

## **Minority Student Experiences in Engineering Graduate Programs: Socialization and Impact on Career Trajectories**

**Dr. Catherine T. Amelink, Virginia Polytechnic Institute and State University**

Dr. Amelink is Associate Vice Provost for Learning Systems in the Office of the Provost at Virginia Tech. She is also an affiliate faculty member in the Departments of Engineering Education and Educational Leadership and Policy Studies at Virginia Tech.

**Dr. Mayra S. Artilles, Arizona State University**

Mayra S. Artilles is an assistant professor in engineering at the Polytechnic School of the Ira A. Fulton Schools of Engineering at Arizona State University. Her research expertise includes engineering doctoral education structure, experiences of underrepresented minorities in doctoral engineering programs, and doctoral student motivation and persistence. Her research methods specialty is qualitative data analysis. Prior to transitioning into engineering education, Artilles worked at Ford Motor Company as an Electrified Vehicle Thermal Engineer. She holds a B.S. in Mechanical Engineering from the University of Puerto Rico at Mayaguez, an M.S. in Mechanical Engineering from Purdue University, and a Ph.D. in Engineering Education from Virginia Tech.

# Minority Student Experiences in Engineering Graduate Programs: Socialization and Impact on Career Trajectories

## **Abstract**

This paper examines the academic and social interactions during graduate engineering program enrollment among racially underrepresented doctoral and master's students and how those interactions shape their career goals. Using socialization theory, this study explored daily interactions of students with faculty and peers, overall perceptions of fit, knowledge about the graduate school process, and opportunities for mentoring provided in the institution as well as through outside engagement during industry internships. The findings presented in this paper build upon an earlier study conducted at one university to a national research sample.

Quantitative and qualitative data provide evidence that underscores the importance of having a supportive and accessible faculty advisor, the need for mentoring programs and peer groups that students from traditionally minoritized in engineering can identify with, and the role that regular feedback and clear expectations can provide in shaping the academic and social interactions of underrepresented engineering graduate students. This national study is comprised of 109 underrepresented domestic engineering graduate students who identified themselves as African American, Black, Hispanic, or Native American. Results show that in addition to the academic and social interactions in an academic setting, internship opportunities and related interactions in industry-based settings can play an important role in shaping the career trajectories of minoritized graduate students enrolled in engineering programs. The findings from this study can better inform the design of diverse, inclusive, and supportive graduate communities that encourage long-term careers in engineering fields in industry and academia.

Keywords: underrepresented graduate students, internships, career pathways

Acknowledgements: This paper was supported in part by the National Science Foundation award #1744636

A workforce that is representative of the demographic make-up of the current society in the United States (U.S.) is of critical importance to economic viability and continued innovation. In technical fields such as engineering, the underrepresentation of African American, Black, Hispanic, and Native American engineering graduate students compared to peers who are White is a well-documented issue [1]. For every seven majoritized students that complete a doctoral degree in engineering, only one minoritized student will obtain the same degree in the U.S. [2], [3].

Commissions have identified disproportionate representation in the workforce as a major challenge due to barriers that are socio-cultural, economic, and historical in nature [4]. At the same time, research studies have provided empirical evidence that highlights the differences in the experiences of African American, Black, Hispanic, and Native American domestic engineering graduate students compared to peers who are White [5], [6]. For example, members of these groups of traditionally underrepresented minorities in engineering are more apt to experience feelings of isolation [7], [8]. These feelings can be further exacerbated by conflicting value systems and prior experiences that do not align with those held by majority peers and faculty [9], [10]. This isolation can negatively impact students' transition to graduate school and, ultimately, retention and progress to degree [5]–[9], [11].

A study at one university highlighted how domestic underrepresented engineering graduate students are significantly more likely to indicate that prior knowledge about graduate school and professional skills such as the ability to network, negotiate, and resolve conflicts were factors impacting their success in graduate school [12]. These students are also more likely to indicate that they need to look outside of their home departments to establish a community of support than their majority peers that are not underrepresented [12], [13]. As more is learned of underrepresented racial minority (URM) student experiences during the graduate degree process, enrollment studies have also identified how the experiences of URM graduate students have impacted their career trajectories. For instance, in some cases experiences in graduate school have reinforced initial career goals to pursue faculty careers [14].

