

System Factors Affecting Underrepresented Minorities in Doctoral Programs in Engineering : A Literature Review

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Abstract— Several studies have shown that underrepresented minorities (URM) (African Americans, Native Americans, Pacific Islanders, and Latinos) are more likely to drop out of engineering doctorate programs before graduation compared to international and majority students. In addition, transitioning into the doctoral programs without having a good understanding of what it entails can make the PhD experience difficult. To address this issue, a team of researchers from four US universities developed a project called “the Rising Doctoral Institute (RDI)”. One of the research goals of this project is to better understand how factors in the academic system interact dynamically to influence (i.e., support or hinder) incoming URM students’ access, success, persistence, and retention in engineering doctoral programs. To accomplish this goal, we will use a comprehensive analysis approach known as System Dynamic Model (SDM). This work-In-Progress article represents the starting point to develop this model and its overall goal is to conduct a systematic literature review to identify the factors in the academic system that impact URM students’ experience in doctoral engineering programs. We followed a process suggested by Okoli and Schabram [1] which consists of four major steps. The first step is presenting the purpose of the literature review, protocol, and training. The second step consists of selecting the literature and practical screen. The next step is the quality appraisal and data extraction. Finally, the analysis of findings and writing the review. By identifying the factors and the relation between them, we could help ensure a more diverse and equitable STEM education. Although some external factors can affect students’ access, success, persistence and retention in engineering PhD programs, this study is limited to exploring the factors and interactions within the academic system that can potentially impact the successful experience of underrepresented minorities in PhD programs in engineering such as Advisor-Advisee Relationship, Student’s Experience, Academic Support and Faculty-Students Interaction.

Keywords— *Minorities, Engineering, PhD, Access, Success, Equity, Diversity*

I. INTRODUCTION

Studies showed that the completion rate of doctoral engineering programs for underrepresented minorities (URM) (African American, Latinos, Pacific Islanders and Native Americans) is low compared to their majority counterparts [2]. This trend is due to lack of understanding of what a PhD in engineering means which makes the process difficult for underrepresented minorities and can cause attrition from the program [3]. Thus, it is crucial to work on changing this situation to help underrepresented minority students’ access, succeed and persist in their programs by managing the broader environment of the doctorate early in the process. A project funded by the National Science Foundation (NSF) aims at developing the Rising Doctoral Institute (RDI) to develop early interventions that prepare students to be successful in doctoral degree programs and help level the playing field for URM students entering an engineering doctorate.

II. PURPOSE

The specific purpose of this paper is to present a preliminary result of one of the research processes behind the RDI. The first step of this research is conducting a literature review to identify academic factors influencing underrepresented minorities’ students’ access, success, persistence, and retention in engineering doctoral programs. By identifying these factors, we can better understand how they interact in the academic system dynamically to influence (i.e., support or hinder) incoming URM students’ access, success, persistence, and retention in engineering doctoral programs.

III. METHODS

Recognizing that over time there are many academic factors influencing underrepresented minority students' access, success, retention, and persistence in doctoral engineering studies. we crafted two overarching research questions to identify variables influencing doctoral student experience from minority backgrounds, these questions are:

- What academic factors are facilitating and/or hindering the underrepresented minority students' experience in doctoral engineering programs?
- How do underrepresented minority students' experience impact their access, success, retention, and persistence in doctoral engineering programs?

To answer these questions, we have conducted a systematic literature review [1] to identify the factors in the academic system (i.e. Available resources and infrastructure, institutional policies and cultural) [4] that impact URM students' experience in doctoral engineering programs in the United States of America. The data sources for these articles were Ebsco host and ProQuest. We included journal and conference papers that: 1. were peer reviewed 2. had a combination of these keywords: (underrepresented minorities, graduate studies, engineering, and STEM).

We started with papers focusing on graduate studies in engineering, and STEM, then we narrowed to papers with a focus on URM students in engineering and STEM, further we looked more specifically on papers with a focus on URM engineering doctoral students. The total number of papers was 17. We excluded papers that addressed non-academic factors (i.e., family support) because our study aims to identify factors that academic institutions could have agency to change.

IV. ANALYSIS

During our analysis, we first created a Microsoft Excel Spreadsheet. Then, we extracted data from the selected peer reviewed articles and organized it by columns in our created spreadsheet. We specifically extracted for each paper, the authors, the title, the purpose, the references, and academic factors affecting students' access, success and persistence. The second step consisted of adding our comments to each factor to help us understand the extracted factors. We conducted a thematic analysis to classify and organize the factors in categories or themes. The following paragraphs describe those categories.

