Characterizing Doctoral Engineering Student Socialization and Attitudes toward Academic Career Trajectories

Blinded for Review
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address

Blinded for Review
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address

Blinded for Review
line 2: *dept. name of organization (of Affiliation)*
line 3: *name of organization (of Affiliation)*
line 4: City, Country
line 5: email address

***Abstract*—This research full paper explores interview data with N=36 engineering graduate students to understand the factors and characteristics of graduate socialization, with the effort of better preparing students to succeed in doctoral programs. This research is motivated by the alarming fact that nearly one-third of engineering doctoral students will not finish their PhD programs; however, little research has been conducted on the various factors that can lead to attrition or enhance persistence in graduate engineering programs. This paper presents the results from the interview phase of a larger study investigating doctoral engineering socialization, attrition, persistence, and career trajectories. The participants for this study come from large research-intensive universities across the United States, and were sampled for maximum variation in a number of different categories, including stage in their doctoral program, gender, and race. Upon collecting and analyzing interview data from our participants through constant comparative and content analysis methods, several themes arose including concerns for mental health in engineering graduate students and uncertainties with joining the culture of academia in their future careers. Further, although the participants for this study are currently graduate students who anticipate completing their PhDs, nearly half of the participants discussed strongly considered leaving at some point. This study adds to the body of literature surrounding engineering attrition and the underlying issues driving engineering PhDs away from academic engineering careers.**

Keywords—graduate engineering education; socialization; persistence; attrition; content analysis

I. Introduction and Review of Relevant Literature

In engineering, the education, attrition, and persistence of graduate students is rarely studied, despite the fact that between 24% and 36% of doctoral students leave their programs [1], and despite the fact that the number grows to over nearly 60% for Black and African American doctoral engineering students[2], [3]. The doctoral socialization process is complex and individualized, since doctoral education has roots in apprenticeship [4] and carries with it myths of meritocracy[5] and the academic mythical ideal worker, who is white, male, and wholly devoted to his research [6], [7].

These dominant images of academia pervade all disciplines, and capture some of the issues facing doctoral students as they enter into and progress through their doctoral degree programs. Nerad critiques the system of graduate school only preparing graduate students for academic careers in spite of a changing research economy and increasingly tight research budgets, low faculty salaries, and high competition for faculty positions[8]–[10]. Austin's work similarly notes the structures in place that are intended to socialize graduate students to become future professors and researchers[11]–[14].

Doctoral engineering education is interesting because, in fact, 80% of engineering students will pursue careers in industry[15], [16], rather than academia, and in reality, most graduate students are still not prepared for academic roles including teaching, grant writing, and mentorship [12], [17]. Although each research group and department has different cultures dependent highly on the role of the research advisor and the structure and size of the research group[18], most engineering graduate students are not prepared for many of the skills and competencies required to be a steward of the discipline [19]–[21]. Further, graduate-level engineering attrition and persistence seem to off-end several common narratives of attrition across other disciplines, particularly in relationship to funding and time to degree[22], [23]. Most graduate students in engineering disciplines are funded by their departments and/or research advisor, may not be required to teach, and have a short time to completion. This results in attrition rates that are indeed lower than other disciplines; however, attrition is still high, especially for women and scholars from traditionally underrepresented groups [1]–[3].

Research on the issue investigates the reasons why undergraduates pursue graduate study[24], structural and sociological factors influencing persistence—such as mentorship [25]–[27] and departmental climate[28], [29], and unseen or untaught professional competencies, such as writing, that serve as mediators of progress in graduate school. With these pieces of research in mind, this study sought to characterize some of the experiences of graduate school in order to better understand how PhD students at various stages correspond to desired career trajectories. While Kiley [30]

studied threshold concepts of doctoral study that correspond to the milestones of doctoral study to explain students' struggle and breakthroughs, resulting in the development of resilience and identity, we seek to understand how widespread various attitudes toward or away from academic careers are within each threshold. This paper seeks to answer the following research question: How do doctoral engineering students perceive and develop goals toward or against academic career trajectories?

