



Understanding the Investment of Underrepresented Minorities in Doctoral Engineering Programs

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UNDERSTANDING THE INVESTMENT OF UNDERREPRESENTED MINORITIES IN DOCTORAL ENGINEERING PROGRAMS

Abstract

Underrepresented minorities (URM) tend to have lower completion rates than their majority colleagues in the pursuit of the Ph.D. in engineering. This phenomenon of doctoral attrition has been related to a poor socialization process into becoming an independent scholar. Using the Graduate Student Socialization Framework, this qualitative study aims to describe the types of investments URM students in engineering experience in the pursuit of the doctoral degree. Through a qualitative analysis of semi-structured interviews, we found four types of investment in the doctoral pursuit: effort investment, time investment, financial investment, and mental investment. We conclude that while most of the types of investments found could be applicable to all doctoral students, the differing investments may present harmful implications for URM students' degree progress.

Introduction

Since the industrial revolution, the US has had a significant need for highly trained science, technology, engineering, and mathematics (STEM) workforce; a need currently being met with highly skilled immigrants [1]. This demand was also established by the President's Council Advisory on Science and Technology in their Engage to Excel report, which specifically pointed to groups historically underrepresented in STEM as a promising non-immigrant recruitment strategy [2]. At the doctoral level, previous studies have shown that students traditionally underrepresented in engineering, tend to have a longer time to degree and ultimately persist at lower rates than majority students in their pursuit of a doctoral degree [3].

Previous research has suggested that students depart from their doctoral program due to a poor socialization process [4], [5]. If a student cannot understand how the experiences they face in their doctoral program prepare them for their choice of future career, this student is more likely to become frustrated with the experience and decide to not persist in the doctoral pursuit. Thus, as part of helping meet this demand for engineers and scientists, it is imperative to understand the perceptions of underrepresented graduate students already in doctoral programs regarding their socialization process as a way to enlighten efforts to improve retention.

The purpose of this descriptive qualitative inquiry is to study the experiences of underrepresented minorities in doctoral engineering programs as these experiences relate to their socialization into the scholarly community and their persistence towards degree completion. We used the Graduate Student Socialization Framework [6] as a lens through which to interpret their experiences and assess similarities within this population. Our study addresses the following research question:

RQ: What types of investment are expressed in the socialization experiences of underrepresented minorities pursuing doctoral degrees in engineering?

More specifically, the purpose of this analysis is to characterize the experiences of underrepresented minority (URM) graduate students in doctoral engineering programs in predominantly white institutions (PWI), as these institutions are the top producers of engineering Ph.D.s [7]. Results of this study could be used to inform retention practices geared toward doctoral URM students in engineering. This analysis is part of a larger NSF-funded project that studies motivation in URM students toward doctoral engineering

program completion. The purpose of the grant is to provide a workshop for URM students in the process of completing the dissertation while researching these graduate students' motivation.

Theoretical Framework

We used the Graduate Student Socialization framework [6] as a lens through which to interpret student's experiences in their doctoral pursuits as they acquire the role of scholar. The framework describes graduate students as developing through four stages of role acquisition: anticipatory, formal, informal, and personal. The anticipatory stage of role acquisition consists of the individual becoming "aware of the behavioral, attitudinal, and cognitive expectations held for a role incumbent" [6, p. 12]. This stage consists of the preparatory and recruitment phases of a student into the doctoral program, where the student's knowledge about graduate education is mostly based on stereotypes and generalizations. In the formal stage of the socialization process, the student receives formal instruction regarding the role. The student, as an apprentice, observes older students in the same role of pursuing a Ph.D. and learns the normative expectations of the role. The student's interactions are mostly informative and aim to integrate them into the role. The informal stage consists of the student learning of the informal expectations of the role. In this stage, student "develop their own peer culture and social and emotional support system among classmates" [6, p. 14]. The student becomes aware of the flexibilities they can practice in their role as graduate students. The personal stage takes place when students form a professional identity and reconcile this identity with their self-image. In this stage, students have learned how to accommodate their individual needs with those requirements of the role. This framework suggests that students go through all of these phases in the prescribed order but the length of time in they remain in these stages varies between students. These stages are also not related to degree progress but to the development of the student's identity within the discipline in which they aspire to become a scholar.