Given the established literature that highlights differences in experiences, this study sought: (1) to focus on exploring in greater detail the internal and external factors that domestic underrepresented engineering graduate students identified were important to their success in graduate school; and (2) how they saw different factors impacting their career trajectories.

## **Context**

Using the same aims and goals of the study to inform our methods/approach, we used a purposeful sample [15] that encompassed domestic URM students pursuing graduate degrees in engineering across the U.S. All of the participants were affiliated with a national consortium that is focused on creating pathways to graduate school for domestic underrepresented students in engineering and science. More specifically, the sample was drawn from attendees at the consortium's annual conference. Based on conference attendee demographics, we find this sample is representative of most of the URM population pursuing graduate engineering degrees in the U.S. per the National Science Foundation and ASEE By the Numbers [3], [16]. We focused our study on this sample purposefully, as these students would be more likely to highlight a variety of support structures that have enhanced their doctoral journey and supported their persistence [17].

The consortium brings together institutional liaisons, industry representatives, and students. The consortium hopes to positively impact the number of URMs who are graduate

degree earners in the U.S. working together to encourage underrepresented domestic undergraduates to enroll in graduate school, helping to identify industry and institutional funding to support students as they enroll in graduate school, and seeking to create a mentoring structure for the students involved. Over the years, the consortium has established a network of alumni who have graduated from institutions throughout the U.S. that represent the population that is at the center of the consortium's work. Involvement in the consortium also provides the opportunity to participate in an annual conference that brings together the institutional liaisons, industry representatives, and graduate students. In many cases, the institutional liaisons and industry representatives who attend the conference may be alumni who participated in the consortium as a graduate student. The annual conference provides a major opportunity for professional development for the students and a vehicle for socialization at no cost to students. The annual conference follows a similar model and agenda every year. Graduate student programming at the conference included networking sessions and panel presentations. The panel presentations focused on how to secure a faculty position, and provided tools to support the successful matriculation into a career by emphasizing networking skills. The conference also had technical presentation competitions for the student participants.

## **Methodology**

Data were collected through an online survey that was administered to a national sample of domestic underrepresented engineering graduate students who attended the consortium's annual conference during 2017, 2018, and 2019. The survey was administered less than one week after the conclusion of the final session of the conference. Participants were given one week to complete the survey and then received a reminder if they had not submitted a response. It is possible that attendees could have attended multiple conferences and received the survey more than once. In the responses it was possible to identify individual respondents by a number of indicators. Before replacing the individual identifier with a subject code to de-identify the respondents a count was conducted to determine if there were respondents that completed the survey across years. In total multiple responses provided by the same participant are less than 10 and the team decided it was important to keep all of the responses because at each point in time the respondent may have been having a different experience in graduate school. Initial survey questions were developed and reviewed by a group of current engineering graduate students across various demographic groups. The review of the questions and a pilot study in 2016 led to a final survey administered for the first time in 2017 and subsequently in 2018 and 2019. The survey collected demographic data on the participants as well as student perspectives on their graduate student experience and the factors they believed to be related to their success. For instance, we asked them to indicate the contribution of prior skills and experiences, relationships with peers and faculty, and their funding status and degree progress students have made to their success in graduate school at the time of taking the survey. Open-ended questions on the survey asked the graduate students to describe what experiences in graduate school have influenced career goals and the social experience they have had as a graduate student and what groups or people provide support or a social network.

Once the data were collected, the responses were combined across the cohort years. A mean score was derived for each scaled item and then items were ranked. The open-ended items were analyzed using thematic and pattern coding [18]. The open-ended items were reviewed for emergent themes and refined as themes were identified.

## Results

In total, 287 participants received the survey of which 109 responded. Of the 109 respondents to the survey, all of the students were enrolled full-time in graduate school in engineering and were between 20-30 years of age. The majority of the respondents were African American, Black, or Hispanic.

<b>Ethnicity</b>	<b>N</b>	<b>%</b>
African American, Black	51	56.6%
Hispanic	31	34.4%
Two or more races	8	8.8%
Native American, Pacific Islander	-	0.00%

The respondents most frequently reported that the highest degree earned by their mother or father was a high school degree or equivalent followed by a bachelor's degree. The engineering graduate students who responded to the survey included students enrolled in a master's degree program followed by a PhD program. Not all students intended to pursue a doctoral degree in engineering.

