Pathways Into and Out of the Professoriate: A Study of STEM Doctoral Students' Career Decision-Making at an Elite Research University

Citation

Permanent link

Terms of Use

Share Your Story

Pathways into and out of the Professoriate:

A Study of STEM Doctoral Students' Career Decision-Making at an Elite Research University

Lisa Utzinger Shen

Natasha Kumar Warikoo
James Soto Antony
Matthew L. Miller

A Thesis Presented to the Faculty
of the Graduate School of Education of Harvard University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Education

2019

Dedication

To Zachary, for teaching me patience.

To Timothy, for loving me unconditionally.

To Daniel, for being a good sleeper.

And to Dong, for making all things possible.

Acknowledgments

This dissertation has been a pleasure to research and a joy to write. Thank you to my committee of readers for giving me this opportunity and for guiding me on this journey: Professors Natasha Kumar Warikoo, James Soto Antony, and Matthew L. Miller. Thank you for your patience, your flexibility, and your enthusiasm for my work. Your collective insights and advice have stretched me intellectually and made this dissertation immeasurably better. I am especially indebted to my adviser and committee chair, Natasha Warikoo. Thank you for your many hours of labor and your constant good cheer. You pushed me when I need to be pushed, often in uncomfortable but ultimately rewarding directions. In the end, your belief in my abilities carried me over the finish line and I could not be more grateful.

Thank you to the faculty and staff of Harvard University who have guided my learning and training over the years. Much of what I know about higher education, I learned working as a teaching fellow for Judy McLaughlin. Judy has made me a better researcher and a more empathetic educator, teaching me the importance of people, perspective, and process. Julie Reuben, Mandy Savitz-Romer, and Hunter Gehlbach (of UC Santa Barbara) oversaw my qualifying paper. I will forever be grateful to them for helping me see myself as a scholar. Carla Lilvik, HGSE librarian extraordinaire, has been a constant companion throughout my doctoral studies. Thank you, Carla, for teaching me how to access the research literature and for your shared excitement in my dissertation topic. Jenny Bergeron of the Bok Center for Teaching and Learning has been a tremendous advocate. Without Jenny, this dissertation project would not have been possible.

My friends at HGSE have been incredible peer role models over the years. Thank you to Martha Ferede who encouraged me to apply to the doctoral program and then taught me the "hidden curriculum" of graduate school. Marc Johnson inspires me with his tireless work ethic and his commitment to diet, exercise, and perfect pizza dough. Adrienne Mundy-Shephard's razor-sharp wit keeps me laughing when the going gets tough. Leslie Duhaylongsod always tells it like it is and pushes me to reach outside of my professional comfort zone. Thank you to my writing partners: Amy Cheung and Elisabeth Hahn. Amy, the obstacles you faced and overcame in graduate school are nothing short of amazing. Your friendship, support, and intellectual camaraderie have sustained me over the years. Most importantly, you helped me convey my ideas clearly, especially when I was mired in a pit of anxiety and self-doubt. Elisabeth, your discipline and focus, your beautiful and cogent writing, and your steadfast resilience were beacons on which I tried to model my work. Navigating the ups and downs of doctoral student life has been far less lonely with you by my side.

Lastly, I am very grateful to the 40 doctoral students at "Calder University" who so openly and bravely shared their experiences with me. It is rare for a researcher to interview participants who are just as passionate about her research as she is. I found this to be the case with my study. The students I interviewed hoped that their voices would contribute to improvements in STEM doctoral education. This dissertation, I believe, is one small step towards that goal.

Table of Contents

Abstract

Trends in the academic labor-market indicate that faculty research positions in STEM are on the decline. In 2017, over half the graduating cohort of STEM doctoral students entered careers outside of the academy (NSF, 2017). Yet American doctoral programs continue to train scientists very narrowly. Using the apprenticeship model, faculty train students to follow them into the professoriate, despite the fact that many will not assume these positions. Meanwhile, wide gender gaps favoring men persist at all levels of the tenure-track ladder.

With few exceptions, the majority of research on the career pathways of STEM doctorate holders has focused on documenting the supply and demand mismatch quantitatively. There is less research explaining how students end up in their postgraduate careers, both within and outside of academia. In particular, we lack in-depth examinations of how STEM Ph.D. students navigate the career planning process during doctoral study and why, at the point of Ph.D. completion, the academic career pipeline is so "leaky" for women.

Through interviews with 40 STEM doctoral students at one elite research university, this study investigated the doctoral student socialization experiences associated with different career pathways. I find that the Ph.D. adviser is, for STEM graduate students, one of the most important factors affecting students' post-graduate career plans, and in particular, their adherence to the academic track.

In an elite university context, students who engaged in non-academic career searches often felt disapproval from their advisers, in spite of the aforementioned labor market trends. Those students who successfully identified non-academic positions by graduation engaged in strategic career exploration processes, including participation in internships and extra-curricular activities. Unfortunately, those who pursued more haphazard non-academic job searches typically wound up in fall-back postdoctoral fellowships, remaining in academia by default.

The findings from this study suggest that more attention should be paid to advising in STEM doctoral education, with a focus on improving the adviser selection process and subsequently, communication between adviser-advisee pairs. Additionally, this study points to the important role graduate internships and extracurricular activities play in enabling STEM doctoral students to make informed decisions about their post-graduate careers.

Chapter 1. Introduction

I. Two Professional Pathway Paradoxes

Doctoral education in science, technology, engineering, and math (STEM) plays a

critical role in training the nation's next generation of scientific researchers. Through

their work, society benefits from, among other things, advancements in health care,

machine learning technology, and strategies to reverse climate change. STEM doctorate

holders produce new knowledge and contribute to an innovation economy that is one of

America's defining characteristics. However, despite the diverse array of career paths

STEM Ph.D.s pursue, American universities still train their doctoral students very

narrowly. Using the traditional apprenticeship model, STEM doctoral students are

trained by their advisers to follow one distinct path: the path to the professoriate.

Through coursework, lab work, and interactions with faculty and peers, doctoral

students in the sciences are socialized to believe that academia holds the key to the most

professionally and personally fulfilling life. Unfortunately, the numbers of STEM

academic positions available are either stagnant or on the decline. According to the

National Science Foundation, the proportion of STEM doctorate holders working in

tenured faculty positions decreased from 53% to 47% between 1997 and 2013; while

those working in tenure-track positions remained relatively steady during this time

period, from 16% to 15% (NSF, 2014). Using slightly different data, the American

Association of University Presidents found a larger 13 percentage point decrease in

tenured and tenure-track STEM professorships over the past 15-20 years (AAUP, 2013).

Meanwhile, the number of STEM doctorate holders has been steadily on the rise. During

the 2016-2017 academic year, of the 54,664 research doctorates awarded by U.S.

institutions across all fields, 76% went to scientists and engineers[1], with these recipients more than doubling, growing from 18,298 in 1977 to 41,438 in 2017 (NSF, 2017).

With the number of STEM Ph.D.s on the rise and the academic labor market on the decline, over half of science and engineering doctoral recipients in 2017 left the academy, opting instead for positions in industry or business (NSF, 2017). These trends call into question the current practice of universities training doctoral students primarily for careers in academia. Meanwhile, women's share of science and engineering doctorates awarded increased from 36% in 1998 to 42% in 2009, and continues to hold steady at this percentage today (NSF, 2017). However, although women's qualifications for these positions has increased, they remain persistently underrepresented in STEM academic careers. For instance, despite earning 55% of Ph.D.s in the biological sciences, only 29-36% of tenure track positions go to women (Nelson and Brammer, 2007; Sheltzer and Smith, 2014) .

Within STEM doctoral education lies two big professional pathway paradoxes. One, why are STEM doctoral programs preparing students for careers as academic researchers, when the majority will ultimately end up working outside of academia? And two, why are more women than ever entering the pipeline to STEM faculty careers, but exiting it, despite the fact that women are sometimes given hiring preferences during the search committee process (Ceci & Williams, 2015)? This dissertation study attempts to address both paradoxes by investigating *how* doctoral students make decisions to pursue an academic or a non-academic path, and *why*. I believe these are important questions for policymakers and higher education leaders to grapple with as they seek to create a better

---

[1] Science and engineering, defined by the Survey of Earned Doctorates, includes life sciences, physical sciences, earth sciences, mathematics, computer sciences, psychology, social sciences, and engineering.

trained academic science workforce as well as a more diverse and inclusive professoriate. In the next section, I describe the background and context of American doctoral education today, including how doctoral programs continue to draw from the original German model. I will then make the case for more research on doctoral education, with the underlying aim to provide new information and tools to doctoral students, from which they can draw to make choices that will better prepare them for their future careers.

II. Background and Context: American Doctoral Education

American doctoral education has both changed and remained the same since its early beginnings at Yale over 150 years ago. While it is no longer the sole purpose of doctoral education, training the most talented students for careers as researchers and future faculty remains a primary goal. In this regard, doctoral education today still largely reflects the original German model (Gumport, 1993). Also drawn from the German model, research doctoral students continue to enter a community of peers and faculty devoted to the production of knowledge (Council of Graduate Schools, 2005). Doctoral students engage in coursework, but do the bulk of their training through one-on-one guidance and mentorship with faculty.

Upon graduation, approximately 50 percent of new Ph.D.s remain in academia, typically as postdoctoral fellows, teaching faculty, or research faculty (NSF, 2017; Walker et al., 2008). These are the people who will educate today's undergraduate and graduate students. They will also go on to become deans and university presidents, and other national and international leaders both inside and outside of the academy (Holley & Joseph, 2013). They will determine the country's science and engineering enterprise, its

economic and homeland security strategies, and its production of new knowledge across the range of academic disciplines (Gardner & Mendoza, 2010). Yet compared with other sectors of American K-12 and higher education, doctoral study has attracted relatively little attention from administrators, researchers, and policymakers (Golde & Dore, 2004).

The relative paucity of research on doctoral education is particularly striking when compared to the breadth and depth of study devoted to undergraduate teaching and learning (Astin, 1977; Pascarella & Terenzini, 1991). The few in-depth empirical studies of doctoral education have focused primarily on departmental culture (Golde, 2004), attrition rates (Lovitts, 2001), time-to-degree (Bowen & Rudenstine, 1992), and the future of doctoral education (Ehrenberg & Kuh, 2009; Walker, et al., 2008; Woodrow Wilson Foundation, 2005). Meanwhile, calls have been mounting for a new generation of faculty that is more demographically representative of today's increasingly diverse college student population (Antonio, 2000; Antonio, 2003; Chait & Trower, 2002; Hartocollis & Bidgood, 2015; Lindholm, 2004; O'Brien, 2016; Patel, 2016; Prinster, 2015; Wong & Green, 2016).

This is a moment of intense self-reflection for doctoral education. In the U.S., federal research grants have declined by nearly 20% from 2003 to 2016 in real dollars (Blank et al., 2017). Meanwhile the number of doctorates awarded across all fields in the U.S. shows an upward trend, with an average annual growth of 3.3% since 1957 (NSF, 2017). Specific to STEM, Sauermann & Roach (2016) found that many people enter doctoral education and postdoctoral fellowships without full consideration of the range of significant research opportunities inside and outside of the academy, including in industry, government, and science communications. Leaders in academia, professional

organizations, and foundations must work to provide better information on the processes

and mechanisms in doctoral education that are associated with certain career outcomes.

Without this information, universities are not compelled to increase their effort preparing

students for the full range of careers available to them, and students are unable to make

informed choices about their postdoctoral plans (Blank et al., 2017).

This study is based on the premise that in order to persuade universities to better

prepare STEM doctoral students for careers both within and outside of academia, we

need clearer insights into the experiences students go through that shape their career

trajectories and decision-making processes. In light of harsh labor-market realities, many

doctoral programs have been forced to re-think student training and career preparation, in

order to support both academic and nonacademic job searches (Antony, 2002; Ehrenberg

& Kuh, 2009). Yet this re-thinking has not produced a meaningful shift in how doctoral

program curricula and career services offices prepare students for careers outside of

academe. Confronted by a strong culture of doctoral study that still prizes academia as

the most attractive career pathway, attitudes and dispositions, especially among faculty,

are difficult to change (Sauermann & Roach, 2012). Additionally, the scarcity and

competitiveness of faculty jobs only serve to increase their desirability and high status in

the minds of students.

Given these and other complexities inherent to doctoral education, it is no wonder

the pathways into and outside of the professoriate are not well understood. What little

information we do know is based on research of doctoral students' experiences and career

outcomes obtained through quantitative analyses of large-scale national surveys

(Figueroa, 2004; Golde & Dore, 2004; Moore, 2007; Nerad & Cerny, 1999; Smith, et al.,

1996). Meanwhile, the processes and mechanisms by which doctoral students make career decisions to pursue academic and non-academic jobs, and particularly how these processes may differ by student background and personal characteristics, remain less clear. With this broader understanding of the role of doctoral education, the trends in STEM doctorate holders' careers, and the purpose of this study, I now turn to the process of how doctoral students are socialized into faculty career aspirations and the theories behind it.

III. Socialization Theory, its Criticisms, and Modifications

Research on doctoral education identifies socialization as the primary way that students develop an identity to and commitment with a particular profession. Through socialization, doctoral students go through a set of complex processes, all the while honing their professional identity as a scholar (Walker et al., 2008). Because a scholar's professional identity, in all its dimensions, will impact their choice of career pathways, I grounded this study's research design using the theoretical framework of socialization. I will now define socialization theory, explain some of its criticisms, and describe the modifications made in response to one such criticism.

Socialization Theory

Socialization is defined as "the process by which persons acquire the knowledge, skills, and dispositions that make them more or less effective members of their society" or profession (Brim, 1966, p. 3). During the socialization process of graduate education, new information is acquired through both direct and indirect communications that shift

the individual from a place of confidence and security, to feelings of uncertainty, and then back to a sense of stability again as the student progresses through a series of new and different professional situations (Cahn, 1986; Staton, 1990). Socialization has been described as "an upward-moving spiral" propelling the novice through a set of repeated processes toward the aim of becoming a professional in the field (Weidman et al., 2001, p. 5). As they begin to adopt a set of norms and standards of behavior and develop a sense of commitment and professional identity (Weidman et al., 2001), students are transformed from neophyte to expert, foreigner to native (Bullis and Bach, 1989). In order for this transformation to occur, they must achieve a basic mastery of their chosen academic subject. Simultaneously, they should also experience several types of meaningful interactions with their peers and faculty mentors (Ketefian, 1993), such as working collaboratively with faculty and other students through teaching and research assistantships (Lovitts, 2001).

In describing the socialization dynamics of graduate programs, Thornton and Nardi (1975) posit that socialization is a developmental process and that knowledge acquisition, investment, and involvement are linked to the development of role identity and commitment. As a graduate student progresses through a series of increasingly more difficult program requirements—coursework, qualifying exams, proposal, thesis, defense—her acquisition and ownership of the identity and commitment of a scholar, researcher, and future faculty member intensifies.