Each of the stages is characterized by the following three core elements: knowledge acquisition, investment, and involvement. Knowledge acquisition refers to the main mechanisms through which the student obtains information about the program and their progress. Investment refers to the opportunity costs the student makes at each stage in the pursuit of the Ph.D. Involvement refers to the degree through which the students participates and becomes a fuller member of the academic community. The nature of these core elements changes as students' transition between stages and they advance in their degree progress.

This framework has been argued to be both individual and organizational as the graduate students not only learn how to become a part of the larger organization in the scholarly community but also must do so addressing their individual beliefs, behaviors, and identities [8]. Previous research has used this framework as a lens to interpret the experiences of doctoral students. Gardner [9] used this framework to study the role of disciplinary culture and context in the students' socialization. In a contrasting manner, Barnes & Austin [10] used this framework to analyze the advising experience from the advisors' perspectives. Our study aims to expand on this extant literature by focusing on how the graduate school experience can be similar across institutions for URM students enrolled in engineering programs.

While the framework can be used to parse out multiple components of the graduate experience, this analysis, as part of a larger study, focused on the individual student's investments in the pursuit of the Ph.D. and the implications each of these investments has on their persistence towards degree completion. We selected investment as the focus of this study as it was through this code this construct that we were able to understand the effect of a URM identity in their doctoral pursuit.

We refrained from labeling students as identifying in any particular stage of the socialization process. This choice was made because a person's development is rarely a unidirectional process and people can

fluctuate in demonstrating ways of knowing from multiple stages for the different aspects of their development [11].

Methods

To characterize the graduate experiences of URM graduate students, we conducted a qualitative analysis with students traditionally underrepresented in engineering from multiple PWI institutions across the US who attended a workshop designed to support dissertation completion. The study was designed using a constructivist epistemological perspective [12]. We adopted a case study approach by following Yin's [13] criteria which define the three conditions that merit case study research as (1) the nature of the research question is typically explanatory, exploratory, or descriptive; (2) the investigator lacks methods to control the site and participants; and (3) the phenomenon being studied is contemporary and the context is real life. These conditions are met by our study as we attempt to **describe** the socialization experiences of underrepresented graduate students in their ongoing process of obtaining their Ph.D. in engineering, as it is a phenomenon which is contemporary and not controlled. Therefore, given these definitions, the case is defined as the experiences of URM graduate students pursuing doctoral degrees in PWIs.

Participants. Our study includes eight participants all of which are URM graduate students enrolled in doctoral engineering programs at eight different PWIs across the United States. The participants identified as two males and six females. Six participants identified as African American, one as Hispanic, and one as Native American. All participants were in the final stages of their doctoral degree and in the process of writing their dissertation or doctoral proposal in predominantly white institutions. Access to the participants was obtained through their participation in a dissertation workshop targeted towards URM students.

Data Collection. We selected semi-structured interviews as the main form of data collection as the goal of this analysis is to understand the student perspectives on their doctoral socialization [14]. The interviews took place during a dissertation workshop. Each interview lasted approximately one hour. We designed the interview protocol using Weidman, Twale, and Stein's graduate student socialization framework (2001). The questions in the protocol were intended to elicit responses that describe the typical activities and interactions of the participants in their academic activities as well as their perceptions of their progress in their doctoral pursuit. Examples of the questions included in the protocol are "What role does your advisor play in your process?" and "What would you say are your largest obstacles at this point?" In accordance with our approved human subjects research protocol, we de-identified all results and assigned pseudonyms to the participants to ensure their anonymity. All interviews were audio recorded and later transcribed for ease of analysis.

Limitations. Concerning limitations of the sample, our study relied on volunteers that participated in a dissertation completion workshop and were willing to share their perceptions of the graduate process. Their participation in such a workshop and willingness to participate in the interview could be related to common personality traits that made them seek help to finish their degree and share their experiences in the process. Additionally, the participants in the sample, while sharing characteristics of race and ethnicity, attend different institutions and pursue doctoral degrees in different disciplines of engineering. While we believe these variations should have a minimal influence on the results, they may have contributed in ways not easily visible to us.

