

Work in Progress: Bridging the Gap in Doctoral Engineering Education—Critically Investigating Factors Influencing Performance Outcomes on First Doctoral Degree Milestones

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My name is Nicole Jefferson (she/her/ma'am). I am a second-year Ph.D. student studying Engineering Education. Because of a GRA appointment where I research exemplary engineering colleges and their production of successful Black and brown engineers, I am currently interested in the preparedness of underrepresented students from undergraduate and master's engineering programs to doctoral engineering programs. I am excited about having the opportunity to become a better ENGR/ENGE researcher. In the future, I aspire to be an engineering education policy advocate and have plans to develop a research preparation consortium.

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Milestones

Abstract

It is well documented that Black students tend to enroll and complete engineering Ph.D.s at disproportionately lower rates than their peers. What is less understood are the most critical factors influencing their success at critical junctures in the Ph.D. program. Existing scholarship on the socialization processes embedded in pursuing a graduate degree are based on the premise that transitioning into a hyper-specialized area is challenging. One of the most challenging aspects of pursuing a Ph.D. are the academic milestones that are unique to degree completion (e.g., qualifying/comprehensive exam, proposal/preliminary exam, dissertation defense). The creation of the Dissertation Institute is one example of a program for engineering students hoping to succeed in the latter milestones. However, the focus of this study is the first milestone – depending on the department, this may be a qualifying, preliminary, and/or comprehensive exam that assesses students' understanding of foundational concepts introduced in core courses. There are multiple reasons why success on milestones may be challenging. Unlike course assessments of an isolated concept or skill that may have been the norm in prior degrees, successful completion of program-level degree milestones embedded in pursuing a Ph.D. require students to integrate ideas, skills, and ways of being learned across courses to accomplish a unique task that comes with being a scholar in the discipline. The purpose of this preliminary mapping review is to outline the major categories of scholarship on salient factors that influence Black engineering Ph.D. students' successful completion of their first academic milestone. The findings of this work-in-progress study will provide the basis of a future study that will have implications for Black graduate students hoping to excel in their Ph.D. program and the faculty involved in preparing Ph.D. students with diverse lived experiences to pass their first of many academic milestones.

Overview

This work-in-progress focuses on the factors that influence a student's transition into an engineering Ph.D. program – with an emphasis on the successful completion of the first-degree milestone. Although the format and content of these exams vary across programs, we are choosing the first milestone because across all programs, this assessment is the first major barrier that students encounter. The findings of this study would have implications for graduate students hoping to excel in their graduate program and the faculty involved in preparing Ph.D. students from diverse pathways to successfully complete their first Ph.D. program milestone examination. This work-in-progress paper is organized into five sections: Motivation, Purpose & Research Questions, Theoretical Framework, Methods, and Conclusion. The detailed survey mentioned in the Methods section is included in the Appendix.

Motivation

Doctoral students' studies are usually separated into two stages in their academic journey: dependent and independent. During the dependent stage, students are involved in acquiring the

knowledge base of their discipline areas, studying their discipline's theories and practices, and forming connections with peers, instructors, and their advisor. In the science and engineering fields, the dependent stage comprises a mix of classroom work and supervised or guided research (Lovitts, 2005). Students' connection with information shifts throughout the independent stage from studying what others know and how they know it, to performing original inquiry and developing knowledge. While engineering Ph.D. students are made aware of the structure and procedures involved in successful doctoral conferment, the nature of the new processes they confront in the independent stage, such as completing the first academic milestone, researching, and writing a dissertation, are frequently hazy and strange notions (Lovitts, 2002).

Engineering Ph.D. programs tend to require the successful completion of four main academic components to complete the degree. Students usually start with coursework to prepare for their first academic milestone, the qualifying examination (which may be called by a different name depending on the program). The qualifying exam is designed to establish evidence of foundational knowledge in the discipline. It evaluates a students' fitness to continue in the Ph.D. program, as well as helps spotlight inadequacies that may be impeding their future growth and achievement. The preliminary examination is the next milestone after the qualifying exam. It is used to determine students' ability to synthesize existing scholarship as part of beginning to articulate a niche research interest. To begin dissertation research, the student must defend a research proposal that defines the project's motivation, a literature review, goal/purpose, research question(s), methodology (with quality measures), and potential contribution to the discipline. The final milestone that is shared among all Ph.D. programs is the final dissertation defense. Before their advisory committee, all Ph.D. students must produce and defend a written dissertation detailing their research work and its findings, then orally defend it before their committee and a public audience.