Criticisms of and Modification to Traditional Socialization Theory

Many scholars have turned to socialization theory as a conceptual framework for understanding the process by which graduate students develop their professional commitments and identities (see Antony, 2002; Austin, 2002; Kirk & Todd-Mancillas, 1996; Menges & Associates, 1999; Nyquist et al., 1999; Schuster, Wheeler, & Associates, 1990; Weidman, Twale, & Stein, 2001). However, critics of socialization theory have also emerged, pointing out the ways in which it is limited (Bancroft et al., 2016; Clarke & Antonio, 2012; Cole & Griffin, 2013; Daniel, 2007; Felder & Barker, 2013; Felder, Stevenson, & Gasman, 2014; Gopaul, 2011, 2016; Griffin et al., 2016; McGaskey, 2015; Mendoza, Villarreal, & Gunderson, 2014; Sallee, 2011; Winkle-Wagner & McCoy, 2016). For example, one limitation is that the theory does not take into account the variety of institutional conditions students are exposed to. Socialization has traditionally been viewed as a linear, unidimensional model (O'Toole, 1996). It ignores the possibility of a socialization process that is more unique, individualistic, and reflective of the diversity of personal and professional backgrounds graduate students enter their programs with (Feldman, 1974; Gilligan, 1978; Tierney, 1997). This is because socialization theory—conceived of at a time when women and students of color were rarities in the academy—was designed with a homogenous student population in mind (Weidman et al., 2001).

In response to this limitation, Stein and Weidman (1989, 1990) developed a graduate socialization framework that positions socialization as a multifaceted developmental process that can be analyzed at either the group or individual level. Rather than a linear, causal relationship developed by Bragg (1976), Stein and Weidman's (1989, 1990) framework assumes a bi-directional connection, whereby the

graduate school context, background characteristics, personal and professional communities, and socialization processes influence each other. For example, the student's background characteristics and prior experiences impact her graduate school socialization outcomes, while her graduate school experiences influence her personal and professional communities (Stein, 1992; Weidman et al., 2001).

A second major criticism offered by Antony (2002) is that traditional socialization theory requires students to adopt the profession's ethics, norms, and values to the point of defining or even replacing their own professional identity and self-image. Additionally, institutional racism, racial micro-aggressions, and stereotype threat can impede students of color from making the necessary adjustments to reach their academic potential (Antony & Taylor, 2004; Rowley, 2014). Antony (2002) argues that in traditional socialization theory, in order for a graduate student to be successfully socialized, he must first develop characteristics—such as a theory-driven research orientation versus a practice- or service-based orientation—that are *congruent* with his peers and the faculty in his department. Next, he must *assimilate* his values to be consistent with the standards of his chosen field, such as what counts as knowledge and the accepted processes by which knowledge is created (Golde & Dore, 2004; Rowley, 2014). Antony (2002) refers to this problem as a congruence and assimilation orientation, which rests on three problematic assumptions. First, it assumes that there is only one way to effectively socialize graduate students. Second, it assumes that all graduate students in a particular field or discipline should be socialized into one type of career. Third, it assumes that future success in the field is defined by both content mastery and internalization of a particular set of professional norms and standards.

In response to the limitations of the congruence and assimilation orientation of traditional socialization theory, Antony (2002) proposed a modified socialization framework for graduate students. This modification is differentiated from the traditional socialization framework by the student's development of an *awareness* of the field's content, values, and norms rather than a wholesale personal *internalization* of them. In Antony & Taylor's (2001) study of Black graduate student socialization, those students who successfully pursued an academic career had been socialized to learn how to navigate the normative expectations of the field without jettisoning their own values. Meanwhile, those who felt pressure to adopt the field's norms and values as their own experienced a great amount of cognitive and emotional distress, leading them to ultimately give up on an academic career path.

Antony's (2002) modified framework also advocates for the socialization of graduate students to take on multiple formats, methods, and experiences. For example, he recommends that graduate departments engage in more interdisciplinary socialization that can push students to develop understanding and skills beyond those offered by their faculty advisers and disciplinary departments. Finally, Antony (2002)'s framework puts a high premium on a socialization process that emphasizes intellectual individuality. He argues that the traditional socialization models put too much onus on intellectual conformity. This may have the unintended consequence of suppressing important scholarly advancements and contributions. Intellectual individuality, on the other hand, acknowledges the accepted values, norms, and content of the field. It then uses that knowledge as a starting point for creating new intellectual approaches to move the field forward.

Starting with the Weidman, Twale, & Stein Model of graduate student socialization theory and drawing from Antony's critique of the congruence and assimilation orientation of traditional socialization theory, I designed my study to investigate the decision-making processes and explanations students gave for following a particular career path. Given the trends moving away from academic jobs, these assumptions—that there is only one way to effectively socialize students and that all students should be socialized into one type of career—were particularly salient to my study. Next, I will describe the context for this study, explaining the role of disciplinary culture in graduate student socialization and my motivation for focusing specifically on STEM doctoral education.

IV. The Importance of Context in Graduate Student Socialization

Disciplinary Context

Logistically, the graduate disciplinary department controls most aspects of doctoral education, including the determination of financial support, curricular requirements, and the dissertation process (Berelson, 1960; Bowen & Rudenstine, 1992; Gumport, 1993a; Gumport, 1993b). Within the departments of various disciplines, cultural influences imbued by the current faculty determine how students are socialized for their future careers as researchers, scholars, and faculty members (Golde & Dore, 2004). According to Becher and Trowler (2001), there are significant qualitative differences among disciplines. Doctoral students in the sciences and engineering typically conduct their thesis research in collaborative teams (Mendoza, 2007), while their counterparts in the humanities and social sciences tend to do their research and

writing in isolation (Smallwood, 2004). Thus, in researching graduate student

socialization and doctoral students' career pathways, the significance of disciplinary

culture was an important distinguishing factor to consider (Baird, 1992). I will now

explain why it made sense to focus this study specifically on STEM doctoral students.

STEM Doctoral Education

An important cultural distinction among the disciplines is access to meaningful

interactions with faculty and peers. These interactions inherently influence the amount

and type of socialization doctoral students experience (Gopaul, 2011). For this reason, I

decided to focus this study on the experiences of STEM[2] doctoral students. Students in

the sciences are typically trained on research teams, working with other graduate

students, postdoctoral fellows, and faculty members (Golde & Dore, 2004). This makes

doctoral education in the sciences an especially social endeavor, and one well suited for

analysis using a graduate student socialization lens. Moreover, in their 2004 study, Golde

& Dore found that pedagogical training, such as professional development workshops on

teaching and an increasing amount of teaching responsibly over time, was weakest in

scientific fields, such as chemistry. STEM faculty are also among the least diverse in

terms of race and gender. In 2013, women constituted only 30% of science and

engineering tenured faculty in the U.S. (NSF, 2014). Additionally, U.S.-born,

underrepresented minority women make up only 3.6%, 2.5%, and 1.2% of all assistant,

---

[2] STEM is an acronym commonly used to denote the fields of science, technology, engineering, and mathematics. Throughout this study I use this acronym to refer to my participants, who were primarily in the life sciences and physical sciences. Engineering and mathematics students were not included in this study.

associate, and full professors, respectively, in the STEM disciplines (Mack, Rankins, & Woodson, 2013).

Women in STEM

Robust and varied attempts to address the underrepresentation of women and people of color in the STEM fields at all educational and academic professional levels have been met with minimal success (Mack et al., 2013). Women's underrepresentation in STEM fields can be explained by structural, systemic, and cultural barriers, including the dearth of same-sex mentors (Berg & Ferber, 1983). Additionally, in 1982, Hall and Sandler coined the term "chilly climate" to describe how disparities in academia favoring traditionally masculine norms and behaviors were figuratively freezing women out of faculty positions (Hagedorn & Laden, 2002) and doctoral programs (Crawford & MacLeod, 1990). This "chilly climate" issue is problematic across the academic disciplines (Fox, 1998; Washburn & Miller, 2006), but especially so among women pursuing STEM doctorates. Studies have found that women in STEM cite lower levels of self-confidence and satisfaction with their doctoral programs (Fereira, 2002; Ulku-Steiner, Kurtz-Costes, & Kinlaw, 2000), problems with gender discrimination (Litzler, Edwards, Lange, & Brainard, 2005), and a hyper competitive environment, more than their male counterparts (Ferreira, 2002; Litzler et al., 2005; Sallee, 2010). These barriers have led to women being discouraged from selecting STEM majors in college, less likely to complete STEM graduate degrees, and sometimes, but not always, less likely to be hired into tenure-track assistant professor positions (Ceci & Williams, 2010). For the few women who ultimately do pursue STEM faculty careers, they are more likely to exit the

field than men at every stage of their careers (Preston, 2004). This is equally true for women with and without children. This research suggests that gender is an especially important factor to consider when studying doctoral education and how socialization into academic and non-academic career pathways is experienced within STEM fields.

VI. Chapter Summary and Study Rationale

In this chapter, I have outlined two paradoxes in STEM doctoral education: the narrow training towards academic careers despite the shrinking academic labor-market and the persistent gender gap in STEM faculty, despite the closing gap between male and female STEM Ph.D. recipients. I described the American doctoral education landscape and its role in promoting leadership, technology, and innovation, asserting that STEM stakeholders must provide better information on the processes and mechanisms that may lead to certain career outcomes. It is not clear whether the proportion of STEM Ph.D. holders committing to non-academic jobs after degree completion represents students reacting to the shrinking academic labor-market or whether there are more fundamental changes in students' career goals and preferences. This study seeks to shed light on this question.

I reviewed the literature that examines the influence of socialization in doctoral education, and how doctoral students are socialized to embrace faculty career aspirations. I described how Antony's (2002) modified socialization framework, which outlines the problematic assumptions of a congruence and assimilation orientation, informed my study design. Having set the theoretical context for the study, I then moved to the disciplinary context. I explained my rationale to focus this study on the professional

socialization of STEM doctoral students. Since career outcomes for all Ph.D. recipients are largely embedded and constrained by disciplinary context and since the non-academic career options in STEM are among the most robust, focusing on doctoral students in the sciences was an ideal choice. Lastly, I described some of the research explaining women's underrepresentation in academic positions and how socialization is viewed by researchers as a gendered process dominated by gendered norms (Sallee, 2011).

With few exceptions, the majority of research on the career pathways of STEM doctorate holders has focused on documenting the supply and demand mismatch quantitatively. While quantitative analyses of survey data can inform us about the prevalence of certain experiences and perceptions within demographic groups, it does not provide much needed insight into how and why people make the career choices they do. Through this dissertation study, I seek to further understanding of the processes and mechanisms by which doctoral students make career decisions. I elucidate how and why these processes and mechanisms may differ between men and women. Using qualitative research methods, this study contributes to a more nuanced understanding of the career mindsets of STEM doctoral students at the point of degree completion. In addition, this research adds to the literature on doctoral student experiences and pathways to faculty positions in higher education. More importantly, it covers new terrain by helping to explain how students navigate pathways into non-academic positions. Although survey data has been documenting STEM doctoral students' move away from academic careers, the reasons for these trends are not well understood. As leaders in higher education policy and practice aim to reduce the obstacles faced by doctoral students on the

pathways into and out of academia, this research provides much needed empirical

evidence by which more effective programmatic and policy efforts can be built.

VII. Overview of Dissertation

This dissertation is divided into six chapters. In the following chapter, I describe

the research design of the study and the methodology used to collect and analyze my

data. Chapters 3 through 5 offer the findings that emerged from my research. In Chapter

6, I conclude by providing an overview of my findings, discussing the implications for

my work, and highlighting opportunities for future research.

Chapter 2. Research Design and Methods

Drawing on the modified frameworks for graduate student socialization proposed by Weidman, Twale, & Stein (2001) and Antony (2002), this study utilized qualitative research methods to explore the academic and non-academic career pathways of STEM doctoral students at an elite research university. This in-depth study of a single institution, "Calder University,"[3] focused on how doctoral students conceptualized the decision to pursue traditional academic employment or non-academic employment and how their experiences may differ across gender. It also investigated the processes and mechanisms that enhanced or limited doctoral students' academic and non-academic career decision-making. By asking doctoral students to reflect on their career planning experiences in graduate school, this study aimed to create a more nuanced understanding of how doctoral students navigated the pathways towards or away from the professoriate, given the obstacles of graduate study and the realities of a competitive and unpredictable academic job market. The following questions guided my study:

- How do STEM doctoral students at Calder University explain their decision-making process in choosing to follow academic and non-academic career pathways?

  o Do these explanations differ across gender? If so, how?

- According to STEM doctoral students, what are the processes and mechanisms that enhance or limit their career aspirations?

  o Do these processes and mechanisms differ across gender? If so, how?

---

[3] "Calder University" is a pseudonym.

I. Research Context and Participants

STEM Doctoral Education

This study focuses exclusively on doctoral education in the life sciences and physical sciences at an elite research university. I chose to focus my research on the life sciences and physical sciences for several reasons. First, while career pathways in STEM disciplines have been examined at length, very little research exists pertaining to the STEM doctoral experience, despite disturbingly high attrition rates that are strongly related to student demographics, such as race, gender, and academic discipline (Bowen & Rudenstine, 1992; Lovitts, 2001).

Second, the life sciences and physical sciences, unlike the social sciences and especially the humanities, have a robust number of lucrative, non-academic career options, in fields ranging from data science to consulting to biotechnology. Although STEM doctoral students' movement away from careers in academia has been well established quantitatively, it is still not well understood (Roach & Sauermann, 2017; Sauermann & Roach; 2012). My hope is that this research will shed some much-needed light on the mechanisms and processes underlying these trends.

Third, doctoral advising in STEM is typically characterized by more interactive and social adviser-advisee relationships. STEM doctoral students often work 40+ hours a week in a lab setting with their advisers, enabling more frequent, often daily, interactions. With regard to social interactions with faculty, Nettles & Millett (2006) found these to be among the highest in engineering, sciences, and mathematics disciplines and the lowest among the humanities and social sciences.

Lastly, while participation by women and underrepresented racial minorities has improved in academia, women and minorities are still vastly underrepresented in STEM academic careers. For example, although women earn more than 50% of doctorates in the biological sciences, only 33% of newly hired tenure or tenure-track positions go to women (Jolliff et al., 2012; NSF, 2017). Even worse, while 12.9% of engineering and science Ph.D.s are awarded to students from underrepresented racial backgrounds, only 7.7% of tenure and tenure-track research faculty are underrepresented racial minorities (NSF, 2017). Thus, it seems especially worthwhile to investigate doctoral education in the sciences, where women and minorities are actively leaking out of the academic pipeline at every level (Mack, Rankins, & Woodson, 2013). Furthermore, within STEM, I specifically hone in on the life and physical sciences as two examples of STEM doctoral education with especially high (life sciences) and especially low (physical sciences) levels of female participation.