<b>Which scenario best describes your situation this academic year</b>	<b>N</b>	<b>%</b>
This is my first year/semester in my master's degree program.	33	30.61%
This is my second or third year in my degree program and I am completing my Master's degree.	24	21.94%
This is my first year/semester in my PhD program	23	21.29%
This is my second or third year in my PhD degree program.	13	12.22%
This is my second or third year in my PhD degree program and I have passed my qualifying exam.	5	5.81%
I have passed the qualifying exam in my PhD degree program and I am working on writing my dissertation.	7	7.01%
Other	3	3.07%

In terms of career plans, the majority of the respondents were thinking about a career in industry followed by academia.

**Quantitative items.** Respondents identified a number of factors related to their success in graduate school. Among the top ranked were ability to find funding, motivation to persist and commitment to earning a degree, prior academic preparation, and community support. Following these items peer and faculty interactions registered as important factors contributing to their success in graduate school.

<b>Factors contributing to success in Graduate School</b> (1=Not at all, No Contributions, 2=Minimal Contribution, 3= Somewhat of a Contribution, 4=Major Contribution)	Mean Score
Ability to find funding to support graduate study	3.75
Motivation to persist and commitment to earning a degree	3.67
Prior academic preparation (e.g., undergraduate experiences)	3.57
Community support (e.g., family, religious groups)	3.39
“Soft skills” such as ability to network, negotiate, resolve conflicts	3.37
Academic aptitude (e.g., IQ, mastery of content knowledge)	3.32
Peer support	3.25
Faculty support and interactions other than with advisor	3.20
Relationship with Advisor	3.18
Ability to deal effectively with ambiguity	3.18
Prior knowledge about graduate school, graduate student performance expectations	3.08
Progress on research projects	3.02
Engagement in the scientific community (e.g., presentations, professional networks)	2.97

**Open Ended Responses.** In response to a prompt about what experiences in graduate school have been factors related to their success and influenced career goals, three themes emerged from the answers the graduate students provided.

The main theme found in the open-ended responses included the influential nature that a community of support that includes peers, faculty, and external mentors can have on career goals. Interactions helped them formalize their career goals and hone in on specific areas they found compelling. The following quote shows an example of such (quotes in italics):

*“This [network] led me to consider alternative career paths for my Ph.D., such as at a national lab, where the research scientists are more involved in projects that are geared towards the national interest of the U.S. (and thus assumes a relatively faster pace).”*

In some cases, daily interactions with faculty and others internal to a university helped them understand a clear path forward. Many of the respondents were attaining their graduate degree at a research institution but interactions with faculty and others helped them understand how they could use their graduate degree in other areas.

*“Interacting with different research professor has made me realize that I wouldn't want to be a professor at a research I institution. I can see myself at a teaching institution, an industry R&D lab or a national lab.”*

*“I have not been in grad school for too long since this is my first semester, but seeing people working on innovative things makes me want to work for a company that gives importance to this.”*

In terms of a second theme, respondents noted the importance of attending conferences. Many respondents noted how important the consortium conference was with regard to influencing their career goals. Several of the attendees noted that attending the conference solidified their goal to attain a PhD and also helped them understand how to secure a job in academia. They noted that having the opportunity to network with people at the consortium conference who have attained a PhD in engineering, and who were also URM, was important to learn about a variety of career options. For instance, the conference exposed them to PhD earners who are employed at national labs.

From the respondents’ perspective, a critical aspect of the conference was how it served as a venue to continue to motivate them to finish their graduate degree.

*“It was sincerely invigorating to hear from professionals both working in the field, and working to make academia more accessible to all groups. I had went [sic] in with little expectations, but was able to have candid conversations regarding potential career paths and how to deal with the initial steps to navigating industry. I reinforced my plans to both complete my PhD and enter the working world even more as a result of attending the conference.”*

Especially important was the fact that the messages about viable career pathways were communicated by industry and academic leaders and senior level peers that the graduate students could identify with.

*“It was great seeing so many graduate students of color, especially coming from a graduate program where there is [sic] very few students of color. The speeches at the dinners and breakfast were very motivational. I am ready to finish my thesis!”*

Attendees noted that the conference exposed them to opportunities in academia, including a faculty career, and the sessions helped them understand what they would need to do in order to apply for a faculty position. Additionally, participants noted that the conference allowed them to build additional relationships with industry representatives and consider how they could use their graduate degree in an industry setting.