II. Theoretical Orientation

The theoretical lenses that guides this study are role identity theory[31] and ideal worker theory[7], [32]. Role identity theory posits that in different circumstances, individuals develop and perform different roles. A psychological approach to identity development, it has been applied to doctoral engineering education [33], [34] and graduate education in general, noting that graduate students may experience tension as they develop and are asked to perform new identities as producers of knowledge while oscillating between established identities as consumers of knowledge. In contrast, ideal worker theory is a sociological view of workplace culture, positing that an "ideal worker" is white and male, and has underlying currents of meritocracy that promote that any "extra" identities or activities, such as having a family, distract from the devotion of all time and energy to the pursuit of disciplinary excellence. Any level of "otherness" in terms of identity, for example, being a person of color, a woman, or identifying as LGBT+ detracts from one's ability to be an "ideal" worker, especially in science and engineering disciplines that are arguably more gendered and raced than other disciplines [6], [7], [32], [35], [36]. Parenthood, too, is a category of "other" that detracts from the appearance of being entirely devoted to scholarship[37], [38]. The ramifications of ideal worker theory manifest in dominant narratives from the point of both students and faculty of who can be a successful professor. The present study will continue to elicit a discussion on how engineering graduate students at various stages perceive academic career trajectories and the thresholds for academic socialization, and how these visions are shaped through socialization into the roles, expectations, and norms of the discipline.

III. Methods

Administrators of ten R1 universities around the United States distributed the survey to current PhD students at their respective schools. As a part of a bigger study, the survey asked an array of questions including career aspirations after graduate school, experiences with academic writing, and the students' overall experiences throughout graduate school thus far. Gender, ethnicity, discipline, stage of graduate study, and a battery of quantitative instruments studying writing attitudes were captured using Qualtrics survey software. The writing attitudes data are peripheral to this study, which focuses on the interview portion of the study with these students.

Of the students that received the survey, N=808 current engineering graduate students started the survey and N=614 completed the survey and their responses were recorded using Qualtrics online survey software. Participants received a $5 Amazon gift card as compensation for survey participation. They were also given the opportunity to participate in a follow-up interview. Maximum variation sampling was used to create a list of potential interviewees with the aim to create a diverse pool of participants in terms of gender, ethnicity, current stage in graduate school, institution, and discipline. We defined "early career" to be years 1 and 2, or enrolled in a Master's program, or before qualifying exams; 'mid-career' to be years 3 and 4 of a doctoral program, or between qualifying exams and defending a PhD proposal; and 'late-career' to be after year 5, and after the dissertation proposal but before graduation. Three participants graduated between the time that the survey was deployed and the interviews were conducted. These participants were categorized as late-career graduate students. We contacted 40 of the interested respondents to invite them to participate in an interview, and of those N=36 responded, and who comprise the participants in this study.

Of the study participants, 18 identified as women and 18 as men. Ten of the participants reported being in the beginning stages of their programs, 13 participants in the ending stages of or had completed their programs, and 12 participants currently in the middle stages of their programs during the time in which the interview took place. Twenty-seven participants identified solely or partially as Caucasian, 7 identified as solely or partially as Hispanic, 4 identified solely or partially as Asian, and 2 identified solely or partially as African American. Three late career graduate students who had completed the survey and were selected for interviews had recently graduated with their PhD at the time of the interview.

Each interview lasted approximately one hour and were completed via Zoom appointments. During the interviews, the participants were asked to elaborate on their graduate school experiences including their education trajectory, academic publishing expectations, and the justification of preconceptions around graduate programs. Recordings of the interviews were then transcribed by a professional transcription service and checked for accuracy by a member of the research team. The transcripts were analyzed using the constant comparative method through a constructivist paradigm [39] using an abductive analysis approach [40], which considers how data relate to existing theory rather than solely generating new theory. After open and axially coding the data for emergent themes in relationship to the theoretical orientation in this paper and other relevant related theories, we re-analyzed the data through content analysis methods to get a snapshot of the numbers of students who struggled with some central issues in graduate education, stemming from our group's prior and concurrent work [41], [42].