These examination milestones can become gatekeepers for progression toward the completion of the degree. According to "The Role and Nature of the Doctoral Dissertation" (Hancock, 1991), the attrition rate of doctoral students in the US has been estimated at 50% since the 1960s. According to the CGS, this situation is "one of the most challenging difficulties that US graduate education faces" (King, 2008; Wendler et al., 2010). In particular, the 10-year completion rate for Caucasian engineering Ph.D. students is 60%, compared to 55% for Hispanic Americans, 53% for Asian Americans, and 47% for African Americans (Kerlin, 1995). In 2008, the Council for Graduate Schools reported a quantitative study tracking attrition and persistence, noting that graduate attrition in engineering is between 24%-36% for men and women in engineering, respectively (Sowell, 2008). More recently, in 2015, Sowell, Allum, and Okahana reported data disaggregated for graduate engineering men and women of color, noting alarming statistics for most traditionally underrepresented groups, including that ten-year completion rates for African American engineering graduate students, are only 48% (Sowell et al., 2015). With these statistics in mind, it is not unreasonable to suggest that a students' success in the first milestone is critical in order to be able to build upon learned knowledge and progress to the next milestone, and ultimately graduate in a timely manner.

There are multiple reasons why success on the milestone may be challenging. Unlike course assessments of an isolated concept of skill, program-level degree milestones force students to integrate ideas, skills, and ways of being that they have learned across courses to accomplish a unique task that comes with being a scholar in the discipline. Consequently, it is safe to assume that Ph.D. degree milestones are unlike any other assessment an engineering

student has taken before transitioning into a doctoral program. Given the uniqueness and importance of milestones in the Ph.D. program, it is imperative that engineering programs keep preparation for milestones in mind when thinking about students' transition into the program.

The NSF-funded Dissertation Institute (DI) is one of few nationally-scaled examples in the engineering community that is focused on graduate student success on a milestone (i.e. the dissertation proposal) (Hasbún et al., 2016; Miller et al., 2020). It is a one-week writing workshop that gives Ph.D. students a secure place to support one another among like-minded peers while they modify their task assumptions about the dissertation and develop good habits that might lead to degree completion.

Although this is an excellent resource for Ph.D. students at later stages of the Ph.D. process, there is no parallel effort (that I am aware of) focused on the first degree milestone. However, before we can talk about ways to assist students in successfully completing the first milestone, we need to better understand the factors that influence success on the first milestone.

Purpose & Research Question

The purpose of this study is to advance our understanding of factors that influence an engineering Ph.D. student's likelihood of passing their first evaluative degree milestone. This will be achieved by surveying engineering Ph.D. students who have successfully completed at least one degree milestone, and developing a regression model that explains the relationship between milestone exam outcomes, demographic characteristics, and graduate education socialization factors. The corresponding research question is:

What personal attributes (i.e., race, gender, SES, degree type, discipline/major, type of the previous institution) and graduate education socialization factors (i.e., knowledge acquisition, investment, involvement, & engagement) tend to best predict the exam outcome of an engineering Ph.D. student's first academic milestone?

Theoretical Framework: Graduate and Professional Student Socialization

Socialization is the process by which graduate students can move from the edge to the core of their newly-selected field. Since the first year of their graduate education marks the formal beginning of this process, it is important to understand what this process may entail. According to some graduate education scholars, there are four core elements related to graduate students' development of an identity congruent with the norms and values of their field: knowledge acquisition, investment, involvement, and engagement (Weidman, 2006). *Knowledge acquisition* describes how students learn skills and information that will help them perform well in their new role as a Ph.D. student, as well as gain an understanding of what academic success entails. Through knowledge acquisition, students become aware of normative expectations of the Ph.D. student role and can make a realistic assessment of their personal ability to pursue their desired career. The student's *investment* reflects their commitment to learning and understanding the skills and values associated with their new roles, which necessitates a commitment of time, energy, reputation, or other personal assets. The third stage of socialization, *involvement*, reflects the students' active participation in the formation of their identities and fit for their new graduate student role. To learn the skills and values associated with their field, the student must be willing to train and practice, as well as initiate and develop relationships with others (Weidman et al., 2001). The previously described core elements of socialization combine to form the fourth core

value of socialization, the concept of *engagement*, which was developed in a later work by Weidman (Weidman, 2006). Students become engaged when they form attachments to people and environments in higher education institutions, which leads to students developing the skills, competencies, and knowledge needed to succeed in doctoral programs (Twale et al., 2016).

The Graduate and Professional Student Socialization framework will be applied to this study in two distinct ways. First, the survey that will be used to collect data from graduate students who participate in this study, is based on this theory. More specifically, the four core elements of the socialization process are reflected among the survey items. Secondly, the outcomes of the analysis may reveal which core element(s) of the socialization process need to be addressed in order to improve students' success on their first academic milestone.