*“Attending the conference gave me the opportunity to talk to representatives in person about opportunities they have at their companies in my discipline. This was great because when I went to look online at what they have to offer in my [biomedical engineering] background (cellular and molecular biology; host-pathogen interactions) the websites felt very allusive and non-descriptive but the representatives for those companies offered more context.”*

*“The conference exposed me to other people who look like me with PhDs. It was amazing! The experience gave confidence, hope and empowered me...”*

The final theme that that emerged from the responses was the influential nature of internships that graduate students participated in. In particular respondents noted the importance of the internships they participated in with industrial partners in the national consortium.

*“My [consortium] internship at [name of company] the summer after my second year of the PhD solidified my desire to attend graduate school!”*

*“My internship with [name of company] after receiving the [name of consortium] fellowship influenced me to seek industry as a career goal after graduate school...”*

In addition to internships that students were already participating in, other graduate students indicated that they are going to be seeking internships with industry to help clarify career goals in the near future as part of their graduate experience.

*“Thus far in graduate school I am still getting my feet under me as a first-year grad student therefore I have not experienced many situations that have influenced a change in my career goals. However, I have learned that my program is focused heavily on design research, even more than I was originally aware. Consequently, I have considered searching for an internship this summer to conduct user experience research.”*

## **Discussion**

Quantitative and qualitative data provide evidence that underscores the importance of several internal and external factors that are important to the success of underrepresented domestic graduate students and their career goals. Findings demonstrate that having a community of support that includes groups comprised of faculty and peers at their university. This theme aligns with one of the main tenets of socialization theory which posits that learning in the doctoral journey best occurs when supported by those in a student’s immediate departmental community [9], [10]. Results further underscore the importance of having role models that underrepresented students can identify with; a finding which has also been confirmed in prior studies in STEM and engineering [19], [20]. In addition to the academic and social interactions in an academic setting, internship opportunities and related interactions in industry-based settings can play an important role in shaping the career trajectories of underrepresented graduate students enrolled in engineering programs. These types of interactions can help students clarify their career goals and understand options in terms of what options are available to use their graduate degree that fall outside academia. They learned new ways to align with their skill set that they had not been aware of previously. A critical component of the interactions with mentors and industry representatives was the way those interactions served to motivate graduate students to persevere through their graduate studies and attain their degree. While these findings align with other studies that have focused on understanding postgraduate career decisions for doctoral students [4], we uniquely highlight tangible benefits that leveraging connections between academia and industry can bring specifically to URM students.

As with any study, this study does have some limitations. First, we do not know how the institutional context may influence the individual experiences of students at their campus. However, our findings do match those described in other studies [6], [13], [14] which leads us to believe most institutions offer similar support making the student experiences similar across institutions. Second, our sample did not include Native American or Pacific Islanders. While their number are low in the general engineering graduate student population [16], it is important to understand how their experiences may differ from those of other URM students more broadly represented in higher education. Third, the participants all attended a conference which may be one of the reasons for which they discussed conference participation as a key element of their graduate experience.

## **Implications and Conclusions**

The results from this paper can better inform the design of diverse, inclusive and supportive graduate communities that encourage long-term careers in engineering fields in industry and academia. For example, institutions can promote connections and communities through which students can develop networks of URM students as these can help reduce the



isolation they can experience in predominantly white spaces. Similarly, given students' overwhelming interest to pursue careers in industry over academia, institutions can provide assistance for students to identify internships or industry experiences that best match their post-graduate school career goals.

The framework that is used by the consortium to bring together institutional representatives, industry representatives and graduate students could be used built on by universities. Institutions may want to consider how to develop opportunities for graduate students to engage in industry-based internships that are related to their career goals. In addition, creating mentoring structures that provide opportunities for graduate students to engage with industry representatives, particularly those that they can identify with, could allow for increased retention and degree attainment rates as these types of interactions provide increased motivation. Future research can evaluate the specific mechanisms these industrial relationships can be leveraged to encourage persistence in the doctoral journey for these specific communities. Authors are willing to provide copies of the survey that was used for this study. Requests can be made by email to the primary author.