IV. Results

In this results section, we present a snapshot of our participants and their trajectories to and through, and anticipated paths after their doctoral programs; relationships with advisors and support structures; and managing mental health. These overarching topics are timely given recent calls to study the doctoral trajectory with the goal of increasing student support structures and maintaining students' mental health. We present our findings through descriptive statistics of our participants, and present some quotations from the participants to provide context when discussing the trends in the data.

A. Trajectories To, Through, and Past Graduate Study

20 of the 36 participants had switched academic disciplines at some stage during their academic careers, for example, between disciplines of engineering or between science and math disciplines to engineering. More than half the participants who reported considered leaving their doctoral programs at some point were people who had switched disciplines. All our participants who went into industry after obtaining a master's degree and returned to complete a PhD program had switched academic disciplines for graduate school.

On par with current statistics of attrition rates in engineering graduate programs, approximately one-third (12) of students expressed that they had given serious consideration to leaving their PhD programs at some point, with or without having first obtained a Master's degree. Another 8 students stated they had given some consideration to leaving but felt it was brief and during times of heightened levels of stress. Some common themes amongst these participants were difficulties with advisory relationships, negative outlooks on academic culture, and shifts in academic disciplines.

Table 1: Participant reported likelihood to pursue various engineering career trajectories

	Self-reported likeliness to pursue career sector after graduate degree			
CAREER SECTOR	Highly Likely (%)	Likely (%)	Unlikely (%)	Highly unlikely (%)
ACADEMIA				
Tenure-track	2.8	2.8	16.7	11.1
Non-tenure track	2.8	0.0	0.0	0.0
Research-focused	8.3	5.6	8.3	11.1
Teaching-focused	11.1	13.9	5.6	5.6
INDUSTRY				
R&D	27.8	22.2	0.0	0.0
Non-R&D	5.6	8.3	0.0	0.0
RESEARCH	5.6	0.0	0.0	0.0
GOVERNMENT	2.8	0.0	0.0	0.0
ENTREPRENEURSHIP	2.8	0.0	0.0	0.0
OTHER	2.8	2.8	0.0	0.0

Of the topics discussed in the interviews, views on academic culture and academic writing had the most surprising results. When asked about career aspirations after graduation, only seven participants expressed strong dislike for the idea of teaching in the future. However, fifteen students reacted negatively to academic life with several specifically critical to the academic culture in the U.S. compared with that of other countries. Angela, who completed her PhD at the time of being interviewed, said that "there's just so much drama and stress in academia right now." Although she enjoys writing and the idea of someday teaching, she went on to say that "I just don't want it badly. Not to be underpaid and overworked and all of that."

Identifying academia as "publish or perish" in nature, this student felt the pressures for constant incremental advancements takes some of the joy out of performing research. Eighteen students conveyed distaste for the writing required, noting that the amount of academic writing required in graduate school was substantially greater than undergraduate programs and many expressed that they lacked opportunities to build their writing skills prior to their graduate work. One of the greatest deterrents for participants in considering academic careers was the amount of grant writing and pressure associated with financially supporting a laboratory. Of the fifteen participants disenchanted with academic culture, eight attributed their unfavorable views largely to the necessity of writing for funding. Instead, participants reported their anticipation of pursuing a variety of careers: Table 1 shows the distribution from these 36 participants. All participants either selected pseudonyms themselves, or were assigned pseudonyms by the research team if they did not choose one.

B. Role of the Advisor, Mentors, and Support Networks in Persistence and Setting Career Trajectory

While describing the decision process in choosing their graduate programs, there were several determining factors amongst the participants. One of the most common determinants was the people they would be working with throughout the duration of their program, their advisor and colleagues of their lab. Exactly one-third of the participants reported choosing their programs because of their desire to work with a specific advisor. This demonstrates the importance many graduate students place on their advisor relationship in shaping a good graduate experience. Connection with peers in the same lab group was another common for choosing a certain lab in which to complete their PhD research. One-third of participants also recalled the importance of having someone that they viewed as an academic mentor in assisting them throughout their graduate careers. Other lines of support mentioned were spouses, family, and other graduate students within the university. Overall, strong personal relationships and support networks were viewed as crucial for these participants in succeeding in their programs. With a considerable amount of importance placed on these relationships, participants described them as playing critical roles in both creating and alleviating the hardships they experienced. Consequently, many participants described negative side effects when these relationships were strained or didn't provide the support that was expected.