Calder University

The decision to situate this study at an elite research university was also intentional. The prestige of a candidate's doctoral degree-granting institution matters greatly in both the academic and non-academic job market. With regard to academic jobs, Ph.D. holders from elite research universities are much more likely to successfully acquire faculty positions and competitive postdoctoral appointments than their peers from non-elite research universities (Warner & Clauset, 2015). In a 2015 study by Clauset, Arbesman, and Larremore, the backgrounds of nearly 19,000 faculty members were analyzed in the fields of business, computer science, and history at 242 schools. They

found that 25 percent of all universities produce 71 percent to 86 percent of all tenure-track faculty in these three fields in the U.S. and Canada. For example, 50 percent of all history professors hold doctorates from one of only eight universities. Furthermore, the top 10 universities in the *U.S. News and World Report* annual rankings produced three times as many future professors as those ranked 11-20. Because elite universities wield so much power in the academic labor market, I decided it was important to develop an in-depth understanding of doctoral students' career pathways at these universities. Additionally, I chose an institution which is particularly known for its strengths in the life and physical sciences.

For these reasons, Calder University—a large, private institution with an R1[4] status, indicating the highest levels of research productivity—was an ideal site for my study. As a well-resourced research university, Calder University is able to provide generous funding to all of its Ph.D. students, including full financial support for at least five years. Thus, in comparison to other doctoral degree-granting institutions, Calder University Ph.D. students enjoy generous opportunities to focus on their own career development and professional training, largely unencumbered by financial stresses. In addition, many of the STEM faculty at Calder University are considered the finest in their fields, with national and worldwide reputations that can open doors for doctoral student trainees. Calder University is also located in an area of the country with robust non-academic career opportunities for STEM Ph.D. holders. This makes summer and academic year internships as well as full-time career opportunities in non-academic fields very accessible. The university also houses other well-established graduate and

---

[4] R1 universities are those designated by the Carnegie Classification as yielding "very high research activity." http://carnegieclassifications.iu.edu

professional schools, which offer career-focused extracurricular activities, such as a biotechnology club, a consulting club, and a data science club. In short, with its academic prestige, world-class faculty and research centers, successful track record for placing graduates into both academic and non-academic positions, and generous financial support of doctoral students, Calder University is equipped to propel all of its STEM doctoral students into successful academic and non-academic careers. This presented as an ideal institution to study STEM doctoral students' career pathways.

Recruiting Participants

For this study, I interviewed 40 doctoral students in the life and physical sciences at Calder University. Participants were interviewed during either their last or penultimate year of graduate school, or within their first year out of graduate school. For clarity purposes, I refer to all participants in this study as "students" even though some were, in fact, alumni when we spoke. I recruited students by sending a recruitment email to all the program coordinators and administrators in the life and physical sciences at Calder, which I asked to be forwarded on directly to students (see Appendix A). The email invited students to participate in one 90-minute interview, scheduled at a time and location of their choosing. Due to geographical constraints, seven students participated in the study via online video conferencing. The rest were conducted in person. Interviews lasted between 60 and 150 minutes, with most averaging 90 minutes. As an incentive for participation, I offered each student a $25 Amazon.com gift card. I also employed a snowball sampling strategy (Marshall, 1996) by asking each participant to forward a recruitment email from me to their friends and colleagues who met the study criteria.

Several participants were identified through this word-of-mouth recruitment. I took this as a sign that at least some of the participants found the interviews to be pleasant, worthwhile experiences and that I was a trustworthy and competent interviewer.

Participation was limited to U.S. citizen or permanent resident students, since international doctoral students are more likely to live and work abroad after graduation (Finn, 2010) and may experience the doctoral socialization and career planning processes quite differently from American students. However, one international student was interviewed inadvertently, as I did not realize this student's citizenship status until we were conducting the interview. This student originally came to the U.S. to pursue an undergraduate degree and stayed here for graduate school. Ultimately, I decided to include this student in the sample, given the content of the interview, most of which presented themes consistent with the experiences of the U.S. citizen participants.

Participant Overview

A summary of demographic characteristics for my interview sample is presented in Table 1. While gender distribution was more balanced amongst the physical sciences students (47% females to 53% males), the majority of life sciences students interviewed were female (81%). The majority of students in both groups were white, but this was particularly the case in the physical sciences (74%) compared with the life sciences (57%). Also notable was the complete lack of underrepresented minority students in the physical sciences compared with the life sciences, where 23% of the students identified as Black, Hispanic, or mixed race. This is despite targeted outreach efforts, including emails to the minority graduate students' association. There were 3 students who

identified as Lesbian, Gay, or Bisexual in the physical sciences compared with only 1

LGB student in the life sciences. Both life sciences and physical sciences groups had the

same number of single students in it (8) compared with those who were married or

partnered: 13 and 11 in the life and physical sciences, respectively.

Using parents' level of education as a proxy for socio-economic background, the

participants in both groups appear to both be from mostly middle and upper-middle class

families. Although life sciences students (91%) had more mothers with a bachelor's

degree or higher than the physical sciences students (74%), the two groups were very

similar in terms of fathers with a bachelor's degree or higher: 86% in the life sciences and

89% in the physical sciences. However, 26% of the students in the physical sciences had

a father with a doctoral degree, which is notable since only 2% of the U.S. population

holds a doctorate degree and only 31% holds a bachelor's degree or higher according to

the 2017 U.S. Census.[5]

---

[5] https://www.census.gov/data/tables/2017/demo/education-attainment/cps-detailed-tables.html

Table 1. Participant Characteristics

		Life Sciences n=21		Physical Sciences n=19	
Participants' average age (range 26-38)		28		27	
Gender	Female	17	81%	9	47%
	Male	4	19%	10	53%
Race	White	12	57%	14	74%
	Asian	4	19%	5	26%
	Black/African American	2	9%	0	0%
	Hispanic	2	9%	0	0%
	Black and White	1	5%	0	0%
Sexuality	Heterosexual	20	95%	16	84%
	Lesbian/Gay/Bisexual	1	5%	3	16%
Marital Status	Single	8	38%	8	42%
	Married	6	29%	3	16%
	Long-term partnership	7	33%	8	42%
Mother's Education Level	H.S. diploma	2	9%	2	11%
	Associate's degree	0	0%	3	16%
	Bachelor's degree	10	48%	3	16%
	Master's or Prof. degree	8	38%	8	42%
	Doctoral degree	1	5%	3	16%
Father's Education Level	H.S. diploma	2	9%	2	11%
	Associate's degree	1	5%	0	0%
	Bachelor's degree	5	24%	10	53%
	Master's or Prof. degree	11	52%	2	10%
	Doctoral degree	1	5%	5	26%
	Unknown	1	5%	0	0%
Parents' Birth Country	United States	13	62%	11	58%
	Outside the U.S.	8	38%	8	42%

II. Data Collection

Interviews

Because my objective was to understand how doctoral students conceptualize the decision to pursue academic and non-academic career pathways and the processes and mechanisms by which they are professionally socialized towards these ends, I decided to use semi-structured, open-ended interviews as my primary means of data collection

(Seidman, 2006). Qualitative in-depth interviewing allowed me to identify cultural assumptions, norms, or behaviors by soliciting illustrative stories of faculty-student interactions and student-student interactions (Rubin & Rubin, 2005). Qualitative interviews also teased out the processes leading up to the outcome of interest, which in this case was selecting post-graduate employment (Weiss, 1994). All interviews included questions on individual, departmental, and institutional experiences in order to delineate differences in the various factors affecting career planning. A semi-structured interview protocol is included in Appendix B. Its questions were grounded in the Weidman, Twale, and Stein (2001) graduate socialization framework, organized by the core elements of socialization (knowledge acquisition, investment, and involvement) over which the academic program and university have primary control.

Prior to data collection, I piloted the protocol on one recent Ph.D. graduate from another elite research university as well as four Ph.D. graduates from Calder University and edited the questions for clarity and length. After each interview, I wrote my initial observations and reactions in field notes and then wrote interview profiles of each participant. I also wrote memos to keep track of themes and ideas that emerged from the data throughout both data collection and analysis.

Demographic Questionnaire

At the end of each interview, participants completed a short demographic questionnaire (Appendix C). The questionnaire asked participants for information about their gender, racial, and sexual orientation identification. It also captured information about their socio-economic background and immigration status via parental level of

education and country of origin. Participants were also invited to choose their own

pseudonym, with few students taking the opportunity to do so.

III. Data Analysis

Each participant provided informed consent to participate in the study in written

and/or verbal form. I digitally recorded the interviews and then transcribed verbatim the

interview content. I then coded the data and compared the concepts and themes that

emerged across interviews (Rubin & Rubin, 2005). I started analyzing interviews right

away in order to test out my interview protocol and adjusted the protocol as necessary to

ensure that the information elicited would enable me to answer my research questions.

Within 24-hours after each interview, I wrote-up my impressions, observations, and

reactions in a reflective memo (Cresswell, 2009; Maxwell, 2005; Yin, 2014). I also

wrote a profile of each interview participant, where I described my experience

interviewing him or her, summarized the data shared, and noted any emergent themes and

patterns within and across interviews.

Coding

I first read through the interview transcripts while listening to the audio recording,

pausing to take notes on emerging ideas, patterns in the data, and preliminary codes. To

analyze the memos, interview profiles, and interview transcripts, I used the qualitative

data research software NVivo 12 to carefully code all the documents. Working slowly

and methodically through the data, I developed a list of both emic and etic codes. During

the initial stage, I started by using a preliminary list of etic codes, those drawn from my

review of the literature (see Appendix D). The code list evolved as I collected and started to analyze themes that emerged from the data. I also compared these categories both within individual interviews and across interviews. This initial coding served as the foundational framework from which I built my analysis (Charmaz, 2014). Next, I moved on to the focused stage of coding. Here, I analyzed my data using only the codes that best answered and addressed my research questions, as well as the codes that were the most common. Throughout this process I continued to write analytic memos to document patterns, ideas, and anomalous occurrences in the data. Using the focused codes, I was better able to compare participants' experiences, behaviors, and explanations across interviews. Throughout this process, I met with my writing group to discuss my interpretations of the data and obtain their feedback. I also presented some of my initial findings at an American Educational Research Association national conference (Shen, 2018) and received helpful comments and questions that improved my analysis of the data.

IV. Validity

In order to increase the reliability of my study and minimize any possible threats to its validity, I employed three strategies. First, I triangulated the data by confirming evidence from interviews with doctoral students with evidence documented by the literature (Cresswell, 2013; Miles & Huberman, 1994). Using emic and etic coding techniques, I was able to identify patterns that emerged directly from the data (emic) and check the connections to theories offered up by the literature (etic). Second, I conducted "member checks" by soliciting the participants' feedback (Miles & Huberman, 1994). I

invited students to read and react to their interview profiles and asked them to provide me with any inaccuracies or missing elements from the profiles. About a third of students responded with feedback on their profiles, which I adjusted as necessary. Third, I engaged in "external audits" by sharing my memos and drafts of my analysis with a peer writing group (Cresswell, 2013; Miles & Huberman, 1994). I asked these external auditors to examine my written analysis and assess whether my findings, interpretations, and conclusions were supported by the data.

V. Limitations

This study has two main limitations. First, the study relied on interview participant volunteers. It is possible that those who volunteered for participation may be different than those who opted out; perhaps, for instance, students who volunteered have faced more challenges in their doctoral studies and career planning than those who did not volunteer. To mitigate this risk of self-selection bias, I actively monitored the backgrounds, characteristics, and dispositions of the participants. While there was a dearth of underrepresented minority students in this study, especially within the physical sciences group, and while the life sciences group skewed towards women, I found the dispositions, personalities, and experiences of the participants quite varied. Some of the participants had mostly positive experiences and straightforward career searches while others reported stories of struggle. Stories of hardship often resulted in emotional distress and sometimes even tears during the interviews. On the whole, participants usually discussed a mix of positive, negative, and neutral experiences. It should be noted that all of the participants were either recent graduates or soon-to-be graduates; students who

withdrew from graduate school were not included in the sample. These students may have had exceptionally negative experiences, leading to their attrition. These critically important perspectives were not captured in the data.

A second limitation of this study is its focus on one elite research university. While the findings of this study are not generalizable to all STEM Ph.D. students, the doctoral student training and career advising experienced at Calder is similar to that experienced by students at its peer institutions. Since Calder University does educate many STEM Ph.D.s and postdocs who go onto assume faculty careers at other R1 universities, it is plausible that they take some of Calder's doctoral socialization practices with them to their new institutions. Therefore, I believe my study may reveal important insights that could be helpful to understanding STEM doctoral education at elite research universities throughout the U.S. It is my hope that this research will help inform the study of doctoral education at other elite institutions, thereby assisting other STEM doctoral students in their career decision-making. I also hope that it will generate new hypotheses and theoretical contributions that future researchers could investigate with larger samples using either quantitative or qualitative research methods.

VI. Issues of Anonymity

As one might expect in a study about Ph.D. students, the participants in this study were highly intelligent, self-reflective, and thoughtful individuals. Taking two hours out of their busy schedules to speak with me, they volunteered for this study with a sincere desire to be helpful. Many were pleasantly surprised when I handed them a $25 gift card at the beginning of the interview; their primary motivation for participation in the study

was clearly non-monetary. Several mentioned how important they believed this research was; they wanted me to use their stories to help improve the doctoral experience for those students who would follow. Towards that end, students spoke candidly about deeply personal experiences. I admired their honesty, vulnerability, and willingness to give back to their doctoral student communities in this way.

In order to protect their identities, provide for anonymity, and ensure that the data collected was of the highest quality, I use pseudonyms for the name of the university as well as every individual mentioned in this study. I also altered, in direct quotes, any references to the university that would enable its identification. For example, I substituted generic names for university titles, offices, and events, rather than using the exact names or acronyms referenced by students. I changed or omitted the names of subfields, specialized research techniques, internship companies, or geographic locations where students conducted research. I refrained from identifying students by their department or academic discipline. For further protection of identities, I do not mention students' or advisers' racial or ethnic backgrounds. I only mention their gender and the gender of their adviser. I also assigned Anglo-American pseudonyms for all students, including many students whose first names signaled a particular racial or ethnic identity. Names like Alejandro or Chong would be given pseudonyms like "James" or "Benjamin."

I tried to strike the right balance between precision and accuracy on the one hand, and risk of identification on the other. Through this process, some salient and compelling details were inevitably lost. This was a limitation of the research but one that I found necessary in order to protect the identities of the students I interviewed as well as the

identities of their faculty advisers, none of whom had agreed to participate in this study.