A limitation of this study is that the selected framework was not developed taking into consideration students' identities relating to underrepresentation in their program, discipline, or institution which literature

more broadly shows to be important [15]–[17]. To address this, we designed our protocol to also take into account additional extant literature on the experiences of URM students in pursuing graduate degrees. By incorporating the socialization framework in the analysis section through our use of a priori codes, we were able to understand how the students referred to their identities in the context of the larger socialization experiences and how these identities affected their doctoral pursuit.

Data Analysis

Using a constructivist worldview, we analyzed the transcripts using a priori coding [18] based on participants' articulations of investments made in their doctoral pursuit. We operationalized the investment code as articulations of what the student may have had to give up to persist in the doctoral pursuit.

After coding for investment, we analyzed the excerpts for themes within the concept of investment. In this analysis, we found four types of investment that were common across the students' experiences. The four types are time investment, financial investment, effort investment, and the mental investment. Once we understood these four types of investments, we parsed how students communicated their experiences concerning each investment.

Trustworthiness. Multiple techniques were used to ensure the quality of the study's analysis [19]. The research team met multiple times throughout the analysis of the data to obtain multiple perspectives as well as agreement on differing interpretations. Results were also triangulated within and between participants as a way to ensure the salient themes were consistent.

Role of the Researcher. The first author is a graduate student in engineering, and she identifies as a woman and Hispanic. The intersection of these ethnic and gender identities was fundamental in the process of creating rapport with the study's participants as they were more willing to openly discuss the difficulties of being a minority in graduate school with a peer of similar identities. These identities also helped provide insight into the information and the experiences being shared by the participants. As a counterargument, these identities could have also introduced a bias into the analysis as the first author could have personally identified with the participants' experiences. To mitigate this bias, the first author debriefed regularly with the second author (a white faculty member) to discuss the findings and ensure that bias was minimized.

Results

We identified four types of investment that were common across the students' experiences. The four types are effort investment, time investment, financial investment, and the mental investment. The following section will discuss examples and trends for each type of investment and will provide example quotes from the student interviews. We describe each of these types of investments, including sub-types, using examples and in the order of the number of participants that expressed each.

Effort Investment. The most common theme that emerged across all of the interviews is the investment of effort. Participants described their efforts as a resource allocation choice. Two specific themes found are the investment of effort in activities for which they had a high expectancy of success and the investment of effort in persisting despite the uncertainty of success. In the following quote we see how this participant describes the choice to engage in the Ph.D. pursuit as one requiring a minimal effort investment:

"I don't have to pay for anything. And if anything goes wrong in the guidebook, it says, "I'll just leave with a master's." – Ph.D. in Information Science

This quote shows how his decision to pursue the Ph.D. was influenced by his goal of obtaining a graduate degree. While the participant did not decide to pursue the Ph.D. knowing he would finish, but ensured that his effort towards the Ph.D. would count for success in something even if it was to just obtain a master's degree. In a contrary manner, the following quote shows how another participant continues to invest effort into the doctoral pursuit despite feeling unsure of her ability to complete the degree:

"I don't have this like, "I'm definitely going to finish," at this point, and I don't know why but I realized that about myself just like an hour ago. I don't have that innate knowledge. I'm pretty hopeful. You know, I'm pushing pretty hard, to get done what I need to do. But it feels like at this point, I've lost sight of the intrinsic motivation and I'm really just going around day to day because this is what I do. You know, I've been doing it for years." - Ph.D. Student in Biological Engineering

Here we see how this participant continues to persist as an effort in and of itself despite not having a firm expectancy of success in the doctoral pursuit. We can also note that the student's discussion of effort investment is different from the time invested towards finishing the degree. While the student recognizes that time is passing, she states effort as an additional element necessary in order to progress towards degree completion.

Time Investment. The second most common theme found in our sample was the investment of time participants had to make to complete the degree, as articulated by 7 out of 8 participants. This investment of time was discussed in two ways: time as a motivator for persistence or time as a resource they had to manage. The time participants had already invested in the degree served as a motivator to persist when participants discussed the option of quitting the Ph.D. In the following quote, we can see how one of the participants sees the time already spent in the pursuit of the Ph.D. as a 'sunk cost' that could be recouped by completing the degree:

"I do feel like there's a lot of kind of like sweat equity at this point, so I've just - I've already put in five years and I feel like I'm so close. On some level, I do want to prove to myself that I can complete a big task, a long-term goal." - Ph.D. Student in Chemical Engineering

Through this quote, we see how this participant believes that the time already invested in the doctoral pursuit is reason enough to be close to finishing and to continue persisting until that finish.