A common trend amongst participants in the interview portion of this research recalled adjusting to communication and advisory styles upon entering their graduate programs. Many had high expectations of more consistent communication and guidance when performing research and writing proposals than they ultimately experienced with their advisor. One participant discussed almost departing with their master's degree with their first advisor in graduate school who failed to communicate effectively before ultimately finding a new advisor and deciding to stay with the program. Although their new advisor had very high expectations for publishing, the

third-year graduate student had found graduate work much more manageable while having "an advisor who speaks their mind."

Angela, who chose her graduate program to work with a certain advisor, recalled the stressful advisor-advisee relationship, especially late in her program, that led to seeking counselling services. In her experience, most communication issues arose in the fifth year of graduate school with the participant receiving a job offer that was compromised with the delay in graduating. While this participant did not consider leaving the program as she were in the final stages before graduating, she attributed much of her success to overcoming this stressful time in graduate school to seeking mentorship from others and negotiating a later start date with the company looking to hire them. These circumstances contributed greatly to Angela's view of the drama filled academia that was mentioned previously. With several participants being heavily influenced in choosing a graduate program based on who they will work for, these narratives illustrate the importance some of those entering graduate school place on their relationship with their advisor.

Other participants felt that the support they received from their advisor and peers within their lab attributed to their success in graduate school. One participant, Omar, who recalled one inspirational professor as the determinant in his current academic trajectory, recounted his rotation in the lab he would eventually join. He remembered being initially intimidated by how large of a lab it was but quickly decided in pursuing his PhD through that environment. He described his advisory as "...always tremendously open to meet and to answer questions via email." Having his advisor's office right next door to the lab led to many weekly interactions and constant communication. The structure of the lab also allowed for great support between the postdocs and graduate students of the lab as well. On top of 1-on-1 interactions with their PI, the entire lab would meet a couple times a month as formal staff and several subgroups of researchers formed to meet in addition. Omar declared that "...within our subgroups, we have heavy interaction and everyone's highly collaborative, which I absolutely love." This lab structure provided this student with several opportunities to gain insight from numerous sources weekly in the work that he was doing and provided her with an abundance of support. Although he is reportedly in the early stages of his program still, he has so far never considered leaving or changing labs.

Most participants stressed the importance of support networks to navigate their graduate programs. While some were able to gain this support from their advisors or colleagues from their lab, others found mentorship outside their immediate academic circle or sought comfort from family. It was common amongst those interviewed to express that the drastic change in their social life compared to their time in undergraduate school was a huge adjustment when beginning their graduate careers. This further demonstrates the value graduate students place on relationships, both within and outside academics, while working towards acquiring their PhD.

C. Mental Health

20 of the 36 participants discussed encountering mental health issues, which was interesting because mental health and seeking counseling was not part of the interview protocol. Students reflected on their own and others' mental health and potential for mental health disorders, ranging from imposter syndrome to severe anxiety. Six students explicitly noted they had sought counselling services either through the university or within the surrounding community. While many noted that they felt some level of stress was to be expected as part of a doctoral program, the students also reported misconceptions about the working environment as a potential graduate student.

Several participants had a particularly difficult time adjusting to the change in pace of graduate work compared to their undergraduate careers, moving from a predominantly lecture-based structure to one that has fewer classes and involves much isolated research work. Expectations of them and their ability to gauge success played major roles in participants inability to balance their efforts. Kelsey, a participant in her third year of graduate school, summarized common circumstances experienced by many graduate students in the early years of their programs. She stated that "...in my first semester I just had a lot of trouble striking the balance between three classes and trying to learn what research is and how to contribute to my project and all that. And I'm at the tail end of classes now but I still feel like I haven't necessarily always known how to set up goals and work towards a PhD." While the change in course load might be an anticipated adjustment that isn't alarming in itself, the inability to structure goals around research and academic writing was described by several students as a contributor to delayed research progress in their PhD programs.