Since students' relationships with their advisers can have a long-lasting and positive (or

negative) impact on one's career, I took issues of confidentiality and anonymity very

seriously. In doing so, I lost the opportunity to describe issues in the data that were

unique to certain marginalized sub-groups, such as underrepresented minorities and

LGBT students, or unique to certain disciplines. Hopefully I, or another researcher, can

pursue these lines of inquiry in future studies with larger samples.

VII. Insider/Outsider Status & Positionality

In many ways, I held an "insider" position with the doctoral students at the center

of this research. As a doctoral student in education at an elite university, I could relate to

the students' experiences engaging in coursework and research; teaching others and being

taught; presenting at national conferences; navigating relationships with faculty and

peers. Like 65% of the participants, I am a woman. Like 23% of the participants, I am

Asian, which is not considered an underrepresented racial minority group in STEM. My

solidly middle-class upbringing mirrored most, but not all of the participants, some of

whom had been raised by parents with Ph.D.s and professional degrees. I found these

similarities helped to foster a safe environment where students felt comfortable revealing

vulnerable truths. With most, I was able to develop an instant rapport that engendered

the trust needed to ask extremely personal questions and obtain reliable answers.

While my "insider" status provided me with credibility and trustworthiness, I also

felt like and came across as an "outsider." As someone who studied the humanities and

social sciences in college and graduate school, STEM doctoral education presented me

with many unfamiliar terms and acronyms—industry-specific, department-specific, and university-specific. During the first few interviews, I had to ask participants to spell out unfamiliar terms and processes to me. Terms like "translational research" and "prize fellowship" and "assay" were defined patiently, while I felt embarrassed and self-conscious of my ignorance. I quickly became fluent in this esoteric language. I also got better at deciphering which terms were important for me to know as a researcher, and which ones could pass by unexplained.

Conscious of how part of my background might impact the data collected, I did my best to conceal some aspects of my identity, such as my age and life stage. At age 38, I am 10 years older than the mean age of the students in my study. I am married, a homeowner, and a mother of young children. In this regard, my personal life stage is very different from those of the mostly Millennial generation participants I interviewed. In order to appear more youthful and hopefully, relatable, I eradicated the gray from my typically salt-and-pepper hair; I wore make-up to cover the sun spots on my face; I dressed in a casual manner; I removed my wedding rings. If students began talking about work-life balance or prioritizing their partner's career or planning to start a family, I nodded along empathetically, as my 28-year-old self would have. I withheld my personal opinions and experiences with these topics. In rare occasions when I would offer reflections from my own life, I would wait until after the interview was over and the tape recorder was off.

It is possible that despite my best efforts, my age, race, gender, sexual orientation, and social class affected how I asked questions and the answers provided. As the sociologist Mary Waters (1999) put it, "there are strengths as well as weaknesses in the

characteristics people notice about you, which open doors even as they close some" (p.

371). I did my best to maximize the doors opened while minimizing the impact of those

that were closed, maintaining a mindfulness of how my "insider/outsider" perspectives

could unintentionally bias this study. I wrote reflective memos after each interview and

while coding and analyzing the data. I discussed my personal biases and objectivity with

my writing group. During the writing phase, I worked hard to present findings that

summarized the accounts and narratives of the participants with great attention to

authenticity and objectivity. In short, I thought continuously about how my positionality

might impact the data and did my best to reduce the risk of bias at every turn.

Chapter 3. Constructing Post-Graduate Plans: Doctoral Students' Career Mindsets

I. Introduction and Background Literature

Most students start STEM doctoral education with the aim of becoming a professor. Through coursework, lab work, and interactions with faculty and peers, they are socialized to believe that academic careers are within their reach. Yet labor market trends suggest otherwise. The numbers of Ph.D. scientists have not adjusted to the commensurate reduction in permanent research positions in academic science and the private sector (Alberts, et al., 2014; NIH, 2012; Daniels, 2015). For instance, during the early 1970s, over 50% of Ph.D. graduates in the life sciences obtained tenure or tenure-track positions within five years of graduation; now that percentage is closer to 10% (Blank et al., 2017; National Science Board, 2014; Stephan, 2012). Meanwhile, federal research funding has declined by nearly 20% in constant dollars from 2003 to 2016 and research project grants have become increasingly competitive; the average principal investigator (PI) age at which the first R01 grant from the National Institutes of Health (NIH) for major independent research has been steadily rising (Blank, et al., 2017).

But despite the competitive and uncertain academic job market, STEM doctoral students are still narrowly trained to follow their faculty advisers into academic careers. Traditionally, through the social and intellectual integration into their scientific field during graduate school, doctoral students are trained to develop aspirations, values, and beliefs that often perpetuate the research orientations of their graduate adviser (Lovitts, 2001). However, through exposure to more diverse career paths, doctoral students can and do develop more preferences for non-academic employment post-graduation (Gemme, 2005). Unfortunately, although they are growing, industry positions are not

abundant enough to capture all the STEM Ph.D. holders who do not land tenure-track positions (Cyranowski, 2011). Instead, these folks go into industries such as K-12 teaching or science communications, which do not require 5-7 years of intensive doctoral education. This is a waste of federal training grant money, institutional resources, and most importantly, Ph.D. holders' time.

Given the sobering trends of the academic job market, the reduction in federal grant funding available, and the faculty orientation towards academic careers, the pathways into academic and non-academic positions in STEM are not well understood. Further, the existing research we do have on doctoral students' experiences and career outcomes rely primarily on quantitative analyses of large-scale national surveys (Figueroa, 2004; Golde & Dore, 2004; Moore, 2007; Nerad & Cerny, 1999; Smith, et al., 1996). For example, Gibbs, McGready, Bennett, & Griffin (2014), analyzed the results of a survey of 1,500 American biomedical sciences graduate students that examined student career preferences over the course of their graduate training experiences. They found that on average, scientists from all social backgrounds showed significantly decreased interest in faculty careers at research universities, and significantly increased interest in non-research careers at the completion of their Ph.D., relative to their attitudes at program entry. Of note, they identified women and underrepresented minority men as less likely to report high interest in faculty careers at research-intensive universities relative to well-represented (i.e. white and Asian) men, with underrepresented minority women showing lower interest than any other group. Underrepresented minority women also showed the highest interest in non-academic careers at Ph.D. completion.

As tenure and tenure-track positions are reduced, there has been a commensurate rise in postdoctoral fellowships. The American Institute of Physics surveyed postdoctoral fellows who earned physics doctorates in 2009 and 2010; 13 percent reported they were in the postdoc not because they wanted the training but because they could not find any other position. This percentage was up 2 points from two years prior (Jaschik, 2013). Additionally, while postdocs are necessary in some fields for entry into tenure-track positions, they do not enhance salaries in other job sectors over time. Kahn & Ginther (2017) found that scientists were paid much less during postdoc training than they would have been had they entered the workforce directly after receiving their doctorate. Of the people who started in postdocs, the median annual starting salary during their first four years after the Ph.D. was $44,724 in 2013 dollars compared with $73,662 for their peers who entered the workforce directly. This research points to a substantial financial penalty for those who start careers in a postdoc only to eventually leave academia. These financial implications underscore the need for doctoral education stakeholders to better understand how students are socialized towards academic or non-academic careers and the processes and mechanisms that support their career planning.

While quantitative analyses of survey data can inform us about the prevalence of certain experiences and perceptions within demographic groups, it does not provide much needed insight into how and why people make the career choices they do. In this chapter, I will examine the career decisions of STEM doctoral students at an elite research university. This study builds on previous work (Gibbs, McGready, Bennett, & Griffin, 2014) examining the mechanisms underlying the career interest formation of recent or soon-to-be Ph.D. recipients in the sciences.

II. Findings

In this chapter, I describe the different career-orientations towards academic and non-academic jobs for STEM doctoral students at one elite research university. I compare the career-orientations at the start of graduate school with those at the end of it. I discuss the processes and mechanisms that produce different career outcomes, in particular, advisers' attitudes towards and support for academic and non-academic careers. I also consider the mechanisms that support students' career planning and preparation towards an academic career, including adviser relationships, peer group community, passion for teaching, and interest in helping other women in science. This is followed by a discussion of the mechanisms that inhibit students' academic career plans, including struggle with one's research project, competition and uncertainty, and disillusionment. Next, I turn to the career planning and preparation processes students interested in non-academic careers engage in. I find that the most successful students participate in a proactive search process. Typically, this involves taking advantage of university resources, networking with alumni, and participating in internships. I argue that students who engage in more haphazard and less strategic job search processes are less likely to identify a desirable non-academic job by graduation and more likely to end up in a fall-back postdoc position, remaining in academia by default. The final section of this chapter introduces a typology I developed based on my research. It identifies Four STEM post-graduate Career Mindsets. These include *Academia or Bust*, *Ambivalent about Academia*, *Best of Both Worlds*, and *Opting-Out of Academia*. I close the chapter by discussing how these pathways differ by gender and scientific discipline.

Post-Graduate Career Orientations at the Start and End of Ph.D. Program

Career-orientations at the Start of Graduate School

Before analyzing the processes and mechanisms that result in different career outcomes for STEM doctoral students, we must first understand students' career dispositions when they began graduate school. At the start of their Ph.D. programs, the students in my study generally fell into one of three types of career orientations: *academia-focused*, *non-academia focused*, and *undecided*. Those whom I describe as *academia-focused* entered their doctoral program with the overarching goal of becoming principal investigators (PIs) leading their own labs, either at a university or a research institute. For these students, faculty careers seemed the most direct manifestation of this goal, primarily because that was their professional model when they were conducting undergraduate research in college. Most students (58%) fell into this *academia-focused* category at the start of graduate school. The *non-academia focused* (10%) were interested in using their Ph.D. to pursue a myriad of other scientific careers, such as those found in industry, consulting, or public policy. They entered graduate school with the intent to use their doctorate to work outside of academia. The remaining 32% of students were *undecided*, open to either an academic career or a non-academic career. Since most of the participants in my study (75%) entered their doctoral program straight from college or from a master's program, without full-time work experience, their perceptions of both academic and non-academic careers at the start of graduate school were inchoate. For instance, a handful of students came from small liberal arts colleges. There, they encountered an average faculty research output that is much lower and a faculty teaching commitment that is much higher, than those at Calder University. Having described

students' career orientations at the start of graduate school, I will continue in the next section outlining the ways students' ideas around this changed.

Career-orientations at the End of Graduate School

As I show in Table 2, below, 50% of participants in my study finished graduate school with the intention of remaining on the academic track. For the most part, these *academia-focused* students are pursuing academic postdoctoral fellowships or have accepted full-time faculty positions. Five of these *academia-focused* students (13%) entered graduate school in the *undecided* or *non-academia-focused* categories. Through graduate school socialization, typically driven by their faculty adviser and their dissertation research, students became oriented towards an academic career. While the proportion of *academia-focused* students, 58% at the start and 50% at the end of graduate school had a nominal decrease, the proportion of non-academia focused students grew from 10% at the start to 35% at the end. Additionally, and not surprisingly, the proportion of *undecided* students declined over time from 33% to 15%. What accounts for the growth in the *non-academia-focused* group? I will answer this question in this chapter and the two chapters that follow it. But before I address this question I will first discuss advisers' attitudes towards academic and non-academic careers.

Table 2. Students' Career-orientations at the beginning and end of their Ph.D. programs

		Women/ Life Sciences	Women/ Physical Sciences	Men/ Life Sciences	Men/ Physical Sciences	Totals
Academia-focused	Start of Ph.D.:	5	7	2	8	23
	End:	6	4	3	7	20
Non-academia focused	Start of Ph.D.:	3	2	0	0	4
	End:	7	3	0	3	14
Undecided	Start of Ph.D.:	9	0	2	2	13
	End:	4	2	1	0	6

Advisers' Attitudes Towards Academic and Non-Academic Careers

Advisers' Biases Towards Academic Careers

The cultural norm and default assumption of faculty was that students would

pursue academic research careers, most likely with a postdoctoral fellowship in a

different lab with a new PI as their next step. This was the career path the advisers

themselves had followed, so they had personal experience from which to draw when

helping their students identify a good postdoc match. Students universally acknowledged

that faculty are understandably biased towards their students pursuing careers in

academia. For those students who ultimately chose to pursue so-called "alternative"

careers, such as in industry or consulting, advisers would initially push back, making sure

students had thought through the decision thoroughly. Often, faculty assumed students,

especially women, were shying away from the competitive academic job market due to

confidence issues. For instance, Anne recounted telling her adviser about her decision to

pursue a consulting position after her Ph.D.: "I think my adviser was a little taken aback

[by my decision]. Initially, he was trying to still convince me that, 'oh yes, you can still

get a faculty position, you have to think higher of yourself.' And I think he, at that time, was still thinking academia is still the prize at the end of the day and so, for you to do something else is a little bit like a second choice."

Over time and with persistence, students like Anne were able to eventually convince their advisers that they were pursuing the right path for them. However, the bias towards academic careers was strong, even though, as Alison told me, "the older faculty know they aren't supposed to show bias." There was a common belief, expressed by Alison and several other students, that the older faculty "are the type who sailed through the [faculty] job process." Many faculty members approach advising and mentoring with the conviction that they are investing their time and effort to train the next generation of scientific researchers. When their students decide to leave the field, faculty are understandably disappointed, both for the loss of their investment of time and to the perceived rejection of their own career choices. How much faculty advisers let that disappointment actually affect their behavior towards students is variable. Overall, most faculty try to be outwardly supportive of students' choices, even when they may be personally disapproving of them. Marian, a life sciences doctoral student who landed a pharmaceutical research position after graduation, described her adviser trying to barter with her in jest: "I asked him for funding to go to a conference and he was like, "do one [academic] postdoc application, then I will [give you the money]." While Marian knew he was joking and did not ultimately apply to any postdocs, the messaging was clear; her adviser's preference was for her to stay in academia. Marian later heard from a 2nd year doctoral student who had approached her adviser about working together.

> *My adviser said [to him], 'are you thinking academia or industry? Because I*
> *probably won't be a good match if you're going into industry.' I was like,*

> *'Ooooooohhhh! He's mad!" I think he just wants someone to follow in his footsteps. His first student went to industry, I'm going into industry. I think it was like a 'once bitten, twice shy' situation. He was like, 'alright, I want **someone** in academia.'*

Students describe a generational disconnect between older and younger faculty with regard to their attitudes towards non-academic jobs and motivations for keeping their advisees in academia. The biases of older, typically male faculty towards academic jobs were perceived, by students, to stem from their adviser's own relatively easy ascent into faculty positions at Calder. Older faculty were described as out of touch with the realities of today's fiercely competitive academic job market. Meanwhile, the younger faculty had gone through the job search process more recently and knew how challenging it was. Younger faculty also had peers from their own Ph.D. or postdoc cohorts who had pursued industry jobs. As a result, they were well aware of the lucrative salaries and benefits proffered by industry. Still other young faculty were biased towards academia in order to show their competence at training Ph.D. students. This is an important skill future tenure and promotion committees often look for. For example, Caroline describes advice she had gotten:

> *Something I heard at the beginning of grad school was 'don't have an adviser who doesn't have tenure because they're gonna be really pushing you to do well, because it reflects on them in their tenure case… I think the professors who base their own success on their grad students' success get angry when [their students] don't go into academia.*

Meanwhile, many older faculty members with tenure at Calder have already established what one student described as the "Calder web of success"—a long lineage of advisees who have gone on to successful careers in academia. As they near retirement, their students' postgraduate career decisions no longer have a direct impact on them or their reputation as good mentors. Typically, these older faculty may give initial push-

back to a student thinking of leaving academia, but will ultimately support whatever decision they make if the student's rationale is sound.