Participants also discussed the investment of time in terms of time as a resource. The following describes the participants' frustrations with the writing process and her seeming surprise at the large amount of time reporting her research takes her:

"I get frustrated when I write, I'm like I don't know what to write. And then, when I do know what to write, I get stuck on I don't know how to say a certain thing. I don't know what the right word is and like how do I say this clearly? How do I choose the perfect word? And then like an hour passed and I'm still like on the first paragraph. And I'm just like, eh, I wish I could come back to this later (laughs). I can code. I'll code all day for you. But (laughs) I can't write anything [...]. It can be so frustrating." - Ph.D. Student in Industrial Engineering

Through this quote, we see how this participant's investment of time in her writing can frustrate her given the amount of progress she feels she is getting in return for her allocation of time as a resource.

Financial Investment. In total, 6 out of 8 participants discussed financial concerns or responsibilities as an investment they had to make to finish their degree. This theme mostly described how students perceived their funding as an investment. Participants discussed this investment in three ways: funding as an influencer in the initial decision to pursue the Ph.D., funding as motivator towards persistence, and funding as a dictator of the time investment.

The availability of funding for the pursuit of the degree, and by consequence the reduction of the financial investment made by the students, was shown as a motivator to pursue the Ph.D. The following quote shows the participant describing not having thought about pursuing a Ph.D. but changing her mind upon discovery of funding opportunities:

"I went to a symposium where they had [to] go through the grad lab, and they said, "Oh, you get money. You get money, you know, you're underrepresented in STEM, there'll be money, money, money." And so I came back from that like, "Oh, my gosh, I'm [going to] go to grad school!" I never would have considered it. I don't know why. I guess I thought only crazy smart people went and you had to have a lot of money. I had no idea that it was even in the realm." - Ph.D. Student in Biological Engineering

Through this quote, we can interpret that the availability of funding changed this participant's perception of graduate education and ultimately influenced her decision to pursue a doctorate. Similarly, this availability of funding influenced participants' decision to persist in the degree:

"The fellowship I think has definitely helped, um, because at no point, um, have I cost my department anything, so I mean, I cost them like physical space, because I need space to do my work. [...] I do think I would have felt a lot more pressure, I think I would have been in fear a lot more that the decision to leave or stay wouldn't have been mine. So I'm very grateful for the fellowship." - Ph.D. Student in Chemical Engineering

Here we see how this participant views the specific type of funding she has as an agent of choice allowing her to decide how long she wants to remain in her doctoral pursuit. While her decision to depart from the Ph.D. would incur a cost to the entity hosting her fellowship, her inability to put a face to said entity helped her put distance between the financial investment made on her behalf and her decision to persist in the program. Finally, students who were not on fellowships described the type of funding mechanism they used to minimize their financial investment as a progress deterrent as they had to manage multiple and often competing priorities:

"Having to seek for other opportunities for lack of funding or a potential lack of funding, which was at that point last year, I had to seek for other funding opportunities, so that meant another appointment, and also you know, another set of supervisors, that would have, you know, the job for me, which is completely different from my dissertation. It has been, this particular other appointment, has been good for my professional development in terms of what, you know, other things that professors do, right, deal with students, undergraduate students, uh, programs. So, it's not a thing that's been bad, so it's also good for my ... if I want to become a professor, but it has taken time of my research progress." - Ph.D. Student in Biomedical Engineering

We see in this quote how this participant describes her responsibilities towards her funding appointment as enriching towards her career but also deterring from her research progress. While she recognizes that these responsibilities are the ones financing her education, she also sees them as a factor that reduces her ability to invest her time towards her dissertation work.

Mental Investment. The fourth theme that emerged from our participants' experiences is the mental investment as described by 6 out of 8 participants. This investment could also be translated into the mental toll that students incur in the doctoral pursuit. In our specific sample, students discussed this investment in two ways: learning to work with their advisor and their URM identity.