Methods

Participants & Recruitment

Ph.D. engineering students who have completed at least their first Ph.D. engineering milestone within the last five years will be invited to complete a survey. A five-year range will be used because, in a five-year period, there is the possibility of getting responses from people in all stages of the engineering Ph.D. process. Anything past five years would have an increased likelihood of milestone requirement differences. A call for participants will be made through the Engineering Education Graduate Student Network, Graduate & Professional Student Senate, Graduate Life Department, College of Engineering, and graduate student organizations (e.g., ASME, NSBE & SHPE) email listservs at the prospective institution. The goal is to have a relatively diverse pool of participants so we can compare engineering PhD students' experience across demographic groups. If the pool is less diverse than expected, I will utilize snowball sampling, reach out to network connections, and contact demographic-specific clubs/organizations/affinity groups.

Data Collection

Data for this study will be collected using a quantitative survey of Ph.D. students in engineering at an American Research-1 institution. The survey instrument will be adapted from Weidman's (2003) socialization of doctoral students survey to elicit responses to socialization factors and milestones. The survey sections will include Likert scale, multiple choice, yes-no, and open-ended questions. These survey questions will be followed by a demographic information section on race, gender, socio-economic status (SES), degree type, and previous institution type. See the Appendix for the complete survey.

Data Analysis

The survey data will be analyzed using descriptive and inferential statistics. Descriptive statistics will be used to understand the demographics of the survey respondents. In terms of inferential statistics, the survey data will be analyzed using regression analysis. More specifically, a series of four regression analyses will be performed to identify which core element(s) of socialization have an impact on student success in engineering Ph.D. academic milestones. In each regression, the dependent variable will be milestone success and the independent variable will be one of the four core element(s) of socialization. These coefficients

in the regression analyses will help determine which core element(s) matter most, which core element(s) can be ignored, and how these core element(s) influence each other.

Quality Measures

Three quality measures will be considered as part of this research design: replicability, validity, and generalizability. In terms of validity, the phenomenon and data collection that is the focus of this study is designed around an established theory of graduate student socialization and a corresponding validated survey. This research design study is replicable because it uses an adapted graduate socialization survey. The survey questions can be used in similar studies to discover the correlation between demographic characteristics, elements of graduate education socialization, and the exam outcome of a participant's first academic milestone. Lastly, this study has the potential to produce generalizable results because it utilizes metrics that can be used in other academic settings to address academic milestones and transitional preparation.

Limitations

This study focuses on the success of engineering Ph.D. students on first-year milestones, with the gatekeeping mechanism being the primary consideration. However, it is important to note that the actual exam and difficulty may vary across engineering Ph.D. programs. While quantitative data collection is useful, it can sometimes overlook nuance. In this work-in-progress paper, the quantitative analysis is the first step of a larger project. Future work will include qualitative data collection to explore details not revealed by quantitative methods. One limitation of using survey and quantitative methods in this context is the potential for self-report bias (Critchfield, 1994), which can lead to inaccurate data if participants do not accurately report their experiences. Another limitation is the Weidman Socialization of Doctoral Students survey, which was developed in 1989 and may not accurately reflect the current experiences of engineering Ph.D. students. Additionally, the survey primarily covers socialization factors and milestones, potentially missing other important aspects of the Ph.D. experience.

Conclusion

This study will examine factors that influence a student's transition into an engineering Ph.D. program. Additionally, it will advance our understanding of the likelihood of successful completion of the first degree milestone -- one of several obstacles that can serve as gatekeepers for progression toward the completion of the degree. Upon entering graduate school, a student's socialization process entails gaining knowledge of the craft, investigating their academic skills, involving oneself in role formation, and attaching to the academic environment. Ph.D. engineering students who serve as participants for this study will complete a survey that elicits responses related to graduate student socialization and Ph.D. academic milestones. An analysis of the results will likely indicate a relationship between graduate socialization factors and the outcomes of the first major engineering Ph.D. milestone. The results of this study will lead to a discussion of future work to further understand that correlation. Likewise, the results will illuminate characteristics that can be addressed during the transition into engineering Ph.D. programs as students prepare for their first academic milestone. As this study will incorporate quantitative survey methods, future work may include an interview component with respondents who have experienced milestone delays. Interviews could provide additional context to improve faculty support of students during their transition into engineering Ph.D. programs.

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Service.

Appendix: Survey Questions

Variables from Weidman Socialization of Doctoral Students survey

Eligibility questions

1. Did you first enroll in an engineering PhD program in the past five years? (Y/N)
2. Have you ATTEMPTED or completed your first engineering academic milestone? (Y/N)

Milestone Questions

3. What was the first milestone?
 - a. Qualifying Exam/Comprehensive Exam
 - b. Preliminary Exam
 - c. Dissertation Proposal
 - d. Other (please specify)
4. Did you pass your first PhD engineering milestone after the first attempt?
 - a. Yes
 - b. No
 - i. If you did not pass after the first time, how many additional attempts did you make before passing your first milestone: ____.