Advisers' Instrumental Support and Non-Support for Academic Careers

For those students interested in pursuing academic careers, their advisers' support was often incredibly beneficial and primarily came in the form of instrumental support. Backed by the tremendous resources of a place like Calder University, instrumental support took on several forms, generally under the two umbrellas of financial support and non-financial support.

Financial Support. Financial support often came in the form of money to attend conferences or to purchase equipment. Conferences were critical to students' academic careers. They were places students could hone their presentation skills, bolster their confidence levels, gain exposure and interest from others in their work, learn about their place in the broader field or subfield, and make important connections that might turn into job leads. Alison, a physical sciences doctoral student, told me she attended 10 international conferences on five different continents during her doctoral program, all paid for by her adviser. She recalled, "at some point, I sent [my adviser] an email that said, 'here are all the conferences that I have identified as possibly interesting for next year. What do you think?' I was giving him an out to say, 'I think you should go to this one and this one,' but instead, he said, 'you should go to all of them.' Likewise, Katie, another physical sciences student described the financial support for equipment her adviser offered. "[At Calder], I have a blank check. If I wanna order whatever I want, like whatever [specialized equipment] I wanna order, I can order it. My [adviser] said,

'don't tell me unless it's over $1,000. Just order it. You don't need approval.'" Brandi, a life sciences doctoral student, also described spending $10,000 on a routine experiment recently when explaining the type of resources available to students in her lab.

Non-Financial Support. Other forms of support advisers offered that were non-monetary in nature included access to data or specialized computational equipment, and access to the adviser's robust professional network. Some advisers also devoted time to co-writing research papers and coaching students through the grant application writing process. Students interested in pursuing academic positions received a broad range of support through the job search process. Most, but not all, students interested in academia searched for a postdoc position. While there are online job boards and websites where postdoc positions are advertised, many are only found via word-of-mouth. Several students' advisers made important introductions to friends and colleagues in order to help their students connect with the best postdoc opportunities. For instance, Tom, a life sciences doctoral student, described the help his adviser gave him in sending emails to prospective postdoc PIs on his behalf.

> *When I emailed them that I'm looking for a position, I guess two out of the three, apparently, didn't have any positions open. But my adviser emailed them as well, and they're like, 'okay, we'll open a position if [the job talk] goes well.' There's a connection. My mentor knows two of them already, so maybe they would've given me an interview and might not have given another person a look because of this connection.*

As Tom's job search illustrates, a student's relationship with his adviser can open doors that would otherwise be closed on the academic job market. Other students had advisers who provided more strategic career support and coaching. For example, Emily, a life sciences student, worked with her adviser on a strategy for making the most out of a conference:

[My adviser] and I talked a lot about just kind of the timeline for things. We talked about, what are some conferences I could go to that would be [in my research domain], that we could work and meet more people in [my research domain]? Then we talked about how the [biggest conference in my field], I should email people beforehand that I want to work with and then schedule meetings during the conference. And so, then from there, I can kind of narrow down and figure out who actually has funding and who has [postdoc] positions available and then kind of continue the conversation with people where I might be able to go interview. So I did that. I contacted anyone I potentially might be interested in working with. That was really good. I had a lot of great conversations with people and I think that was kind of affirming, too.

As Tom and Emily demonstrate, when students decide to pursue an academic job, their advisers typically take the time to sit down and strategize with them. They go over timelines and the navigation of politics; they help students think through possible shifts and pivots in their areas of focus that might proffer new skills and improve their marketability for faculty jobs in a couple of years. Jessica is a life sciences doctoral student who has received a lot of support from her adviser. She explains,

I think if your goals align with hers, she's super helpful. And so, in my case, she's only been helpful. She's helped me with writing grants…she's been instrumental in helping me write those different grants, and then thinking about the way to best navigate the environment of getting into different labs and different tracks. Yeah, in terms of that, she's only been helpful. And she's done the same for other people that have gone on to do what she thinks is the only thing that you should do.

After graduation, Jessica has been hired on as a postdoc where she will be learning a new specialized technological skill. She is excited to combine her doctoral student training with a new technology that will give her a competitive advantage when she applies for faculty positions in a few years.

The technology that I'm learning [in my postdoc], there's only two labs in the whole world that do it. So, I feel like I'll be able to be a little bit more marketable at that point because I'll have this technology that not very many people have. There are two labs that have these systems set up right now, but neither of them are using [this specialized approach]. So, coming from [my field], I'll be able to

add [this specialized approach], and so it'll be sort of a unique thing that I have, which I think will help as well with getting grants and finding a job after.

Students like Emily, Tom, and Jessica all had the support of their faculty advisers, both during their doctoral studies and in their transition to their next steps after leaving Calder with their Ph.D.s. However, for students who did not have strong relationships with their advisers or who pursued careers outside of academia, their job searches were much more independent and lacking in adviser assistance.

Going it Alone: "I felt like I was giving a Ph.D. to myself"

While most students received their doctoral training and career coaching directly from their advisers, some students sought this type of support outside of their labs. These students often had relationship challenges with their adviser. Susana, who describes her relationship with her adviser as "not net positive," found training outside of her lab when she did not receive the mentorship she was seeking from her adviser. Although she said, "I was ultimately fine with the choice of lab that I was in," she also described being so disconnected with her adviser, "I felt like I was giving a Ph.D. to myself." Susana articulates what it means to give herself a Ph.D.:

> *So, for example, instead of getting a lot of work done in a lab, I took two trips abroad on other research studies that were not related to my doctoral work. I helped write up grants and stuff like that for someone else that was not related to my doctoral work. I learned how to write science policy op-eds, et cetera.*

Related to her difficulties with her adviser, Susana also experienced struggle with her research. She was working on two projects for her adviser and was devastated when one of the projects was taken away from her. Her adviser decided it was a high priority project and that Susana was moving too slowly on it. In losing that project, she also lost

the opportunity to learn a new technology, to publish in her field, and to present at conferences. As for the other project she was working on, her adviser did not think the data was ready to be introduced to the public. She explains, "he was not interested in publishing it. When I wanted to present it or submit it as an abstract for a conference presentation—I had over $5,000 in conference funding that he spent on lab equipment—he wouldn't let me go to conferences…when I said I would go to conferences [without his permission] he said, 'don't say that you're in [my] lab.'" Fortunately, Susana was able to get research training from three other sources: first, by working with the postdocs in her adviser's lab, second, by working with outside labs, and third, through her extracurricular activities. When it came to the job search for an academic postdoc position, her adviser was unwilling to be helpful. "I found my postdoc work without any assistance from my PI," she told me, despite asking her PI for help when she "was kinda desperate." Susana explains, "he just doesn't get involved in anyone's career trajectory."

Like Susana, Jennifer, a physical sciences student, also experienced relationship difficulties with her adviser, resulting in challenges with her research project. Jennifer joined a very small lab and then picked a research topic that isolated her from the rest of the lab. This project was not a good fit since Jennifer considers herself "very social" and someone who likes "thinking through things by chatting with people." When she did not find community in her lab setting, Jennifer turned to a student-run science communications organization and also pursued a master's degree in science technology. With the student-run organization, she began working on a podcast series about science and the media, which she describes as "the highlight" of her graduate career and something that piqued her interest enough that she is pursuing a career in science

communications after graduation. While Jennifer disliked being isolated from the rest of the lab and spent a lot of time "flailing about for a while," she did find utility in being "really on my own in the project in a lot of ways." She reflects, it's "useful, cause now I know I can go pull myself through a whole project if I am able to seek help from people and have the grit to push through it."

While going it alone can be much more challenging than having an adviser put his or her full support behind you, overcoming the challenge of working independently also has its rewards. For Jennifer, it taught her to seek out multiple sources of help and established that she is able to persevere through a difficult situation. It also gave her the opportunity to explore other interests, such as running a 100-person graduate student science communications organization. This helped Jennifer discover her passion for making science interesting to a more general population. It also opened up the possibility of pursuing a non-academic career in science media or science policy post-graduation.

Advisers' Emotional Support for Non-Academic Careers

Students who pursued non-academic jobs or "alternative" careers were typically left to their own devices to come up with a job search strategy. While some advisers would initially push back on students who wanted to leave academia, most eventually accepted their students' decisions, if not outright supported them. Students acknowledged that faculty had limited exposure to non-academic careers and were not in a position to provide much support beyond a letter of recommendation or a phone reference. However, many received emotional support for their "alternative" career choices. Faith, a life sciences student who is pursuing a consulting position after Calder

described her adviser as "supportive" of her decision to leave academia. She recalls,

"he'd start to say things like, 'oh, well, you should practice this skill. You'll really need

this skill as a consultant.' So, I think he was really encouraging and helpful." Jennifer,

introduced above, was grateful that her adviser "never stood in my way." Although they

"didn't talk about it extensively," he expressed to her that science communication work

was "important" and signed off on all the coursework she needed to complete her

master's in science technology. While this may not seem like a significant sign of

support, some students, especially those in the life sciences whose participation in lab

work was time sensitive, had difficulty getting released from lab duties to pursue

coursework or career panels in the middle of the workday. Like Jennifer, Jane, a life

sciences student, also completed a master's in science technology. Jane describes being

upfront about her desire to do the master's degree with her adviser before joining her lab:

> *When I joined the lab, I already knew that I wanted to do it, so I specifically told her, 'I'd like to join your lab, but I'm gonna wanna do this [master's degree]. It's gonna come up next year.' And then it came out next year and she started trying to tell me, 'don't do it.' Sometimes she's a real asshole. The worst thing she said, which triggered me to go to [the program chair] was, 'you know, when we write grants, we have to put in how much effort you are putting in, so if you're gonna do this program, maybe you should take some vacation days to do it—which, I don't have real vacation days at all. I worked every Christmas—'or I will have to write less effort time from you, which means you will get paid less,' which is so ridiculous. Really, she was just trying to be protective of the time I have in her lab, but it was incredible.*

Adviser Roadblocks

As Jane's case, above, illustrates, when advisers are not supportive of their

students pursuing non-academic careers, they have the power to make the pursuit of

"alternative" careers more difficult. Several students also recounted classmates and

postdoctoral fellows who had faced retribution from faculty advisers for not pursuing

academic careers. While seemingly rare, some students' faculty advisers exhibited

behavior that students report is unprofessional and detrimental to their advisees' careers.

For example, Jessica, mentioned above, believed her adviser was only helpful because

she was following in her footsteps. "I'm doing what she wants me to do and when people

do what she doesn't want them to do, she sort of roadblocks them. So, I'm going into a

lab that she approves of, to do a postdoc that she approves of, to go towards a faculty

position that she approves of. Whereas, a couple of postdocs who left and didn't wanna

stay in academia, she basically was like 'F-you.'" Jessica when on to describe a postdoc

who was denied a letter of recommendation from her adviser to teach microbiology at a

liberal arts college. According to Jessica, "she wouldn't write her a letter of

recommendation because she wasn't staying in academia." Other students reported

stories of friends who could not attend career panels or talks regarding non-academic

careers because their advisers would not approve. According to Anne, "faculty expect

students to be in lab, so they can't leave in the middle of the day to attend a panel on non-

academic careers."

Students' Academic and Non-Academic Career Planning and Preparation

As I discuss above, about one-third of the study participants entered their doctoral

programs open to both academic and non-academic careers post-Ph.D. I refer to this

group of students as *undecided.* The almost 60% who were aiming for academic careers I

call *academia-focused*, and the 10% who were focused on non-academic careers, I refer

to as the *non-academia focused* group. At the completion of their doctorates, 50% of

participants fell into the *academia-focused group*, including five students who were in the

other two groups at program entry. Meanwhile, the *non-academia focused* group grew

from 10% to 35% and the *undecided* students fell from 33% to 15%. In the next section,

I discuss how students' career trajectories are formed during graduate school, resulting in

many adhering to the academic track post-graduation and a smaller group turning away

from academia or leaving undecided.

Gaining Momentum: Experiences that Promote Academia

While students' career pathways differed, some of the common experiences

which reinforced students' desire to stay in academia included the impact of their

advisers; confidence-building experiences; strong positive peer role models; a love of

teaching; for women, a desire to improve academia for other women; and research project

success.

Adviser Relationship. It is common knowledge among doctoral students that

pursuit of an academic career is fiercely competitive. There are no guarantees of success,

even for those who have numerous publications, prestigious fellowships, and impressive

job talks. I discuss above, and in more depth in Chapter 5, the impact of one's adviser,

which is foundational to ensuring a student's doctoral program success (Austin, 2002;

Baird, 1992; Golde, 2000, Golde & Dore, 2001). Further, I found that a good adviser

relationship is one of the most important factors impacting students' decision to stay in

academia. For instance, Tom, a life sciences doctoral student described his reasons for

staying in academia:

> *I think it's 90% mentor. If you have a good mentor that has a positive outlook…I*
> *think a lot of my friends that are staying in academia had good mentors, and their*
> *projects went fairly smoothly. Mine went fairly smoothly as well.*

While research indicates that good doctoral advising matters, there is less consensus as to what constitutes good advising (Sallee, 2010). Good advising can result from the investment of time, amount of high-quality interactions, and personal interest in the student's accomplishments (Golde, 2000). It can also stem from students' sense of satisfaction tied to advisers' emotional support of them (Tenenbaum, Crosby, and Gliner (2001).

In my research, students experienced positive advising relationships when their advisers communicated their expectations clearly and maintained an even-keeled demeanor emotionally. For instance, Adam, a physical sciences student, describes his doctoral program experience in these terms: "I got pretty much exactly what I expected out of it." Adam had complete trust in his adviser's advice, listened to him, did what he told him to do, and came away with a number of validating experiences. These experiences confirmed to him that he is leaving graduate school with "the qualities that a PI's gonna need." Similarly, William is a life sciences student who also had a positive relationship with his adviser and who is continuing on in academia. One of his adviser's personality traits that William admired most was his ability to remain emotionally consistent. Regardless of whether William's research yielded results that were exciting or disappointing, his adviser's attitude remained neutral. William describes his adviser's communication strategy as: "I'm going to be a consistent person. I'm not going to treat you differently based on success or failure. I'm gonna just be supportive, rather than demanding." Other students experienced positive relationships when their advisers believed in the work they were doing and also helped them craft it in a way that made an impact in the field. Caroline credits her adviser with helping her "frame my dissertation

questions, coming up with something that would be important and feasible…and useful

to the field." Like Tenenbaum et al. (2001) found, the students in my study experienced

strong advising relationships when their advisers provided emotional support rather than

the emotional distress caused by more demanding advisers.