Concerning the advisor, students discussed the process of learning how to work with, as well as for them, as an investment they had to mediate:

“So I didn't know that he was thinking something else and he didn't know that I was thinking something else. A lot of times, so for like experiments or my proposal, like I had this idea what it should be, and he had another idea, um, and so we got to the proposal, and he just thought I was coming prepared with like something completely different. Um, and I think also just learning his working style. He just got tenure, so he's relatively new, and I think he's still trying to figure out exactly how he wants to run the lab and so sometimes it was not consistent what was expected of us.” - Ph.D. Student in Chemical Engineering

Through this quote, we see how this participant describes the process of learning to communicate with her advisor as an additional cognitive investment as her advisor was not consistent with his expectations of her performance.

When discussing their URM identities, students often referred to these as an additional activity they had to partake in because of the nature of being part of a minority group in comparison to the majority of people in their graduate pursuit. The following quote describes how this participant struggles to handle the daily responsibilities of graduate school as well as those of her community.

“I was actually talking to another native doctoral student, um, just the other day, or earlier and we were experiencing fatigue. We hosted the first powwow on campus. The first tribal leader summit and because there are so few of us on campus, we were being called. We wanted to be there, we wanted to be called on. But there was just a point where, you were just, like, exhausted. [...] I do think there are added, like, responsibilities and pressures at least for me, for sure. just in like the physical, to serve on these or help out with these events or anything like that. But then also mentally and emotionally, because like being one of 12 grad students at- native grad students at [institution]. Like I feel the responsibility to make sure- like, if I don't say it, nobody else is going to say it. Like if I don't speak for my people, or like, for my group, then nobody else is.” - Ph.D. Student in Biological Engineering

This student recognizes her identity as a minority on campus serves a motivator to serve on behalf of her community at the expense of her mental well-being. While she enjoys these activities and wants to participate and represent her identity, she also feels exhausted because there are only so many people that are taking on this responsibility.

Discussion

Our results are both consistent with and expand upon current literature. Findings from our students that are consistent with widely reported findings include the idea that persistence itself is an effort and that

reporting results in writing is difficult for engineering students. The influence of funding type on experiences has been highlighted but not reported extensively in the literature. Additionally, the need for URM students to make unique investments, such as service activities associated with their URM identity, is similar to findings on LGBTQ undergraduates in engineering. Finally, our work sheds additional light on the investments graduate students make in learning to work with their advisors.

Among our findings, certain of the themes align with what has been reported previously in the literature for graduate students. For example, students' conception of persistence as an effort in itself has been previously described in a study by Gardner [9] that discussed doctoral student socialization in high and low attrition departments, one of which was engineering. Similarly, when students described 'sunk time' as a motivator to continue persisting in the degree aligned with a study done by Spaulding & Rockinson-Szapkiw [20] which aimed at understanding identifying and understanding motivators toward degree completion in doctoral programs. We also found that students reported difficulty with the process of writing their results. Students facing challenges with their writing skills at the final stages of the doctoral degree are not uncommon as the increasing independence of the Ph.D. pursuit removes the structure students become used to in the initial years [21]. However, we speculate that our sample being limited to engineering students may have a compounding effect as proper communication, especially in the written form, has not been historically promoted in the training for these disciplines [22].

Some of our findings, while aligned with existing studies, have not been as widely discussed in the graduate education literature. A particular example is how the type of funding influences the student experience. As described in our results, students discussed how having a teaching assistantship or responsibilities outside of their dissertation competed with their willingness to make progress. These findings align with previous studies that indicate how research assistantships to work best towards student training in science and engineering as it increased the interactions between students and advisors [9], [23], [24].

Among the themes that could be unique to our participants' URM identity is how the experience of being a minority in a doctoral engineering program is perceived as an additional investment in the process of completing the Ph.D. As demonstrated in the results, the students articulated their URM identity as an additional cognitive load they had to think about consistently. These findings align with a study done by Cech [25] that described the experiences of students with LGBT identities in engineering. The study describes these students as engaging in coping strategies that required 'immense amounts of additional emotional and academic effort' and how these burdens often brought students' academic and social isolation. This phenomenon also aligns with what has been described in the literature as 'minoritization' or when a student is marginalized due to the overrepresentation of whiteness in a particular context, in this case the doctoral program in which they are enrolled [11]. This minoritization places the student in a position where they have to be consistently paying attention to their identity with respect to the environment in which they are in.

