. You have to leave BME for that and you have to do it yourself which I think there should be a track built in where they teach you that sort of stuff. It shouldn't necessarily be on your own accord that you have to build that curriculum, because if the BME School wants to be top tier, they should split your track and say, okay, if you're a biomechanics interest, you should learn this stuff because this is what you have to learn.

Given the importance of specializing, students who enter the major unsure of the field or of their focus operate at a disadvantage. As Marley states about CAD software skills: “Some people are unfortunate and never pick it up until they try and get in the industry and find out that it's very difficult when you don't know CAD or when you can't do that sort of stuff.” Similarly, Melvin explains how, without CAD experience, “people get to senior design and nobody knows what they're doing.” Statements like these highlight how students must acquire these skills outside the curriculum in order to be successful.

Students with exposure to biomedical engineering prior to college were more likely to know the importance of specializing, what their specific interests are, and how to find the courses and experiences they needed. Yet prior knowledge of BME reflects forms of cultural and social capital that not all students possessed. Many students expressed how their exposure came from family members. For instance, when asked how she knew she wanted to major in BME, Mackenzie said she had “wanted to do medical applications for a long time” because, “My mom is in the medical field, my dad is in - he's in public relations, but works in a hospital. So I've been in the hospital my whole life. So I've always wanted to do something in the medical field.” Similarly, Marvin became interested in BME in high school, when he worked in a medical research lab at a nearby university. When asked about how he learned of this opportunity, Melvin mentioned that his parents, a research scientist and a physician, told him about it and encouraged him to apply. His research at the university sparked his interest in BME and shaped his particular concentration.

Furthermore, many students linked their choice of major to their exposure to engineering, biology, or medicine in middle and high school, highlighting how students draw on the capital afforded from their high school education. Many of these students went to private schools, boarding schools, international schools, or preparatory schools. One student shared how her participation in a high school program called "Project Lead the Way" awarded her college credit for engineering coursework. Several other students mentioned how their high school involvement with research shaped their BME trajectory. For instance, consider Michelle's comment about how she chose a BME major specifically:

> Pretty much from the 8th grade year I've wanted to be a BME, but I did definitely consider mechanical for kind of the same aspects. … but overall I didn't feel that mechanical gave me the medical background and knowledge that I would need to do what I wanted to do.

In contrast, Melora described her lack of exposure to BME before college, and how this led her to leave the major. She stated, "When I started my college search, I had no idea where to start. My parents aren't engineers. My parents didn't go to college, so it was very new to me, and I didn't really know what to do, but I knew that I wanted to go to college." She initially majored in BME because she thought it was a "really cool field" but discovered that she was "really bad at biology." As a result, she transferred into the industrial engineering program. Rather than demonstrating knowledge about BME because of prior exposure to the field, Melora considered it a "cool field" but left after she realized how biology-intensive the curriculum was.

BME Way of Doing: You Must Learn to Learn 'On Your Own'

In addition to specializing 'on their own,' the students perceived that they had to learn course material 'on their own.' The participants perceived that several BME faculty prioritized other responsibilities over their teaching, leading to poorly organized classes and poorly communicated content. For this reason, students felt they were forced to teach themselves and drew on various forms of capital to supplement the learning process.

Students often expressed that faculty appeared ambivalent toward student learning, that research occupied faculty's time and attention rather than teaching. For example, Marley said:

> I don't think any of the faculty want you to fail. I just think some of them don't care. There are people who, it's not necessarily that they don't care maliciously, it's that they would rather be doing something else. They would rather be working on their complex mathematical model or whatever than teaching sophomores and juniors …

Similarly, Mitch expressed that:

> they continue to say 'we want you to succeed' and you know, to a certain degree we can see that, but they're also busy people who are less than perfectly accessible all the time. Maybe they are out of town for a week or classes cancelled day of. Stuff like that.