Socialization Questions (Weidman & Stein, 2003)

5. *Participation in scholarly activities*
 - a. *Been asked by a fellow student to critique his/her work (Y/N)*
 - b. *Held membership in a professional organization (Y/N)*
 - c. *Asked a fellow student to critique your work (Y/N)*
 - d. *Attended convention of a professional organization (Y/N)*
 - e. *Performed research of your own which was not required by your program or studies (Y/N)*
 - f. *Called or written to a scholar at another institution to exchange views on scholarly work (Y/N)*
 - g. *Written, alone or with others, a grant proposal (Y/N)*
 - h. *Authored, alone or with others, an unpublished manuscript (not part of a course) (Y/N)*
 - i. *Authored, alone or with others, a paper submitted for publication (Y/N)*
 - j. *Presented a paper at a conference or convention (Y/N)*
 - k. *Authored, alone or with others, a paper accepted for publication (Y/N)*
6. *Student-faculty interactions*
 - a. *Sometimes engage in social conversation (Y/N)*
 - b. *Often discuss topics in his field (Y/N)*
 - c. *Often discuss other topics of intellectual interest (Y/N)*
 - d. *Ever talk about personal matters (Y/N)*
7. *student-peer interactions,*
 - a. *Sometimes engage in social conversation (Y/N)*
 - b. *Often discuss topics in his field (Y/N)*
 - c. *Often discuss other topics of intellectual interest (Y/N)*
 - d. *Ever talk about personal matters (Y/N)*
8. *supportive faculty environment (5-Point Likert Scale; 1[Completely Disagree]-5[Completely Agree])*
 - a. *I identify more with my professors than with my fellow students. (1[Completely Disagree]-5[Completely Agree])*

- b. *This department emphasizes engaging students in scholarly activities (research, writing other than dissertation/thesis, etc.). (1[Completely Disagree]-5[Completely Agree])*
 - c. *The faculty are accessible for scholarly discussions outside of class.(1[Completely Disagree]-5[Completely Agree])*
 - d. *I feel free to call on the faculty for academic help.(1[Completely Disagree]-5[Completely Agree])*
 - e. *My department offers sufficient enrichment activities (seminars, colloquia, social events, etc.) in addition to regular classes.(1[Completely Disagree]-5[Completely Agree])*
 - f. *The faculty are aware of student problems and concerns.(1[Completely Disagree]-5[Completely Agree])*
 - g. *I can depend on the faculty to give me good academic advice. (1[Completely Disagree]-5[Completely Agree])*
9. *department collegiality, (5-Point Likert Scale; 1[Completely Disagree]-5[Completely Agree]*
- a. *I am treated as a colleague by the faculty. (1[Completely Disagree]-5[Completely Agree])*
 - b. *The faculty see me as a serious scholar. (1[Completely Disagree]-5[Completely Agree])*
 - c. *The faculty seem to treat each other as colleagues. (1[Completely Disagree]-5[Completely Agree])*
10. *student scholarly encouragement. (3-Point Scale; “Please indicate how true each one is (or seems to be) in your department.” very true (3), somewhat true (2), or not true at all (1).*
- a. *An environment that promotes scholarly interchange between students and faculty.(very true (3), somewhat true (2), or not true at all (1))*
 - b. *An environment that fosters and develops scholarly self-confidence in students. very true (3), somewhat true (2), or not true at all (1)*
 - c. *An educational climate that encourages the scholarly aspirations of all students. very true (3), somewhat true (2), or not true at all (1)*
 - d. *Sufficient opportunities for students to participate in the scholarly activities of the faculty. very true (3), somewhat true (2), or not true at all (1)*

Demographic Questions

- 11. *Citizenship (foreign country other than the United States) (Yes/No)*
- 12. *Major department (educational foundations). (Drop Down/multiple choice)*
- 13. *Gender (Multiple choice/gender not listed:cis/trans)-(Gender Survey questions Best practices)*
- 14. *Institution type of previous degree (Carnegie Classifications)(Open-ended: Name of institution to be categorized by researcher)--check for a validated dropdown carnegie survey*
- 15. *Did you earn your bachelors and/or masters at the institution where you are currently pursuing your doctoral degree? (Yes/No)*
- 16. *Race/Ethnicity(Check Box/Not Listed:)*
- 17. *High school zip code (Open ended: Socioeconomic status to be inferred by researcher)*

(Weidman & Stein, 2003)