A. Advisor-Advisee Relationship

This category of factors highlights the influence of the relationship with the doctoral advisor on a student's persistence in a PhD. During the PhD, the advisor is the most important and critical person with whom they develop a relationship [5]. The advisor has a critical role in motivating, helping students achieve their goals, and complete the PhD program:[6] showed that students' research productivity, self-efficacy and career commitment are correlated to the quality of advisors'

supervision (Brazziel and Brazziel, 2001)[7], and [8] stressed on the importance of the advisor's professional support (e.g., giving feedback, and technical assistance) on PhD student's completion. Other studies have stressed on the influence of the types of misfits regulations on students' success:[9] examined the "misfits" that can happen during doctoral programs between students and advisors and showed that types of misfits regulation coupled with personality similarities, value and goal congruence (i.e., compatibility) had an important impact on doctoral students' success. Depending on the students' coping mechanisms to such misfits, they can hinder students' persistence. For example if students' reaction is resignation (learning to live with it) or negation (failing both to live with it and to address it, or reaching a point of no return and ceasing to address the issue) the likelihood of persistence is diminished. On the contrary, if students address the issue and initiate a regulation process, they are more likely to persist. Perceived supervisor's attitude has an impact on students' outcomes since sharing the same values and aspirations for the research project, progress together in the same direction and similar ways of working influence students positively. Advisors supporting style is also considered a key factor in students' persistence since they consider shortcomings in advisement as something of hindrance [7]. [10] investigated the experience of black male in engineering graduate studies in terms of their relationship with their advisors. It was reported that these underrepresented PhD students experienced racial microaggressions in college campuses over their graduate education. However, they had to manage these hostile behaviors from their advisors resulting from conscious or subconscious stereotypes of black males. These students had to adapt and use coping strategies to persist and complete their PhD studies in engineering.

B. Student's experience

This category of factors focus on the influence of students' experience in the academic system which is considered a decision factor in pursuing a PhD program such as the perceived cost, intrinsic and extrinsic motivation of students. The full understanding of the program cost in terms of rewards and benefits is a key factor in deciding to pursue a PhD program. Regarding motivation, it is considered a key factor to pursuing a doctoral program which can be intrinsic or extrinsic. The intrinsic motivation which is related to personal interests and desire has different figures such as the motivation to enjoy learning new things, the motivation to accomplish something and the motivation to go through a pleasing experience. Whereas the extrinsic motivation consists of obtaining reward or avoiding a punishment and receiving support from others. [11]. Another important factor is the sense of belonging that results from feeling accepted by faculty and fellow students [12]. This sense of belonging has a positive impact on the underrepresented PhD student's wellbeing and productivity.

C. Academic Support

This category explores factors related to institutional support and culture which are considered catalysts to students' success in higher education. Previous research experiences during undergraduate studies have a positive impact on the

decision to pursue graduate studies and perform well during their programs. Several studies found that undergraduate students who participated in previous research experiences and communicated their findings through conferences were more likely to forgo a graduate program [13]. Furthermore, [14] pointed out that students who had undergraduate research experience had good graduate research performance. In addition, a good academic preparation (i.e., having a good undergraduate GPA) is considered a key indicator of students' success in graduate programs [13]. [12] reported that underrepresented students who feel less prepared during their undergraduate and graduate learning experiences tend to feel less successful and have lower publication rates than their peers. Another important factor related to academic support was discussed which is clarifying expectations and standards to underrepresented PhD students. This type of interventions can help alleviate graduate education-associated distresses and decrease academic disparities [12]. Another factor that is very important is having Students organizations/Chapters implemented at the University which was found to have a positive impact on student's outcomes. [14] reported that Native American student groups or chapters were identified as another important source of support since students consider it as an extended family. Furthermore, Peer-support and Peer mentorship are correlated with good academic performance; When students reach out to their peers who are in similar circumstances to ask for help, they are more likely to be positively impacted. [14] mentioned that students from Native American backgrounds appreciated peer support through difficult course loads. In addition, they expressed their appreciation of the peer support received from Native Americans or fellow engineering students because it has a positive impact on their academic performance and, consequently, their retention in higher education. In addition, students appreciated receiving mentorship support and advice from older peers. Outreach was also extracted as an important factor from Reichert and Absher's study [15]. It was reported that when juniors and seniors from across the country are placed with faculty volunteers to conduct summer research projects and participate in workshops on preparing for graduate school, a sense of giving back to the community is reinforced by allowing minority students to participate in outreach programs since it helps them act as ambassadors. [15] also pointed to the importance of giving a masters' degree first because when institutions urge students to get a master prior to forgoing a PhD program, the chance of persisting to PhD programs. This category also explored support programs as an impacting factor. For instance, [16] examined the impact of an academic support program called Program for Excellence in Education and Research in the Sciences (PEERS) on underrepresented minority students' performance and persistence. This program was implemented at the University of California and participants were from first- and second-year science majors. The program includes several elements such as, academic, career and research seminars, holistic academic counseling, and collaborative-learning workshops. Students in this program participated in a seminar course that focused on developing