Due to professors' perceived ambivalence toward student learning, the participants often felt that the classes were poorly organized or, in one instance, even restructured halfway through because "the professor stopped showing up and had a postdoc come and teach" (Mitch). In addition, students expressed frustration that many faculty could not teach complex material in accessible ways. For instance, Melanie stated about her thermodynamics teacher: "it's just really frustrating to like, you know, just not be able to understand what he's teaching and then him being like, "oh well why don't you get this?" So that's kind of frustrating." Similarly, Marley mentioned some faculty can appear impatient or confused when students do not grasp the content: "Some of them don't appreciate that they can't show the beauty of math or whatever to everyone else. They see it as, or it comes across as that they are less than enthused."

As a result, students feel that they are on 'their own,' either to teach themselves or reach out for assistance. Melissa explains how poor teaching has taught her to learn on her own:

> I think having bad professors sometimes is a good thing because it forces you to learn stuff on your own. I have learned to teach myself very well, and to be able to not really know what's going on in lecture, but then to go home and figure it out on your own, I think in a way that helps me learn it … I think being able to teach yourself material, not that that's ideal, but get an idea of what's going on in class, and then really understand the details on your own, that's something I've definitely learned how to do through BME.

Students also expressed that faculty reinforce the assumption that students should learn on their own. As Marvin says about faculty office hours:

> You know they wouldn't come chasing you down there. I think that's kind of like, I got the sense at least in the engineering classes I've taken, that that's like kind of a point of pride, that it's on you to do well and if you're not going to make the effort they're not going to help you basically.

Marvin emphasizes that faculty do not to assist students until these students demonstrate attempts to teach themselves. Similarly, Maggie notes that faculty relationships with students assume students' independence in the learning process. She says:

> You all see them in class. You see them in lectures, what kind of relationship does that build? There's not really, I guess, there might be opportunities outside of that, even if someone says, "Oh, you can come to my office hours." That doesn't really build any sort of a faculty-student relationship, if that makes sense? It's very academic, professional, come to me with a what you need sort of a thing.

By labeling faculty relationships with students as a 'come to me with what you need sort of thing,' Maggie echoes a larger sentiment of the students that they feel they must learn on their own, even when classes are poorly organized or taught.

As students feel they must 'learn on their own,' they reach out to various resources to supplement the teaching. For example, students with high school training in engineering subjects draw on these resources. As Macy states:

> I know, coming into [University], I had already taken a physiology course, so the physiology class I'm in now, I have notes from high school that are really helping me out. I'm willing to share those with the people I'm studying with, but then I had no background in coding. Then I have friends who have been coding since they were six, and they're like, "Macy, I can help you."

Macy describes how she draws on her high school education, sharing this capital with others, and receiving it from peers as well. As a rigorous high school education is often associated with family income and education, students' access to this resource reflects access to a form of cultural capital—academic capital—not accessible to all students. Students also draw on their understanding of university resources—navigational capital—to teach themselves the material. When discussing the difficulty of understanding her thermodynamics professor, Melanie describes how she "checked out two really big thermodynamics books from the library and I've been trying to get through those." Melanie's decision to check out library books reflects her ability to draw on navigational capital of the university system to supplement her learning.

Most commonly, students referred to peer social capital as the primary way they used outside resources to learn course material. For example, Marley states, "a lot of the work that they assigned would not necessarily be something that you could do on your own. Some of the homework assignments, everyone I think worked in a group." She describes the learning process as collaborative by necessity, because the information is not taught in a way that a student can grasp the concept or complete the assignment on their own. Melissa echoes Marley's comment, noting, "if I didn't know anybody in BME, or if I had no friends, there would be so many assignments and things that I would get zeros on, because there sometimes I'm just so lost, and you just need someone to talk through it."

Peer social capital is a powerful learning tool for many students, but several students did not express the strong social ties with BME peers. Whereas many of the participants described the student culture as a 'family,' often citing the difficulty of the program as their primary bond, several students perceived the opposite culture—that the students are 'clique-y,' even referring to the BME peer culture like 'high school.' In sum, the students in the tightly knit social circles in BME benefit from the strong social capital, but others felt excluded from this group and its benefits. Although the sample of students participating in the interviews had little diversity, it is worth noting that *all* of the students of color expressed feeling 'outside' the culture.