Additional to coping with their salient identity, minority students expressed being pulled in multiple directions to represent their identity. This finding is consistent with literature on minority faculty that has discussed the management of time for both service and research [26]. While not observed in our results, students in previous studies in undergraduate engineering students have expressed this investment in extracurricular activities as helpful to their persistence [27]. This contradiction could be explained by the graduate students' socialization into the academic research space and as a consequence their primary focus shifting towards their research activities.

One theme in our data that is somewhat consistent with the literature is the investment of learning to work with one's advisor. While this learning process has been found to hold true across multiple students in different disciplines [21]. As described previously, minority students can often face a more isolated path in the

doctoral pursuit. As learning the expectations of performance within the doctoral program often occur informally [6], minority students may not be getting enough access to the cultural wealth [28] from their peers that could help them navigate graduate education successfully; thus, these students persist in pursuit of the degree at a disadvantage. This concept of the lack of cultural wealth is also consistent with a study done by Gardner [15] that studied the experiences of first generation students navigating doctoral education.

Implications and Future Work

In conclusion, this study demonstrated that through the process of pursuing the doctoral degree, URM students undergo the same experiences of most students and make the same investments to complete the degree such as struggling with persisting, writing, and allocating their resources towards degree completion. However, URM students often take on additional investment as they learn to cope with their URM identity in a context where it is not a norm since doctoral engineering education has a more significant problem of underrepresentation than undergraduate engineering programs. Our study also showed that URM students can often be pulled in multiple directions to represent their identity as well as their research. These additional investments could isolate URM students on their doctoral pursuit. This isolation could affect their involvement in the academic community which can have detrimental effects on learning the informal rules of navigating graduate education [6]. This implication is of particular concern as most doctoral programs have uniform expectations about a students' doctoral experiences and performance, yet the access to resources needed to mediate the doctoral process could be stratified across the racial and ethnic lines.

While some of our findings may be applicable to all doctoral students, our sample consisted of strictly URM students. The nature of qualitative research does not allow us to interpret from this data that the types of investments described are applicable to all students. We recommend for future work to compare how non-URM students describe the types of investments made in the doctoral pursuit as part of the socialization process and to take a comparative approach across racial and ethnic groups. A study of this nature could help inform assumptions regarding differences in the doctoral experience of students across racial and ethnic groups.

A recommendation for institutions and doctoral programs is to create spaces where URM students can express their identities freely such as with other URM students. These spaces can help eliminate the mental toll that students experience in their programs, and they provide students with access to a collective body of social capital that can promote the exchange of tools that help them persist in their doctoral pursuit.

The second recommendation for institutions and doctoral programs is to consider the type of funding being offered to students and the effect the responsibilities attached to the funding may have in the particular stage at that point. While a fellowship or scholarship may be convenient in the first years of a student's enrollment as it can help with recruiting, students may be better served by using such funding mechanisms in the final years of their pursuit when they have a firmer direction for their research and should allocate as much as possible of their time and effort towards that task.

While we believe our study could be transferable to people and settings with similar characteristics, some limitations of our study should be noted. Our study did not evaluate the experiences of majority students in the field of engineering. By consequence, and as stated in the discussion section, we do not claim the experiences analyzed in this study are limited to the URM student community. However, we recommend these results be used keeping this intended scope in mind as it is possible that these experiences are not strictly unique to the demographics and identities of our participants. Additionally, the majority (six out of eight) of our participants are underrepresented women. This intersection of oppressed identities may have influenced the experiences detailed in this study due to the 'double-bind' they may face in STEM [29]. While we do not claim other groups may not experience the same things, we acknowledge that our findings

may have been influenced by this intersection. Finally, as with all qualitative studies, the findings are restricted to the case study in question and can only be transferable to circumstances with similar characteristics [30]. While these findings are not generalizable, we believe that they preserve key experiences in the doctoral pursuit that are shared by multiple students of minority demographics.

In conclusion, this study operationalized the construct of investment in the socialization of URM students in doctoral engineering programs. It contributes to the extant literature by providing a different perspective of how a student's URM identity could affect their progress towards degree completion. Finally, it provides institutions with recommendations on how to improve their support for students towards doctoral degree completion.

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