Another student, Michael Scott (a self-selected pseudonym), who was strongly considering leaving her program at the time of being interviewed observed that "...the writing skills and disseminating our research in a scholarly manner, I think that is an area where a lot [of students] would struggle with their sense of confidence and their self-perception of their ability to do that well." Many participants reported excelling in their undergraduate studies, but several found that the change in academic structure left them questioning their effectiveness of their efforts and led several to encounter imposter syndrome, unsure if they really belong in or can succeed in doctoral engineering program.

Strained advisor relationships often led to much bigger issues in terms of mental well-being. Several participants recalled attempts they made to seek assistance in managing their mental health. One student looked for formal resources in their department and college, trying to connect with people as high up as assistant dean, and ultimately found they needed to venture elsewhere as the department was not equipped to provide any resources. Kelsey, who was mentioned earlier as having difficulties adjusting to graduate life in the beginning stages, recalled being turned away from the university's mental health center, despite reporting depression and anxiety: "I tried. I was turned away because they're severely understaffed...I've made several attempts to start seeing a therapist outside [University], and just haven't found a good fit here yet." The

time and dedication it took for several participants to find mental health support and care, some with little success, ultimately further limited these students' abilities to perform highly, both in terms of continuing to struggle with mental health and because of the time and emotion invested in seeking resources.

While some participants acknowledged that they did not experience difficulties in managing their mental health, they were able to easily reflect on what they observed in other graduate students they encountered. Michael Scott, despite a rocky advisor relationship, discussed her struggle with impostor syndrome and the role that her advisor played in encourage graduate students' involvement in other activities. Other students, she went on to reflect, were not so fortunate to have these outlets. "I don't think a lot of people...have the awareness but also not necessarily the support from their advisor. I think that was one thing that I did appreciate about my advisor is, I said 'Hey, I'm gonna to participate in this program.' And he's like, 'Great.' But when I look around, I see a lot of people who just will not do anything that has not been assigned to or are so busy doing research of the feeding and maintaining of their advisor that it's just not important."

V. Discussion and Conclusion

This paper highlights several conversations in engineering graduate education that have not be extensively discussed in engineering education literature. Most importantly, this paper shows that many engineering graduate students consider leaving their degree programs at some point during their tenure as a student, to various degrees of certainty. While other studies show that engineering graduate students most often accept jobs in industry instead of academia [15], [16], this study finds that the climate of academia—or at least what students perceive about the roles and responsibilities of faculty, are driving them from considering academic careers. In particular, the culture of the research economy to be focused on earning money to support a research team rather than actually doing the research is a primary motivator for students to become disenchanted with academic careers and to consider alternate paths where they can continue to work on engineering problems. The disenchantment with graduate school and academia perhaps can be compared to the reasons that students go to graduate school in the first place [24], [43] indicating a fundamental disconnect in what entering graduate students expect about graduate school and what their roles and responsibilities will be, their future goals, and with what experiences they actually are. Another interesting relationship is our finding that of the participants who have considered leaving their doctoral program, half were students who had switched disciplines between undergraduate and graduate programs, either between disciplines of engineering, or from related fields into engineering. Perhaps one explanation for this is that these students have already developed a more nuanced understanding of their identities and the ability to change disciplinary identities. Alternatively, this may indicate that students are seeking some belongingness in academia that they are not findings, which opens opportunities for future research.

Most students interviewed in this study noted the importance of mentorship and support networks to their success in graduate school, which often include advisor relationships as a gatekeeper to degree completion and the opportunity to participate in academic milestones such as publications. Lab structure, too, is important to the success of students: The students indicate feeling supported with a network of fellow graduate students to help them navigate the transition into graduate school and their experiences through graduate school. These findings echo those of Crede and Borrego [18], who discuss the experiences of graduate engineering students in research groups of various sizes, and how lab size and structure can influence graduate students' experiences through graduate school. This work also continues to validate our past work in exploring the connections between graduate students' reasons for considering departing from their graduate programs, particularly that advisor and support networks, and the quality of those connections, can play a significant role in students' decision to persist in their programs or depart either with a Master's degree or as a non-completer [41].