BME Way of Doing: It's on You to Seek Out Professional Development Opportunities

The interviews revealed an underlying assumption in the BME school that 'opportunities are available, but it's on you to seek them out.' As Melissa commented about research experience:

> I think if you really want it, I think it's definitely there for you. I wouldn't say it's easy, you definitely need to put in the effort and reach out to a lot of professors and do research to see what you want to do, but if you're willing to do the work, I think it's not impossible. I think anyone who wanted to get a research position could if they tried hard enough.

Many of the students described how they researched different faculty and initiated a conversation about working in their lab. For instance, Maggie says, "I was looking at what different neuroscience fields [this university] had and what faculty members were doing research in what. I found that one of my professors, from that semester, was doing research in auditory cortex mapping. I went in and just talked to him and let him know this is what I'm really interested in." How students leverage different resources to establish these relationships reflects navigational capital possessed by students familiar with the education system.

Leveraging these forms of capital had a snowball effect for many participants; when students pursued these opportunities, they developed more social capital, resulting in more opportunities and benefits to their professional development. As Maureen explains:

> Yeah, it's nice because whenever BME selects students for things it's done by professors and the associate dean of students. So since I talk to [the associate dean of students] and some of the professors a lot, they know who I am. So then when scholarships come up, like recently they asked a whole bunch of student to submit resumes. My associate dean of students was basically like, 'I think you're gonna get one. Because I'm on the board and I can put in a good word for you.' Same with studying abroad, ETH only takes one BME a year and he told me, 'I'm gonna put in a good word for you. So if you want to go,

> you have a good word.’ So it's kind of like all these people even though they're professors, they have access for you to other things.

Miguel also expresses how working in professors’ labs has led to further benefits as he applies to medical school: “I think it's huge, especially for someone like me who's wanting to go to medical school, to have those opportunities for letters of recommendation, or even clinical connections, things like that. I think it's absolutely huge.”

However, students who lack navigational, academic, or social capital do not always know these opportunities exist, that they are beneficial, or how to access them. Several students referred to confusion over how to pursue these opportunities, indicating a lack of navigational capital. Mickey discussed how he wished he had known about the importance of undergraduate research sooner: “I wish I did have research sophomore year or junior year because I have a few friends who did do that, but I didn't really know how to go about that. There's a little bit of a delay.” Since Mickey did not know how to pursue research opportunities like some of his peers, he feels that he missed out on valuable experience. Similarly, Marshall, an international student, explained his lack of knowledge in the graduate school application process:

> I say that the main obstacle is applying to graduate school. There are [pause] With the research scholar programs, they are helping us to prepare for that. But, specifically to the applications I don't [pause] Well, I guess there's no time here to really give us enough instructions or explanations with that process so my TA for the lab last semester said ‘When I was an undergrad, I just feel like the graduate school is like a black box to me.’ That kind of [pause] Yeah, I definitely want them to tell us more about stories of getting to graduate school.

In addition to navigational capital, not all the students felt the confidence to approach faculty—a form of cultural capital. Mackenzie explained how even if a student learns that she should contact a professor about working in their lab, approaching the professor is intimidating, and not every student feels immediately comfortable doing so:

> I think that it's difficult as a student to feel competent enough to approach a research Professor, especially [pause] I have a Professor that we use his equation in Thermodynamics, so it's crazy to think, “I don't really even want to [pause] I don't want to approach you because you've been doing this for so many years. You've written so many books.” So I think that that can be a little bit of a hindrance is just the fear of not being competent around them and their research.

In addition, Mackenzie felt that she would have had more opportunities if she had the social capital afforded by relationships with professors. She states, “I think if I had like, a better relationship with my professors that I would be able to—well, I think in general, just having a better relationship with professors could help you in having mentors like, to help you through college and having people to help you—mentor you through grad school or to help you like, write recommendations for grad school.” Mackenzie identified how this social capital can yield many kinds of benefits, but not everyone receives these opportunities.