Strong Community of Peers. For Justin, having strong peer role models succeed

in academia was "definitely the biggest thing" that inspired him to stay on the academic

track. He described seeing one of his best friends and office mates get a faculty job

recently and felt encouraged that "good people can make it through." Justin eschews the

stereotype that only the "eccentric brilliant" people who are "super competitive assholes"

make it through and are more valued in academia than "a socially capable person."

Identifying himself with the latter, Justin said,

> *It was nice to see people who are compassionate and able to interact [socially],*
> *who are supportive of students and other people. It was nice to see those people*
> *being valued, kind of pushed forward and pushed up the ranks.*

Other students valued the support and camaraderie of their doctoral cohort.

Although Marian, a life sciences student, is pursuing a career in pharmaceutical research

and development, she credits her "fantastic cohort of students who were super

supportive" with her having a "really good experience" in graduate school, despite it

being "really hard." While some students experienced interpersonal conflicts with lab

mates, including peers and postdocs, that turned them away from academic careers, the

majority of students I spoke with had fairly positive peer relationships.

A Love of Teaching. For other students, a love of teaching helped encourage

them to stay in academia. Michelle described, "I got these really good TA reviews. That

really cemented that I could be a good teacher, even at a Calder-type institution, which is

a big thing. And I think that really set me on that career trajectory." Michelle is now

working as a lecturer at Calder, teaching master's students and doing research on the side.

Ideally, Michelle would like to go back to the small liberal arts college she attended, and

teach there as a professor.

There was wide variability in how much students were encouraged to teach, either

through program requirements or through faculty or departmental support. Most students

served as teaching assistants for 1 or 2 semesters as part of their Ph.D. requirements.

Others volunteered to mentor undergraduates who were working in their labs or writing

senior theses. Adam described his physical science department as one that encouraged

teaching:

> *They're pretty up front about it that we're required to teach two terms to*
> *graduate, and I have done a few extra on top of that just because my adviser*
> *asked me to. I think the development of you as a whole academic is actually a*
> *very strong feature of the department. I think overall, the teaching aspect has*
> *been both encouraged and I guess, taught well.*

On the other hand, other students echoed Michelle's opinion that "Calder's a very

research-focused place and they don't care as much about teaching." The life sciences at

Calder are also geographically dispersed across multiple campuses, resulting in some

advisers actively discouraging their students from teaching. Commuting 30 to 60

minutes each way, from the lab to the classroom several time a week, would simply eat

up too much time.

Tom, a life sciences doctoral student heading into an academic postdoc, liked

teaching so much he taught four different classes a total of ten semesters. This is highly

anomalous at Calder, where students are not financially obligated to take on large

teaching loads, as is the case at other universities. Tom described gaining permission

from his adviser to teach:

> *I always have to ask her every semester. She's like, 'yeah, I don't care.' As long as I was making progress, she didn't really care so much, which is very fortunate, 'cause most advisers would not be happy with that.*

While Tom's adviser was not actively supporting his interest in teaching, she also did not

stand in his way. Tom said he was unsure whether she would support him if he decided

to pursue a teaching, rather than research, focused faculty position. No one from his lab

had ever done that before so he did not have a model to draw from. However, in

choosing his postdoc adviser, he made sure to select someone who would be supportive

of his decision to pursue a non-academic career, including a more teaching-oriented

professorship, if that was the path he ended up in. Like many students, Tom is aiming for

a tenure-track faculty position at a research-intensive university, but he also understands

how competitive those jobs are to get.

Ultimately, I found that most students pursuing the academic path were interested

in doing both teaching and research, with research being the highest priority. Caroline

was one of the few students who enjoyed teaching and writing more than research. She

described her ideal job in these terms:

> *If I had the choice of how to divide up my time…I would spend 80% or 70% of my time preparing for classes, really putting a lot of thought into how to design courses and preparing for them, to maximize student learning and their ability to analyze data, communicate it, and really transform them into the kind of people that I want out in the world. That's what I'm really motivated and passionate about.*

Caroline is doing a teaching postdoc after Calder, where she will be teaching her own

classes for the first time. Meanwhile she is looking for faculty positions that will allow

her to focus her energies on teaching and writing, rather than research. Although she has

explained to the faculty in her department her desire to teach, she said "some of them don't really listen. I explain my reasons for wanting to focus on teaching and not do research. They're like, 'well, just see how you feel next year. I think you're just burned out from your dissertation.'" This attitude of denial demonstrates how STEM doctoral students are continuously socialized towards academic research careers. This comes across casually in their day-to-day interactions with fellow doctoral students as well as in their more explicit discussions with students about their post-graduate career plans. Faculty at Calder view their role as training the next generation of scientific researchers; they want their advisees to follow in their footsteps as faculty at R1 universities.

For students like Caroline who seek to improve their teaching skills, pedagogical training was obtained through working with faculty as course teaching assistants (TAs). Caroline described being a TA for a 400-person introductory science course as "inspiring" and "amazing." She credits the professors as "putting a lot into their lectures and making sure their students got excited about [the material] and also explained it well." Several doctoral students in my study also completed teaching certificate programs through the university's office of learning and teaching. In addition to these two methods of teacher training, Caroline attended a one-week workshop on how to teach college-level STEM at a nearby public research university. She recalled, "that was the first time I met a lot of career university teachers who were totally in it for the teaching." In general, I found that few advisers were actively involved in helping their doctoral students become better classroom teachers. Students were expected to learn pedagogical skills through observing faculty as a TA or through other self-identified certificate programs or teacher training programs.

Promoting Women in Science. Another factor that played into the decision-making for some women students was to improve the pipeline of women scientists to the faculty. Although Hannah struggled with confidence issues in graduate school she said she "never had any overly negative experiences because I'm a woman in science." She had a good research project and a mentor who encouraged her to apply for faculty jobs. However, when Hannah started doing job interviews she noticed she was often the only woman in the room. This motivates her to want to succeed in academia, in order to make it a more welcoming for other women:

> One reason why I want to continue in academia is to make it better for women…there's so many female grad students and so few female faculty members. It's so stark. And it was even more stark when I was on these interviews where I go out to dinner with five men. I loved [the University I accepted an offer from] because they had a woman there and I was like, 'this is great!' And I realized like, 'why did I have so much fun at that dinner? Oh yeah, it wasn't me and a bunch of 50-year-old men.' It was perfectly fine with men at these places. I had a nice time at dinner. But it really did make a difference [when there was another woman there.]

For some women and underrepresented minority students, wanting to improve the academic experiences for other students like them was one factor that contributed to their desire to stay in academia. Although Sam is still trying to decide between a consulting career and one in academia, in the past, he spent time as a volunteer mentor for younger minority students. He described it as "really helpful for me to kinda play that role as a scientist [of color] and say, 'here, I made it, and you can make it too.' And to be able to mentor students like that, give them a role model in a sense, I think is helpful." In combination with other factors, the desire to make STEM more diverse was, for some students, a compelling interest in deciding to pursue an academic career.

Successful Research Project. Every student I interviewed talked about their research projects. Most students had one or two independent research projects during their doctoral program. These were projects that were typically one piece of a larger research project, overseen by the student's adviser. The first project lasted one to two years and ideally resulted in a publishable paper. The second project would be the basis for the dissertation and could direct the student towards a particular postdoctoral fellowship as well. Students frequently referred to their graduate research project in bifurcated terms. According to students, a project was "good," if it was original and exciting; where the analysis was fairly smooth; where the research skills learned through the project were valuable; where the adviser overseeing the project was engaged and helpful. A project was "bad" if it involved a great deal of time and struggle; where the time invested did not pay off with compelling findings that could be published; where working on the project created tension in the adviser-advisee relationship. A "good" project is also one that is a match for the student's needs, interests, and skill level. Beth, a life sciences student, demonstrates this in describing her motivations for picking her project:

> *The [adviser] I ended up working with had a [federal research] grant with a project that lined up really nicely for a graduate student to take on. Because she had already written the grant, she had already thought through some of the theoretical pieces of it. Just the simulations needed to be done, coding, that kind of thing. It was something that was more shovel-ready. I'm not a risk-taker, so I was looking for something that was more of a sure thing.*

For many students, graduate research project success factored prominently in their ultimate decision to stay in academia. For some, a passion for teaching really made a difference, and for others, a desire to populate the faculty ranks with more women was a driving force. These were all important influences that, in combination with other

factors, provided students with the momentum they needed, while in graduate school, to stay the course in academia. Next, I discuss the experiences that students encountered which factored into their decision to turn away from academic careers.

Losing Momentum: Experiences that Dissuade from Academia

For students who were turned off by academic careers, common experiences included struggle with one's research project, a disdain for the highly competitive and uncertain culture of academic science, and disillusionment with the culture and its misalignment with one's personal values. Related to all these experiences was the student's adviser relationship and the modeling provided by the adviser.

Struggle and Lack of Progress with the Research Project. For reasons often attributed to bad luck, several students struggled with their research projects. These setbacks gave students a chance to pause and reflect on how much they wanted to pursue a research career. Were they passionate enough about scientific research to persevere in the face of adversity? Anne, a life science student, found that when her "project wasn't working out that well" she used the opportunity to measure her interest in and dedication to research. She said,

> *I like the grand idea of it, but to see myself asking these scientific questions, it just didn't really drive me. So that's when I thought, 'okay, this probably isn't for me.' Everyone is different, it just didn't seem like the right choice for me.*

For Anne, the struggle entailed working very independently on a project that was not making forward progress. She felt isolated and was frustrated:

> *Basically, I kind of just spent at least two years troubleshooting experiments, doing things that weren't working and that was a pretty frustrating time, cause I felt like, 'okay, am I ever gonna graduate? Am I ever gonna get a paper out of*

this?' It felt very uncertain…I just need to be able to see some kind of progression.

Jennifer was another student who struggled with her research project. Like Anne, Jennifer experienced "long periods when I would spin my wheels in the research." Looking back, Jennifer realized that the main challenges concerned the independent nature of the work and the communication with her adviser who was overseeing the project. Students often experienced a lack of hands-on advising combined with the directive to keep plugging away at a project. As Justin's experience illustrates, this resulted in "many grueling months of just no progress whatsoever." He describes,

> *There were numerous things that I was having trouble with that were just completely not working, like codes that weren't working right in situations. And I ended up realizing after months of struggling with it that [the codes] can't handle these problems. Whereas, my adviser and the people I was talking to, had an attitude of I'm just using it wrong, that there's some easy way to get it to work and I just haven't found it yet. So it…really kind of hampered my progress and my emotional well-being at the time.*

Luckily, Justin found success with his second research project and views his first project as a learning experience that helped him grow as an independent researcher. He feels well prepared for his academic postdoc since he's "effectively been working like a postdoc" with his two hands-off advisers over the last seven years.

William, a life sciences student, also had a hands-off adviser. After graduation he is pursuing an academic postdoc with another hands-off adviser as he found he prefers this management style. While he acknowledged the challenges, at times, of working with an adviser who was hands-off, William describes it as "a productive challenge" and "something that helped me improve." William's adviser explained to him once that his hands-off style was part of his overall pedagogical approach:

> *[My adviser] said that he often will see what the next step of a project should be, and just not say anything about it, because the point of being a grad student isn't to pump out papers, it's to learn. And therefore, by giving someone the answer you're not helping them learn.*

If more advisers framed the struggle inherent in research in these terms—as part of the overall learning process and a pedagogical strategy used in graduate training—perhaps there would be less frustration and more students, especially women and minorities, staying on in academia.

I found that students who struggle with their projects, began to question their commitment to the academic path. It was difficult to keep their spirits up and stay motivated in the face of frustration and a lack of forward progress. Lily, a life sciences student, describes "the majority of my Ph.D. was just kind of banging my head against the wall." She ended up using the data she obtained during her first year of the project for her thesis. She said she would have kept going with it but for her adviser, who told her to stop so she could graduate. She recalls,

> *I'm very happy my adviser stopped me when he did because I could've kept doing that project for another 10 years. It was good [that he stopped me]. I was really not enjoying it anymore. I was honestly hating it. So, I think it was good to be done with it.*

Lily's struggle with her project depicts the fundamental nature of research. It is time consuming, often direction-less, and there is no guarantee that your investment of time will ever pay-off. For students like Lily, the struggle and the uncertainty around research can serve as indicators that academic science research may not be the right path for them. For other students, like Michael, a life sciences student, struggling with your research project is viewed as an important part of the process.

I think this is why we're here. We're supposed to struggle… [you come to Calder] and you think you're gonna go revolutionize medicine or space travel or something, and then you find out that it's hard and it takes longer and you have to temper all of that grandiose delusion. I wouldn't want to take that away from people. I think there's this grind that is important. The way I'm struggling is important. It's gonna help me understand the nature of feasibility.

For Michael, the struggle paid off in that he was ultimately happy with his project, the data it produced, and the papers that came out of it. For some students, the struggle is eventually resolved and they can look back on it as a learning experience that made them stronger. For Nick, a physical sciences student, this was the case. With his second research project, he experienced frustration and "felt like a failure." But then "there was a thing where all the work paid off, and my research started coming out at a good clip, and I found that as my productivity increased, I started seeing the feedback from people that I was doing well." Unfortunately, not every student ultimately receives the satisfaction they are seeking. Students like Lily are just told to stop by their adviser and figure out a way to make the best of the data they have to write up their thesis. This type of research process is frustrating and typically ends up with the student opting-out of a research science career.

Uncertainty and the Competitive Culture of Academic Science. Since many students at Calder enter their doctoral programs straight from college, they are naïve to the realities of the academic job market and the long path to the idealized job that most students hope for: a tenured professorship. Anne describes her initial thoughts,

Coming in, I didn't quite realize how long that path is and how competitive that path is. I thought that people do postdocs for two years and then move on and get a professorship. But postdocs are just as long as grad school now in biology, if not longer. I've seen postdocs in my lab stick around for 10 years trying to finish projects. So I was like, no. I don't really wanna do that.