time management and study skills. In addition, the type of counseling they received focused on implementing yearly schedules for classes matching their backgrounds and goals. In addition, it focused on career preparation to help students perceive themselves as scientists. This study showed that by fostering supportive peer networks, creating a welcoming academic culture, and helping students perceive themselves as scientists have a positive impact on retention of students from underrepresented backgrounds in science related majors. Stolle-McAllister et al. (2011) [17] evaluated the Meyerhoff Scholars Program at the University of Maryland–Baltimore County which aims at integrating students in scientific fields. This program support had a positive impact on the success of minority students and the decision to pursue science doctoral programs. The factors that contributed to the increase in academic achievement were financial support, the formation of a Meyerhoff identity, developing networks, Summer Bridge and belonging to the Meyerhoff family. Summer Bridge consisted of academic and social integration, monitoring, knowledge, and skill development, advising and support and motivation. Another academic factor is financial support (i.e., financial aid and scholarships, including military and merit-based) is considered a key factor of students' persistence since many students are attracted to some universities based on the financial support provided [7,14,15,17].

D. Faculty-Student's Interaction

This category points out the factors related to faculty-students interaction excluding interaction with the PhD advisor. Over the past fifteen years, researchers have demonstrated the importance of the Faculty-Students Interaction on Underrepresented students in STEM majors' academic success, persistence, and academic and personal growth [18]. Mentoring support is important for Black PhD students to succeed since several students reported that having a faculty member or administrator from the same ethnic group helps them succeed. [19] in their study reported that when a professor gives special attention to students, they feel motivated to succeed. Especially that most of the mentors belonged to marginalized groups. This study showed that when students are encouraged by professors, they consider it important to their success. A faculty member having the role of a research mentor to guide the student through the research experiences has a positive impact on students' outcomes. In addition, having a mentor as a source of information and advice regarding applying for graduate school is considered a catalyst of student success [13]. Furthermore, a research conducted by [20] showed that the information about the controversy about black students in engineering can be distributed easily with good mentoring. Students can think that they are not alone and that they are supported in communities. Thus, institutions should provide programs of research experience for black students' programs to provide research experience for black students to develop their interest and improve their relationships with faculty [10]. A study carried out by [22] reported that having more frequent contact with faculty can help students succeed, have more confidence in their engineering abilities, expectations about

career opportunities and the ability to cope in their studies. In addition, this type of interaction leads to students' increase in intellectual development and personal growth. This interaction allows students to be more exposed to knowledge and resources. On the other hand, [18] referred to contact with white faculty as a hindering factor since underrepresented minority students fear being negatively stereotyped and perceived. Meanwhile this can be a factor that increases students' confidence in some cases. Another study that considered this type of interaction as a catalyst for students' success was conducted by [21] in which they mentioned that having a support network of faculty is beneficial to students.

V. DISCUSSION AND FUTURE WORK

The review of the literature shows 25 factors classified into four categories: Advisor-Advisee relationship, Institutional support, students' experiences, Faculty- Students Interaction. These factors influence underrepresented minority students' access, success and retention in engineering doctoral programs and we only explored academic factors although there exist external factors affecting students' experience. These factors can be driving or hindering students' access, success and persistence depending on the context. In addition, since the academic system is complex, we will continue looking into literature to extract more factors affecting students' access, success and persistence in engineering doctoral programs. Furthermore, we will determine the dynamic interaction between them to help us develop our system Dynamic Model (SDM).

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REFERENCES

- [1] Okoli, C., & Schabram, K. (2010). A guide to conducting a systematic literature review of information systems research.
- [2] Council of Graduate Schools in the United States. (2007). *CGS Task Force Report on the Professional Doctorate*. Council of Graduate Schools.
- [3] Lovitts, B. E. (2002). *Leaving the ivory tower: The causes and consequences of departure from doctoral study*. Rowman & Littlefield Publishers.