Most importantly, however, this work opens a conversation of mental health in engineering doctoral programs, a need that has been discussed in recent calls to action for research on graduate education in STEM, especially because graduate students have been identified as being the population most susceptible to mental illness. Some of the findings from our study are alarming, in particular, the accounts of students who reached out to their campus mental health offices and were turned away. Students who cannot find help on their campuses are discouraged from finding resources that may take them further away from their roles and responsibilities as graduate researchers if they need to be away from campus during times when they are expected in the lab.

We easily view our findings from the point of view of ideal worker theory. Students who reported struggling with the decision to depart often discussed the implicit obligations and responsibilities in graduate school, and how they misaligned with what they expected, ultimately leading them to decide that they did not want to align themselves with the ideal faculty member who, in the words of one participant, is "overworked and underpaid." Similarly, students see the pressure faculty are under to win grant money to support a laboratory as a tension with doing 'real' research, and do not want to become that kind of an engineer. While our findings on the importance of mentorship and social support are not necessarily in tension with an ideal worker in graduate school, graduate students at R1 institutions see isolation of faculty members who have to prove themselves through the tenure process, and perhaps do not see themselves thriving in that environment. Further, the emergent discussion on mental health is certainly not embedded in the definition of an ideal professor, who 'should' be able to work to the abandon of all other duties, including upkeeping mental and emotional well-being. Although the literature to the best of our knowledge has not

expanded mental health conversations through ideal worker theory, this seems an interesting area for future research.

Implications for this research for educators include the need for advisors and professors teaching graduate courses to be sensitive to the underlying issues that many graduate students are dealing with, even if the students have not discussed issues privately. If nearly half of the graduate students in our sample had considered leaving graduate school at some point, then so too may be many students in any given engineering PhD program. In addition, we as academics must be careful about messaging our work as engineering academics to be more balanced. While certainly there is stress associated with writing and winning grants to support our laboratories, there may also be opportunities to message the creative and entrepreneurial parts of being a faculty member at a research institution, rather than solely the stressful parts. Indeed, faculty members at research intensive institutions should also make known to their PhD students that there are many career paths that may be good fits for their graduate students, including teaching-focused institutions, that may appeal differently to PhD students with different temperaments and may support the diversification of academic faculty. However, students should also not feel pressured to pursue academic careers if instead they feel better suited to careers in industry. There may be tension between encouraging talented students to pursue a faculty career and respecting students' individual pathways, and of course this remains a challenge with advisorship and mentorship in any sector. This study also calls for a more explicit discussion of mental health in graduate education in research, practice, policy, and counseling communities, and calls for universities to ensure they have sufficient resources to help graduate students who are struggling with mental health issues.

In conclusion, this study sought to understand engineering graduate students' experiences through graduate school, finding that many students consider departing from their programs at different points as they become disenchanted with aspects of graduate school they did not expect. Further, the role of advisor and social support is of utmost importance in helping graduate engineering students acclimate and thrive in academic communities. Lastly, we emphasize the conversations on mental health in graduate education that emerged from this study, and encourage stakeholders (advisors, faculty, and administrators) to take these themes into consideration as graduate policy, both formal and informal, is established and revised.

ACKNOWLEDGMENT

The authors thank the participants of this study who offered their experiences during the study. We also thank the reviewers of this paper for their time and expertise.

REFERENCES

[1] Council of Graduate Schools, "Ph . D . Completion and Attrition: Analysis of Baseline Data," 2008.

[2] R. Sowell, J. Allum, and H. Okahana, "Doctoral initiative on minority attrition and completion," 2015.

[3] R. Sowell and B. Fields, "Ph.D. Completion and Attrition : Analysis of Baseline Data CGS Ph.D. Completion Project," 2008.