The uncertainty of the academic career path often produces a very competitive and aggressive culture for students, one that can easily turn away talented people. Since the postdoc experience is not necessarily guaranteed to produce a faculty job, students do not feel comfortable going down this path post-graduation unless they are very confident in their future success. Unlike Anne, Michael came to his Ph.D. program with a master's degree and several years of work experience under his belt. Yet, coming from a university in the Midwest, he was not prepared for the "dog eat dog" competition at Calder. At his previous institution, "people were not that driven there. We looked out for each other. We talked to each other. There was just more a sense that people matter more than the content, and here it's upside down." Since Michael is planning to continue in academia, he sees the "entrepreneurially aggressive" culture as one that will "make me better" but also describes it as "the hardest part." Michael experiences this culture as highly competitive, where imaginative ideas, rather than productivity, are the coin of the realm. Although Michael has experienced feelings of competition and aggression, he is also confident in his chances of landing a good academic job. For Michael, he has to push his uncertainty to the back of his mind and, as he put it, "run your own race," in order to stay focused and confident in the face of the daunting odds of becoming a successful PI one day.

Disillusionment and Misalignment with Values. The "entrepreneurially aggressive" culture also serves as a deterrent to students who dislike the professional day-to-day work that a PI does. According to Sam, a life sciences student, "it seems like they're just always writing grants, showing out for money, dealing with that stuff. It becomes less about the science and more about managing people and managing funds,

and I didn't really like that. I was in science for the sake of science." Several students described the work their advisers did more akin to running a small business than doing actual hands-on research. This disillusioned them to the nobleness of the field and opened their eyes to what it would actually look like to run their own lab one day.

Students were also disillusioned witnessing the competition that could bubble up to the level of the faculty. For example, some students described faculty engaging in morally questionable behavior. Justin, a physical sciences student, observed faculty in his department go to great lengths to "be the first to work on things." He describes others as making "some questionable research moves," such as "purposefully scooping people or putting out big press releases before something is vetted at all." This speaks to the "entrepreneurially aggressive culture" Michael describes. Other students describe disillusionment in dealing with the internal politics of academic science, such as getting proper citations on papers. David is a physical sciences student who worked very hard and made a significant contribution to a research project that resulted in a major publication. Unfortunately, due to timing issues, his name was not included on the author list for the paper, despite his hard work on it. David explains:

> *There is a requirement on the experiment that you do a year of service work before you're added to the official experiment author list. And so, I had been on the experiment since undergrad and then going into grad school, but I hadn't formally initiated that process of getting onto the author list until maybe my second year of graduate school. So we initiated my qualification process, that's what they call it. But in the meantime, as I was doing my qualification work…we ended up publishing a paper maybe at the end of my third year that had multiple figures and tables and things that I had produced, but because I hadn't yet completed that year of service work, I couldn't be an author on the paper. And I was two months away but they wouldn't make an exception. So that was one specific instance of, "Man, really?" I actually spent a lot of time working on this but I can't even get onto the author list for it, and that was a very disappointing thing. Yeah.*

In the end, David decided that working on that particular experiment did not align with other things he wanted to be doing in his life, such as being a husband. David felt that in order to be a successful junior professor in his subfield of research, he would have to uproot his life and move to a different continent for a few years. Since David's wife is also pursuing a doctorate, he did not want to move abroad. David decided, "I really enjoyed the type of work that I was doing, but the other life factors didn't really line up well for me." Several other students also factored in work-life balance and valuing their mental health more than their desire to work the long hours required to become a successful academic researcher. According to Lily:

> *One of the most challenging things is worrying about how any future job will affect your personal life, 'cause I got married a year ago and in the next couple of years I probably want to have kids, et cetera. I also just learned about myself that I'm kind of a high anxiety person and I'm a lot happier when I'm able to just focus on one thing in a specific allotment of time, and then have the freedom to do things that I like on the outside. I'm just more productive and happy in general. So, I really want to think about how I can achieve the lifestyle that I want, work flexibility, all that kind of stuff. Because I do really care about science, but I don't care about career as much as I do about family and happiness.*

As I discuss in Chapters 5 and 6, work-life balance was a value that many students identified in graduate school. Through the process of working long hours and observing their advisers prioritizing work at the expense of their personal lives, many participants ultimately decided academic research careers were not for them. In the next section, I turn to how students planned for and pursued non-academic careers.

Non-Academic Career Planning and Preparation: The Road Less Traveled

Students who decided to pursue non-academic careers made the choice to pivot at various points in their doctoral program. Acknowledging the competitive academic job

landscape, some were intent on working in industry from the start of graduate school.

Others took a more iterative approach to career exploration after ultimately deciding

academia was not right for them. Still others started late in the process and ended up in

an academic postdoc by default, hoping to transition into a non-academic career soon.

The non-academic careers most often pursued by STEM Ph.D. students include those in

consulting, data science, finance, industry, pharmaceutical research, non-profit research

and development, public policy, science communications and media, and venture capital.

The majority of the students in this study who had non-academic jobs lined up by

graduation were pursuing consulting, pharmaceutical research, or non-profit research

institute work. I found that the students who were successful in securing non-academic

jobs by graduation engaged in proactive career exploration and professional development

work.

Searching Proactively

Students who had jobs lined up by graduation were intentional and thoughtful in

their approach to career planning. Most students entered the program directly from their

undergraduate program. These students typically started graduate school open to both

academic and non-academic careers, with a slight preference for academic careers, the

path they were most familiar with. Once in graduate school, their experiences would

either affirm or challenge their plans to continue in academia. Non-academic career

exploration began at different stages for each student. Some attended career panels and

workshops offered by the University's career services office early on. Others joined

career counseling support groups when they began to question their plans to continue in

academia. Still others identified alumni of their program working in interesting non-academic careers and reached out to them for informational interviews. Students interested in both academic and non-academic careers attended conferences and participated in networking events. Students interested in non-academic careers engaged in extracurricular activities at the University. They joined student-run clubs and participated in coursework at Calder's graduate school of management. Perhaps most importantly, they did summer internships in the fields they were interested in.

University Resources: Career Panels, Workshops, and Support Groups.
Students interested in alternative careers often attended events such as panel discussions and career fairs organized by Calder's career services office. Anne, who is going into healthcare consulting after graduation, attended a life sciences consulting career fair where she "talked to all the different companies and also the people who worked there, to just see what it was like and what the [job] application process is." She credits these career fairs as one of the "main ways that I learned what the companies were and which ones were out there." Zoe is another life sciences student who also "went to quite a few of the panels that they had for venture groups." She found those to be "always extremely well done." However, other students reported attending career panels and finding them less useful. According to Jane, "their main takeaway is, 'oh, you should network,' that's literally all anybody needs to say, because ultimately, that's the only useful thing they say in all those workshops." Katie concurred, stating, "you can go to the career development office all you want, but they're not gonna help. They can't help with every single career path…I've gone to a couple of things at the career development office and they were interesting, but they were no more than, 'networking is important.'"

While the career panels and workshops received mixed reviews from students, David discussed joining a weekly doctoral student support group at Calder called "What am I doing with my life?" At the time, David was going through an "existential crisis" in deciding whether to stay in academia or depart for industry. The support group included doctoral students from a range of disciplines and backgrounds who were in the middle of their graduate career and various life events and didn't know what to do next:

> *I did that for two semesters and I found that was much more useful than talking to individual professors because I was working out my issues with other people that were going through the same thing at the same time. And we had a couple of moderators who had been running this group for years and kinda knew the bigger picture and how people had dealt with [this stuff before].*

David felt that this support group was particularly useful because it helped him to know that he "wasn't alone in this." He was relieved to learn that "actually, there's a lot of people that are going through the same thing." He also found it easier to discuss his problems and insecurities among people whom he did not know well and who were not connected to his field.

> *It felt a little bit more open, that you could talk about things that I wouldn't necessarily talk about with [my adviser]. I wouldn't wanna have that conversation with her just because she's in it, and I wouldn't wanna insult her in that way. But with this [support] group, it felt like I could say things like '[my field] is awful, it's the worst,' and people wouldn't care because most of them didn't know [my field] from any other field.*

University Resources: Extracurricular Activities and Coursework.

Students also joined graduate student clubs and organizations, such as the biotech club, the consulting club, and the science communications and media club. Joining these clubs connected students to a host of non-academic career opportunities. In particular, the biotech and consulting clubs sent job postings and case competition opportunities out on

their email listservs. Since the consulting companies have very structured recruitment

schedules with applications due in the fall, joining email listservs enabled students

interested in consulting jobs to be on top of the deadlines. Additionally, students like

Faith who is going into life sciences consulting after graduation, got her first exposure to

consulting through participation in graduate student case competitions:

> *That summer [two years before graduation] I just teamed up with some friends*
> *who were interested to do these case competitions. So, I ended up doing two that*
> *summer. One was life sciences specific at [nearby university] and one of them*
> *was not, and that was at [a university in New York]. So, in both of these cases,*
> *you're given a problem and it's a business problem. And you have a limited*
> *amount of time to research it and make a presentation and present it. And then, at*
> *the end of the summer after these two experiences, I was interested enough to*
> *explore it further. I joined the consulting club email list, cause that's how you*
> *find out about networking events and other things.*

Through the consulting club email list, Faith joined two different volunteer consulting

groups working directly with a client, serving as pro bono consultants. Unlike other

students I spoke with, Faith did not do an internship in consulting or industry. Instead,

her participation in case competitions and the volunteer consulting group projects gave

her enough experience to ace the case interview questions during her job interviews.

Faith also took advantage of coursework, such as the mini-MBA course offered

by the graduate school of management. Diana, a life sciences student, took a

management course and a machine learning course. She also took courses to learn how

to code, which is something she needs for her thesis project but recognizes that it will

make her more marketable in the data science space. Anne took a course on healthcare

innovation and commercialization offered by the biotech club that focuses on life science

start-ups. Through this course, Anne connected with an alumnus from her department

who came to class one day to advertise a part-time internship at his company.

Networking with Alumni. Like Anne, many students who transitioned into non-academic careers networked with Calder alumni. Some did informational interviews with alumni while others stayed in touch with former doctoral students or postdocs from their labs. Sam, a life sciences student, was one of these students. He kept in touch with a lab mate who is now a consultant at McKinsey, one of the world's biggest strategy consulting firms. His friend strongly encouraged Sam to apply for a consulting position at McKinsey and alerted him that the application was due in two days:

> *I scrambled over the next day to throw together my resume, my cover letter, and all that, and then submitted my application to McKinsey. And it was really that point that really solidified that consulting was a direction that I wanted to go in. Cause once I submit those applications, I need to start preparing for the actual interview, which meant doing case practice and that sort of thing. And in the course of doing all these different case practices and case studies, I really liked the process and the work that consultants do. So, I started being able to see myself in that sort of role.*

Networking with alumni and other professionals in the non-academic fields proved to be critical to students making effective inroads in the direction of non-academic careers. Most departments organized career panels, once or twice a year, featuring alumni with non-academic jobs. Yet, students reported doing a lot of legwork to find alumni to meet with, such as independently searching the online alumni database or using the social media website LinkedIn. Several students cited the need to develop a more cohesive network of alumni and other friends of the department whom students could turn to for advice and support in applying for non-academic jobs. There was a general sense that most faculty want to be helpful, but they lack the knowledge or resources to help in the non-academic job search. Alison explains,

> *Given that we have a lot of alumni out there [working in industry], it would be really helpful for people if that sort of network existed and if there was a list of*

people [we] could contact. That would be really great. The non-academic job stuff is the biggest gaping hole [in our department].

Internships: "One of the Most Affirming Experiences of My Ph.D." Many of the students who were successful in lining up positions in non-academic fields such as consulting or industry had completed internships during graduate school. The internships were valuable in providing students with concrete non-academic work experience. They also clarified for them how well suited their skills and personalities were for a particular industry outside of academia. For example, Anne, who is going into healthcare consulting after graduation, did a 6-month part-time internship with a life sciences venture creation company. This experience helped solidify her desire to leave bench research:

> *When I did that internship, that made me realize that I think I would be okay not doing any bench research and just working in an office and talking to people and things like that. And the questions that they were asking [in my internship] were actually more interesting to me than some of the questions that we would talk about in a lab meeting…going into those meetings every week for my internship, it just felt more exciting to me.*

Anne appreciated how the venture creation company framed their questions in a way that would develop products that could benefit people much sooner and more directly than basic science research. Anne felt that working in consulting or industry would offer "more big-picture" thinking, allowing her to make a deeper impact with her career. Similarly, Marian, a life sciences student, described her internship as "one of the most affirming experiences of my Ph.D. because I was doing [a technique] I had no idea about, like I had no idea what I was doing when I walked in, and I was able to just kinda pick it up and make a contribution really quickly." For students like Anne and Marian, seeing the fruits of their labors almost immediately was immensely gratifying. It made the

decision to leave academia in order to pursue careers in consulting and pharmaceutical research, respectively, very easy for them. Although Anne and Marian were both happy with their decisions to leave academia, their advisers initially pushed back on their decisions, signaling their disappointment in their students choosing an "alternative career."

Caroline is a physical science student who did a two-month summer internship as a science writer for a popular magazine. The internship was arranged through a national science media fellowship program for STEM doctoral students. Caroline has always loved writing and wanted to try her hand at spending the summer being a full-time popular science writer.

> *At the beginning, they mostly wanted me to write about [my academic discipline], but I also wrote about conservation and health and medicine and astronomy and all sorts of fields. My background in science is pretty broad so I did feel comfortable writing about a wide range of topics. And I loved it. I enjoyed being a full-time writer…and then since then, I've been doing a lot of freelance writing and doing about one popular science article a month.*

Although Caroline decided to accept a full-time teaching job post-graduation, she values the internship at the magazine and credits it with giving her "the confidence that…yes, I really can write full-time if I want to or need to." Right now, Caroline would like to continue to focus on teaching at the college level and doing science writing on the side. She is less interested in doing research. Diana, a life sciences student, also participated in a summer fellowship for STEM doctoral students. Diana's fellowship was in data science and involved a full-time summer internship and exposure to an array of different companies with the goal of placing each student in a full-time data science job upon graduation.

For students who are able to pursue them, internships clearly opened doors to job opportunities, provided access to new knowledge and skills, and gave students the confidence they needed to pivot away from academic careers. Unfortunately, there were a number of students, including Faith and Jane, who did the type of lab work that made an internship impossible. As Jane describes,

> *I would've liked to do some kind of internship. There's a science policy internship you can do for three months that I would've liked to apply for, but we work with mice. The lab is small. So, there's no way I could've left for more than a couple of days at a time. It was not realistic, which is unfortunate because there are a lot of industry internships. Maybe I should've pushed [my adviser] harder, but it just seemed like a non-starter from the very beginning, so I never even considered it as a real possibility.*

For many students, especially those, like Jane, who work in wet labs, there are both structural and cultural barriers to pursuing important career exploration activities, such as attending career panels or participating in internships. Lab work, for instance, required set hours for timed experiments. Some students were also afraid to ask their advisers for time off to pursue these activities, since this would pre-maturely expose their interest in non-academic careers before they had made a firm decision yet. Students uniformly experienced lab cultures where leaving academia was viewed as the exception, rather than the rule, despite the statistics showing only 10% of life sciences Ph.D.s will go on to obtain a tenure or tenure-track professorship within five years of graduation (Blank et al., 2017).