- [4] Cruz, J. M., Hampton, C., Adams, S. G., & Hosseinichimeh, N. (2019, June). A systems approach to instructional change in academia. In *ASEE Annual Conference and Exposition, Conference Proceedings*.
- [5] Barnes, B. J., & Austin, A. E. (2009). The role of doctoral advisors: A look at advising from the advisor's perspective. *Innovative Higher Education*, 33(5), 297-315.
- [6] Brazziel, M. E., Paglis, L. L., Green, S. G., & Bauer, T. N. (2006). Does adviser mentoring add value? A longitudinal study of mentoring and doctoral student outcomes. *Research in Higher Education*, 47(4), 451-476.
- [7] Burt, B. A., McKen, A., Burkhart, J., Hormell, J., & Knight, A. (2019). Black men in engineering graduate education: Experiencing racial microaggressions within the advisor-advisee relationship. *The Journal of Negro Education*, 88(4), 493-508.
- [8] Jairam, D., & Kahl Jr, D. H. (2012). Navigating the doctoral experience: The role of social support in successful degree completion. *International Journal of Doctoral Studies*, 7(31), 1-329.
- [9] Devos, C., Boudrenghien, G., Van der Linden, N., Frenay, M., Azzi, A., Galand, B., & Klein, O. (2016). Misfits between doctoral students and their supervisors:(how) are they regulated? *International Journal of Doctoral Studies*, 11, 467-486.
- [10] McGee, E. O., White, D. T., Jenkins, A. T., Houston, S., Bentley, L. C., Smith, W. J., & Robinson, W. H. (2016). Black engineering students' motivation for PhD attainment: Passion plus purpose. *Journal for Multicultural Education*.
- [11] Fisher, A. J., Mendoza-Denton, R., Patt, C., Young, L., Eppig, A., Garrell, R. L., ... & Richards, M. A. (2019). Structure and belonging: Pathways to success for underrepresented minority and women PhD students in STEM fields. *PLoS one*, 14(1), e0209279.
- [12] Slovacek, S. P., Whittinghill, J. C., Tucker, S., Rath, K. A., Peterfreund, A. R., Kuehn, G. D., & Reinke, Y. G. (2011). Minority students severely underrepresented in science, technology, engineering, and math. *Journal of STEM Education: Innovations and Research*, 12(1).
- [13] Gilmore, J., Vieyra, M., Timmerman, B., Feldon, D., & Maher, M. (2015). The relationship between undergraduate research participation and subsequent research performance of early career STEM graduate students. *The Journal of Higher Education*, 86(6), 834-863.
- [14] Cruz Rios, F., Naganathan, H., Tello, L., Adams, S., Cook-Davis, A., El Asmar, M., ... & Parrish, K. (2021). Catalysts and Barriers Faced by Native American Engineering Undergraduate Students in Arizona. *Journal of Civil Engineering Education*, 147(2), 04020017.
- [15] Reichert, M., & Absher, M. (1998). Graduate engineering education of underrepresented populations. *Journal of Engineering Education*, 87(3), 257-267.
- [16] Toven-Lindsey, B., Levis-Fitzgerald, M., Barber, P. H., & Hasson, T. (2015). Increasing persistence in undergraduate science majors: A model for institutional support of underrepresented students. *CBE—Life Sciences Education*, 14(2), ar12.
- [17] Stolle-McAllister, K., Domingo, M. R. S., & Carrillo, A. (2011). The Meyerhoff way: How the Meyerhoff scholarship program helps black students succeed in the sciences. *Journal of science education and technology*, 20(1), 5-16.
- [18] Dika, S. L., Pando, M. A., Tempest, B. Q., Foxx, K. A., & Allen, M. E. (2015, October). Engineering self-efficacy, interactions with faculty, and other forms of capital for underrepresented engineering students. In *2015 IEEE Frontiers in Education Conference (FIE)* (pp. 1-6). IEEE.
- [19] Maton, K. I., & Hrabowski III, F. A. (2004). Increasing the Number of African American PhDs in the Sciences and Engineering A Strengths-Based Approach. *American Psychologist*, 59(6), 547.
- [20] Robinson, W. H., McGee, E. O., Bentley, L. C., Houston, S. L., & Botchway, P. K. (2016). Addressing negative racial and gendered experiences that discourage academic careers in engineering. *Computing in Science & Engineering*, 18(2), 29-39.
- [21] Berdanier, C. G., Whitehair, C., Kim, A., & Satterfield, D. (2020). Analysis of social media forums to elicit narratives of graduate engineering student attrition. *Journal of Engineering Education*, 109(1), 125-147.