[4] D. Belcher, "The apprenticeship approach to advanced academic literacy: Graduate students and their mentors," *English Specif. Purp.*, vol. 13, no. 1, pp. 23–34, Jan. 1994.

[5] R. M. Cutri, J. M. Manning, and M. Chun, "Poverty PhDs: Funds of knowledge, poverty, and professional identity in academia Poverty PhDs: Funds of knowledge, poverty, and professional identity in academia," *Stud. Teach. Educ.*, vol. 7, no. 3, pp. 299–314, 2016.

[6] E. L. Kelly, S. K. Ammons, K. Chermack, and P. Moen, "Gendered Challenge, Gendered Response: Confronting the Ideal Worker Norm in a White-Collar Organization," *Gend. Soc.*, vol. 24, no. 3, pp. 281–303, 2010.

[7] E. Reid, "Embracing, Passing, Revealing, and the Ideal Worker Image: How People Navigate Expected and Experienced Professional Identities," *Organ. Sci.*, vol. 26, no. 4, pp. 997–1017, 2015.

[8] M. Nerad, "The PhD in the US : Criticisms, Facts, and Remedies," pp. 183–200, 2004.

[9] M. Nerad and C. J., "Improving doctoral education: Recommendations from the PhDs–Ten years later study," *Counc. Grad. Sch. Commun.*, vol. 33, no. 6, 2000.

[10] M. Nerad and T. Blumenfield, "Investigating the International Experiences in STEM Graduate Education and Beyond : Report from the February 2011 Workshop to Develop a Research Agenda," no. February, 2011.

[11] A. E. Austin, H. Campa, C. Pfund, D. L. Gillan-Daniel, R. Mathieu, and J. Stoddart, "Preparing STEM doctoral students for future faculty careers," *New Dir. …*, vol. 2009, no. 117, pp. 83–95, 2009.

[12] A. E. Austin, "Preparing the Next Generation of Faculty: Graduate School as Socialization to the Academic Career," *J. Higher Educ.*, vol. 73, no. 1, pp. 94–122, 2002.

[13] A. E. Austin, "Preparing the next generation of faculty: Graduate school as socialization to the academic career," *J. Higher Educ.*, vol. 73, no. 1, pp. 94–122, 2014.

[14] A. E. Austin, M. R. Connolly, and C. L. Colbeck, "Strategies for preparing integrated faculty: The center for the integration of research, teaching, and learning," *New Dir. Teach. Learn.*, vol. 113, pp. 69–82, 2008.

[15] M. Schillebeeckx, B. Maricque, and C. Lewis, "The missing piece to changing the university culture.," *Nat. Biotechnol.*, vol. 31, no. 10, pp. 938–41, Oct. 2013.

[16] J. Watson and J. Lyons, "Aligning Academic Preparation of Engineering Ph.D. Programs with the Needs of Industry," *Int. J. Eng. Educ.*, vol. 27, no. 6, pp. 1394–1411, 2011.

[17] M. Nerad, "The PhD in the US: Criticisms, Facts, and Remedies," *High. Educ. Policy*, vol. 17, no. 2, pp. 183–199, Jun. 2004.

[18] E. Crede and M. Borrego, "Learning in graduate engineering research groups of various sizes," *J. Eng. Educ.*, vol. 101, no. 3, pp. 565–589,

2012.

[19] C. G. P. Berdanier, A. Tally, B. Ahn, and M. F. Cox, “Aligning engineering education with disciplinary expectations: A strategic blueprint for doctoral competency assessment,” *Int. J. Eng. Educ.*, vol. 32, no. 4, pp. 1759–1773, 2016.

[20] R. L. Meier, M. R. Williams, and M. A. Humphreys, “Refocusing Our Efforts: Assessing Non-Technical Competency Gaps,” *J. Eng. Educ.*, vol. 89, no. 3, pp. 377–385, 2000.

[21] B. C. Gamse, L. L. Espinosa, and R. Roy, “Essential Competencies for Interdisciplinary Graduate Training in IGERT,” Washington D.C., 2013.