## References

- [1] National Academies of Sciences, Engineering, and Medicine, *Graduate STEM Education for the 21st Century*. Washington, D.C.: National Academies Press, 2018.
- [2] Council of Graduate Schools, "Ph.D. Completion and Attrition: Analysis of Baseline Program Data from the Ph.D. Completion Project." 2007.
- [3] "Women, Minorities, and Persons with Disabilities in Science and Engineering: 2019," National Science Foundation. National Center for Science and Engineering Statistics., Alexandria, VA, Special Report NSF 19-304, 2019. [Online]. Available: <https://www.nsf.gov/statistics/wmpd>.
- [4] C. Wendler *et al.*, "Pathways through graduate school and into careers.," *Educ. Test. Serv.*, 2012.
- [5] S. K. Gardner, "Contrasting the Socialization Experiences of Doctoral Students in High- and Low-Completing Departments: A Qualitative Analysis of Disciplinary Contexts at One Institution," *J. High. Educ.*, vol. 81, no. 1, pp. 61–81, 2010, doi: 10.1353/jhe.0.0081.
- [6] S. K. Gardner, "Fitting the mold of graduate school: A qualitative study of socialization in doctoral education," *Innov. High. Educ.*, vol. 33, no. 2, pp. 125–138, 2008.
- [7] A. Gonzalez and J. Millunchick, "Extracurricular Engineering Activities and College Success," Jun. 2016, doi: 10.18260/p.26875.
- [8] E. Ramirez, "'?' Qué estoy haciendo aquí?(What am I doing here?)': Chicanos/Latinos (as) navigating challenges and inequalities during their first year of graduate school," *Equity Excell. Educ.*, vol. 47, no. 2, pp. 167–186, 2014.
- [9] J. C. Weidman, D. J. Twale, and E. L. Stein, *Socialization of graduate and professional students in higher education: a perilous passage?* San Francisco: Prepared and published by Jossey-Bass in cooperation with ERIC Clearinghouse on Higher Education, Association for the Study of Higher Education, Graduate School of Education and Human Development, the George Washington University, 2001.
- [10] D. J. Twale, J. C. Weidman, and K. Bethea, "Conceptualizing Socialization of Graduate Students of Color: Revisiting the Weidman-Twale-Stein Framework.," *West. J. Black Stud.*, vol. 40, no. 2, 2016.

- [11] M. S. Artiles, H. M. Matusovich, C. J. Bey, and S. G. Adams, "Understanding the Investment of Underrepresented minorities in Doctoral Engineering Programs," presented at the American Society for Engineering Education, Salt Lake City, UT, 2018.
- [12] C. T. Amelink, C. D. Edwards, and M. S. Artiles, "Understanding Majority and Minority Engineering Graduate Student Socialization Experiences: A Mixed Methods Approach," presented at the American Education Research Association., Toronto, Canada, 2019.
- [13] T. Bluestein, M. S. Artiles, D. Grote, and C. Amelink, "The Role of Graduate Student Funding and Engineering Students' Experiences. American Education Research Association," presented at the The Role of Graduate Student Funding and Engineering Students' Experiences. American Education Research Association, Toronto, Canada, 2019.
- [14] J. T. DeCuir-Gunby, C. Grant, and B. B. Gregory, "Exploring career trajectories for women of color in engineering: The experiences of African American and Latina engineering professors," *J. Women Minor. Sci. Eng.*, vol. 19, no. 3, 2013, Accessed: Nov. 07, 2016. [Online]. Available: <http://www.dl.begellhouse.com/journals/00551c876cc2f027,227df84537ba0187,2ac11ebd7bdafa52.html>.
- [15] J. W. Creswell, *Research design: qualitative, quantitative, and mixed methods approaches*, 4th ed. Thousand Oaks: SAGE Publications, 2014.
- [16] J. Roy, "Engineering by the numbers," in *American Society for Engineering Education*, 2019, pp. 1–40.
- [17] S. R. Harper, "An anti-deficit achievement framework for research on students of color in STEM," *New Dir. Institutional Res.*, vol. 2010, no. 148, pp. 63–74, Dec. 2010, doi: 10.1002/ir.362.
- [18] J. Saldaña, *The coding manual for qualitative researchers*, 3E [Third edition]. Los Angeles ; London: SAGE, 2016.
- [19] J.-L. Mondisa, C. Brown, and R. Adams, "Mentoring African-American Science, Technology, Engineering, and Mathematics (STEM) Undergraduates: An African-American STEM Mentor's Perspective," Jun. 2015, p. 26.1146.1-26.1146.11, doi: 10.18260/p.24483.
- [20] R. Sowell, J. Allum, and H. Okahana, "Doctoral initiative on minority attrition and completion," *Wash. DC Counc. Grad. Sch.*, 2015.