Implications

Through this case study, we discovered how an educational culture in engineering can carry assumptions related to teaching and learning that shape how students activate forms of cultural and social capital in their professional formation. Although the sample is small, by analyzing how certain educational cultures presume engineering students' possession of certain kinds of capital, and how students draw on these forms of capital, this paper provides insight into what resources students need to be successful. In these findings, we described how BME students rallied the resources available to them, and we now discuss the implications of these findings considering research on underrepresented minority (URM) and first-generation college (FGC) students.

The undergraduate education culture in BME at this large, research-intensive university was perceived as positioning students 'on their own' in the professional development process, and this assumption presupposed that students possessed several types of academic and social resources not provided by the program itself. These expectations posed barriers to students without ready access to this kind of capital.

Previous educational research has demonstrated that heavy course loads and restrictive curricula adversely affect underrepresented minority and first-generation students, as they "increase costs as well as time to degree for students who do not enter college with the appropriate educational background" ([5], p. 212-213). By making the BME curriculum broad and intensive, and the expectation to specialize unspoken but pervasive, the BME program presupposes students have the academic capital to weather the heavy course load, cultural and social capital to know the importance of specializing, and the navigational capital to rally the necessary resources to do so. URM and FGC students often possess different kinds of capital, such as linguistic capital, or critical navigational capital—not necessarily extensive knowledge of the biomedical engineering industry or how to find and enroll in outside electives to further their specialization.

In light of existing research on academic success for FGC students, especially URM FGC students, the findings related to teaching and student-faculty relationships are concerning. As URM students may have less academic capital (college prep classes, notes from high school, prior coding experience), they rely much more heavily on effective teaching to be successful. When faculty neglect teaching, the students most likely to suffer are those without these resources to supplement the learning process. Furthermore, when faculty appear distant and unapproachable, the effects are worsened. As Vogt [20] notes, "If students feel more uncomfortable around distant faculty or 'chilly' classrooms, they may be the ones who become less self-assured and apply less effort and fewer active learning strategies" (p. 28). Vogt [20] argues that these students are more likely to transfer or drop out, which also emerged in this dataset, as Max mentioned how feeling on his own in BME influenced his decision to switch majors.

Faculty interactions with students are also significant predictors of students' perceptions of their own competency [20]. FGC and URM students are often less confident in their academic abilities than their counterparts [6]. If faculty resent 'dumbing down' content for students, students may feel that they are not smart enough to persist in the major. Furthermore, if faculty expect students to approach them with what they need, this expectation may pose additional barriers for URM students due to stereotype threat, or the fear of confirming negative stereotypes about one's race or ethnic community. Research shows that URM students may be less likely to rely on peer social capital for the same reasons [21].

When students are ‘on their own’ to seek resources related to professional development, students with less academic and navigational capital are less likely to know they should pursue professional opportunities or how to do so. FGC students often have less knowledge of university resources [15], and fewer mentors [22]. The lack of mentoring is a predictor of URM students’ decision not to pursue graduate work in STEM [23]. For students with the navigational and academic capital that enables them to apply for these opportunities, the benefits multiply. From knowing to reach out and how to reach out, they develop relationships with faculty that lead to letters of recommendation, referrals, or industry contacts. This knowledge can become a ‘rich get richer’ effect, where students who did not know the importance of an opportunity discover it too late and do not develop social capital vital to furthering their professional development.

In sum, research on FGC and URM students highlights how the education programs themselves need to nurture faculty-student relationships, provide ample resources, and structure them into the program. Reinforcing a ‘sink or swim’ culture in engineering [9] is similar to students feeling ‘on their own’ to get ahead in their programs. When engineering educational cultures, particularly at large, research-intensive universities, leave students ‘on their own’ to specialize, learn, and seek out professional development opportunities, it raises important questions about which students can be successful. When the majority of successful students are those from white, affluent backgrounds, these assumptions reinforce that engineering—in this case biomedical engineering—may only be for certain ‘privileged’ students.

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