[22] S. K. Gardner, “Student and faculty attributions of attrition in high and low-completing doctoral programs in the United States,” *High. Educ.*, vol. 58, no. 1, pp. 97–112, Nov. 2009.

[23] J. Lott, S. Gardner, and D. A. Powers, “Doctoral student attrition in the STEM fields: An exploratory event history analysis,” vol. 11, no. 2, pp. 247–266, 2010.

[24] M. Borrego, D. B. Knight, K. Gibbs, and E. Crede, “Pursuing Graduate Study: Factors Underlying Undergraduate Engineering Students’ Decisions,” *J. Eng. Educ.*, vol. 107, no. 1, pp. 140–163, 2018.

[25] D. H. Mansson and S. a. Myers, “Using Mentoring Enactment Theory to Explore the Doctoral Student-Advisor Mentoring Relationship,” *Commun. Educ.*, vol. 61, no. 4, pp. 309–334, Oct. 2012.

[26] V. L. Hesli, E. C. Fink, and D. M. Duffy, “Mentoring in a positive graduate student experience: Survey results from the Midwest region, Part 1,” *PS Polit. Sci. Polit.*, vol. 36, no. 3, pp. 457–460, 2003.

[27] M. D. Sorcinelli and J. Yun, “From mentor to mentoring networks: Mentoring in the new academy,” *Change*, vol. 31, no. December, pp. 58–61, 2007.

[28] J. C. Weidman and E. L. Stein, “Socialization of doctoral students to academic norms,” *Res. High. Educ.*, vol. 44, no. 6, pp. 641–656, 2003.

[29] J. C. Williams, T. Alon, and S. Bornstein, “Beyond the ‘Chilly Climate’: Eliminating Bias Against Women and Fathers in Academe,” *NEA High. Educ. J.*, pp. 79–96, 2006.

[30] M. Kiley, “Identifying threshold concepts and proposing strategies to support doctoral candidates,” *Innov. Educ. Teach. Int.*, vol. 46, no. 3, pp. 293–304, 2009.

[31] M. Jazvac-Martek, “Oscillating role identities: the academic experiences of education doctoral students,” *Innov. Educ. Teach. Int.*, vol. 46, no. 3, pp. 253–264, Aug. 2009.

[32] I. L. Bleijenbergh, M. L. van Engen, and C. J. Vinkenburg, “Othering women: fluid images of the ideal academic,” *Equal. Divers. Incl. An Int. J.*, vol. 32, no. 1, pp. 22–35, 2012.

[33] Authors, blinded for review.

[34] Authors, blinded for review.

[35] E. V Patridge, R. S. Barthelemy, and S. R. Rankin, “Factors impacting the academic climate for LGBQ STEM faculty," vol. 20, no. 1, pp. 75–98, 2014.

[36] D. Bilimoria and A. J. Stewart, “‘Don’t Ask, Don’t Tell’: The Academic Climate for Lesbian, Gay, Bisexual, and Transgender Faculty in Science and Engineering,” vol. 21, no. 2, 2009.

[37] S. J. Ceci, W. M. Williams, and S. M. Barnett, “Women’s underrepresentation in science: sociocultural and biological considerations.,” *Psychol. Bull.*, vol. 135, no. 2, pp. 218–61, Mar. 2009.

[38] W. Williams and S. Ceci, “When scientists choose motherhood,” *Am. Sci.*, 2012.

[39] K. Charmaz, “Charmaz Grounded Theory in the 21st Century,” *The SAGE Handbook of Qualitative Research*. pp. 507–536, 2005.

[40] S. Timmermans and I. Tavory, “Theory Construction in Qualitative Research: From Grounded Theory to Abductive Analysis,” *Sociol. Theory*, vol. 30, no. 3, pp. 167–186, Sep. 2012.

[41] Authors, blinded for review.

[42] Authors, blinded for review.

[43] E. Crede and M. J. Borrego, “Undergraduate Engineering Student Perceptions of Graduate School and the Decision to Enroll,” in *118th ASEE Annual Conference and Exposition*, 2011, pp. 1–15.