Marian's experience demonstrates that doing an internship is doable for some doctoral students. However, it does require perseverance and good planning. Marian identified internships, then applied for and was hired by one. Next, she obtained

permission from her adviser and did the necessary paper work to pause the funding on her graduate stipend, which was funded by a grant:

> *I did an internship the summer after my fourth year, which is not encouraged in my department, which, I understand why, because funding is contingent on you contributing to that funding. But, also, we should be able to have informed choices about our careers. So, the way we get around it is you have to jump through a bunch of hoops to do it, but if you jump through them, then it's fine. And if your adviser thinks you're in a good place, they'll let you do it. It's really up to them and my adviser was fine with it.*

The kind of planning and savviness required to "jump through a bunch of hoops" does not come naturally to all people and shows how proactive and motivated students need to be in order to make the transition to non-academic careers. Marian found her internship listed on a professional association website. She then networked with an acquaintance who was a couple years ahead of her in her doctoral program and who was not a full-time employee at the company offering the internship. He gave her insider information about working there. She recalls, "I think he was probably helpful in me being chosen, quite frankly." After her summer internship, Marian received a full-time job offer but ultimately turned it down in favor of a position with a different pharmaceutical company.

Katie, a physical sciences student, also leveraged a personal connection to gain her internship, which was at a national research and development lab the summer before her final year of graduate school. Her partner, a doctoral student at a different university, had interned at the lab a year before Katie. He had a great research experience and enjoyed working 9:00-to-5:00. He encouraged Katie to apply for an internship there as well. After Katie's internship, she ultimately applied for and was offered a full-time research scientist position at the lab. However, without her partner's knowledge of the

opportunity, she likely would not have done an internship in graduate school. She

recalled,

> *I did an internship in the middle of my Ph.D. I didn't realize I could do an internship.*
> *My adviser didn't know I could do an internship until I started poking and prodding*
> *people and was like, 'is this okay? Is this okay? I need to know. I have an offer*
> *already. I need to know. Can I do this?' And people were like, 'oh yeah, I think*
> *John did this five years ago.' And it's something that people didn't know [they could*
> *do].*

For students interested in transitioning out of academia, internships during graduate

school provided critical professional skills, self-confidence, and confirmation that they

were making the right decision to leave academia. It also served as a powerful market

signal to prospective employers that a student was serious about working in a particular

field. Unfortunately, internships were not always feasible for students who were required

to participate in daily lab work. Internships also required a fair amount of savviness and

tenacity on the part of the student to set up and to gain adviser and departmental approval

for. Lastly, internships were often identified and secured through word-of-mouth and

personal or professional networks. This privileges the doctoral students with the most

social and cultural capital who are more likely to have both the personal connections and

the know-how to tap into them.

Searching Haphazardly

The students who conducted more haphazard searches were less likely to have a job

lined up by graduation. Some relied on the fallback option of a postdoc position with

their current adviser or someone else they had worked with previously in order to have a

source of income while they figured out their next steps. Sam was one of these students.

Although he decided management consulting was an attractive next step for his career,

Sam only made it through the first-round interview at McKinsey. Sam had not done an internship, like Anne did. Nor did he engage in case competitions or pro bono consulting gigs, like Faith. Compared to students like Anne and Faith, Sam had not done enough to obtain the skills needed for a successful transition from life sciences doctoral student to management consultant. His haphazard job search process resulted in Sam falling into a postdoc, "even though I wasn't really looking to do a postdoc." Sam will be working for a friend from his former lab who recently landed a faculty position. The plan is to work in the lab as a postdoc for a year or two while simultaneously preparing to try again for a consulting position.

Sam's experience juxtaposed against Anne's, Faith's, and Marian's provides evidence that in order to successfully transition into non-academic careers, students at Calder need to be thoughtful and proactive. They need to be systematic in their career exploration activities by identifying what they like and dislike about academic research, exploring different opportunities outside of academia, conducting informational interviews, seeking out internships, and applying for full-time positions. Students who engage in more haphazard searches are more likely to fall into a postdoc, which students describe as the path of least resistance.

The Four Post-Graduate Career Mindsets

In this chapter I described the processes and mechanisms involved in STEM doctoral students' academic and non-academic career planning at an elite research university. Through my processes of data collection and analysis, I found that STEM doctoral students at Calder University held one of four mindsets with regard to their

academic and non-academic career plans: *Academia or Bust*, *Ambivalent about Academia*, *Best of Both Worlds*, and *Opting-Out of Academia*. Below I describe these four career mindsets. I explain why some students graduated optimistically, prepared to defy the odds and obtain a professorship in a short number of years, while others decided they were leaving academia for good. The four mindsets, as shown in Figure 1, were associated with varying levels of optimism, adviser relationship satisfaction, and attitudes about their future careers in academic science.

Figure 1. The Four Post-Graduate Career Mindsets Typology

The Four Post-Graduate Career Mindsets of STEM Ph.D. Students

Academia or Bust (22%)
- Career Ambition: P.I. and/or professor
- All had positive adviser relationships
- Optimistic
- Not considering any other career

Ambivalent about Academia (30%)
- Academic postdoc or faculty position secured
- 9 (+), 1 (+/-), 1(-) adviser relationships
- Open to possibility of leaving academia

Best of Both Worlds (10%)
- Straddling between academic and non-academic career ambitions
- Not yet committed, happy w/either
- Mostly industry postdocs
- Both (+) and (-) advising relationships

Opting-Out of Academia (38%)
- Leaving academia definitively
- Mostly in life sciences
- 7 (+), 4 (+/-), 4 (-) adviser relationships
- Academia not the right fit

Academia or Bust

The nine students (22%) leaving Calder with an *Academia or Bust* mindset told me their ultimate career ambition was to become a PI of their own academic research lab. Five of these students were in the physical sciences and four were in the life sciences. Seven of these students had positive adviser-advisee relationships. Two students had a mixed experience with their advisers. One of these students who had a mixed experience had an adviser with almost a hundred people in his lab. This adviser was rarely there to offer mentorship or guidance to Ph.D. students. However, a letter of recommendation from this adviser wielded a lot of power in the field.

None of these students had a mostly negative adviser experience, which indicates that most students who strongly adhere to the academic path have strong adviser-advisee relationships. Eight of the nine students were advised by faculty with tenure. While these faculty may or may not have been pre-disposed towards faculty careers, as tenured faculty, they were able to provide generous instrumental support in the form of both financial and non-financial resources. The instrumental support available to these students was likely more generous than the support provided to students advised by pre-tenured faculty. Only one of the nine students experienced significant research project struggles. Overall, the students with this mindset were optimistic about their future. Their experiences in graduate school were affirming of their decision to remain on an academic path. Notably, only two of the nine students with this mindset are women. Women were more likely to be graduating with an *Ambivalent about Academia* mindset.

Ambivalent about Academia

Twelve students (30%) were planning to pursue academic careers, but were ambivalent about it. They told me that if it didn't happen, they would be okay shifting gears towards other applications of their degree (e.g. industry or teaching). These students were successful on the academic job market. Most had secured competitive postdoc positions, teaching (non-tenure-track) faculty positions, or research (tenure-track) faculty positions. Seven of these students were in the physical sciences and five were in the life sciences. Nine of these students had a positive adviser-advisee relationship, one student had a mixed adviser-advisee relationship, and two students had a negative adviser-advisee relationship. Three of the *Ambivalent about Academia* students were men and nine were women.

While all students encounter struggle in doctoral education, those who left Calder with an *Ambivalent about Academia* mindset experienced some acutely challenging experienced that may have given them pause about academic careers. For instance, seven of students in this study described challenges with their adviser, with three students initiating an adviser switch. Two students, Philip and Natalie, experienced interpersonal conflicts with one or more lab mates, Lauren and Hannah, described working hard to overcome their fear of public speaking. Others were open to academic career success but were also motivated to be examples for other women in science who would follow them. Some of the *Ambivalent* students struggled with their research project. Often this struggle was associated with an adviser mismatch and quickly rectified by switching advisers. These and other experiences resulted in the *Ambivalent* students viewing the competitive academic labor market with uncertainty. These students lacked the optimism held by their peers with *Academia or Bust* mindsets. Luckily, they were not completely

disillusioned by the culture and found most aspects of academia aligned with their

personal values.

Best of Both Worlds

Four students (10%) were straddling between academic and non-academic career

ambitions and had not yet decided definitively which direction they would pursue. One

was in the life sciences and three were in the physical sciences. The three physical

sciences students all decided to pursue industry postdocs that would allow them to keep

one foot in academia and one foot in industry. These students were all confident they

would still be able to obtain a tenure-track faculty position in the future, assuming their

research output and publication records remained competitive. One student, David, had a

mostly positive relationship with his adviser, but watched him go through the tenure

review process, which ended in denial. The life sciences student, Sam, had a negative

adviser-advisee relationship. He applied unsuccessfully for consulting jobs, eventually

ending up in a postdoc offered to him by a friend who was now running his own lab at a

different university. While Sam plans to apply again for consulting jobs in the future, he

is also entertaining the idea of staying in academia. Now that he is no longer working

with his Calder adviser, his passion for scientific research has been re-awakened. He told

me there is a 50 percent chance he would stay in academia instead of pursuing consulting.

What differentiates the *Best of Both Worlds* group from the *Ambivalent about*

Academia group? The *Best of Both Worlds* group felt equally comfortable in either

industry or academic postdocs, with the belief that they could easily switch over to

academia or to industry at some point in the future. For those students with a *Best of*

Both Worlds mindset pursuing industry postdocs, they were enjoying the work, lifestyle, and salary offered by industry jobs, while holding open the possibility of returning to academia in the future. They believed their work advising doctoral students, leading research teams, publishing papers, would keep them competitive on the academic job market in the future. Meanwhile, although the students with an *Ambivalent about Academia* mindset were continuing along the linear academic career path expected of them, they were not entirely sure they would stay in academia. They told me they would abandon it altogether if they were unhappy. Notably, all of the *Best of Both Worlds* students were men. It is possible they were being over-confident in their ability to seamlessly return to academia in the future. In stark contrast, the women doing similar work in industry postdocs all left graduate school with an *Opting-Out of Academia* mindset.

Opting-Out of Academia

Fifteen students (38%) had opted-out of an academic career, choosing instead to pursue consulting, industry, data science, venture capital, policy, or media/communications positions with no intention of ever returning to academic research. Five students were in the physical sciences and ten were in the life sciences. Seven students had positive adviser-advisee relationships, four students had mixed adviser-advisee relationships, and four students had a negative adviser-advisee relationship. Six students with the *Opting-Out* mindset did internships in industry or government. Two students, Faith and Jennifer, participated in extra-curricular activities, such as biotechnology club, case competitions, and a student-run science media

organization. Fourteen *Opting-Out of Academia* students were women and only one was

a man. This gender imbalance could be explained by more women than men

experiencing adviser challenges. Another possibility is that the women in my study

engaged in a more proactive and intentional job search, including the participation of

internships and extra-curricular activities. A third potential cause is that women

encountered more negative advising relationships than men, leading to the decision to

opt-out of academia after graduation.

Table 3. The Four Post-Graduate Career Mindsets
N=40

		Life Sciences (n=21)	Physical Sciences (n=19)	Total
Academia	Men	3	3	6
or Bust	Women	1	2	3
n=9	Adviser Positive	4	3	7
	Adviser Negative	0	0	0
	Adviser Mixed	1	1	2
Ambivalent	Men	0	3	3
about	Women	6	3	9
Academia	Adviser Positive	3	6	9
n=12	Adviser Negative	1	0	1
	Adviser Mixed	2	0	2
Straying	Men	1	3	4
from	Women	0	0	0
Academia	Adviser Positive	0	2	2
n=4	Adviser Negative	1	0	1
	Adviser Mixed	1	0	1
Opting-Out	Women	10	4	14
of Academia	Adviser Positive	6	1	7
n=15	Adviser Negative	2	2	4
	Adviser Mixed	3	1	4

Separating out the career pathways into these four typologies is a useful framing

for students, faculty, program administrators, and policymakers. It is helpful for all

stakeholders to better understand students' attitudes and career mindsets as they leave

STEM doctoral programs. For example, it is noteworthy that the two largest groups are

Ambivalent about Academia (n=12) and *Opting-Out of Academia* (n=15). If students,

especially women in the life sciences, are pursuing academic postdocs and professorships

with ambivalence, PI's and universities should be aware of this. Non-academic career

supports should be made available to these postdocs and junior faculty who are

Ambivalent about Academia. For universities that hope to attract and keep women in

academia, more programs and support should be put in place to retain and promote

women STEM faculty. It is also noteworthy that more women (n=14) than men (n=1) are

in the *Opting-Out of Academia* group and that only men (n=4) comprise the *Best of Both*

Worlds group. In the next two chapters I will address some of the reasons more women

than men are *Opting-Out of Academia.* However, if we hope to diversify the faculty,

more women should be encouraged to consider the types of industry postdocs that would

allow them to pivot back into academia if they choose to. In other words, we should aim

for gender parity in all four groups, with more women in the *Best of Both Worlds* group

and fewer women in the *Opting-Out of Academia* group.

Looking across science disciplines, more women in the life sciences (n=10) are in

the *Opting-Out of Academia* group than in the physical sciences (n=4). I hypothesize that

this may have to do with differences in advising experiences between the life and

physical sciences. For example, more women in the life sciences than men may be

turned off by the CEO-type role of the PI (i.e., several students mentioned their distaste

for the day-to-day work of their advisers, whose work overseeing a lab was more akin to

running a small business than doing scientific experiments). Whereas women in the

physical sciences experienced more one-on-one advising relationships and were less

likely to advised by a faculty member overseeing a large-scale lab with many moving parts.

III. Discussion and Conclusion

In this chapter, I have described the three types of career-orientations found at the start and end of graduate school: *academia-focused*, *non-academia focused*, and *undecided*. While previous quantitative studies (see Fuhrmann et al., 2011; Gibbs et al., 2014; Sauermann & Roach, 2012) indicate that early career scientists report decreased interest in faculty careers overtime, my study did not find this to be the case. For example, the numbers of men (10 at the start and end of Ph.D.) and women (from 12 at the start to 10 at the end) in the *academia-focused* group remained fairly consistent over time, with larger shifts occurring in the remaining two groups; the *non-academia* focused group grew from 5 to 13 students and the *undecided* group dropped from 13 to 7 students. The growth of interest in non-academic careers, however, is in line with the findings in the aforementioned studies.

One possible explanation for the relative stability within the *academia-focused* group in my study, compared with previous research, is that I have identified through my Four Post-Graduate Career Mindsets typology that more than half the students graduating with an *academia-focused orientation* are ambivalent about this career path. Another explanation is that this study takes place at an elite research university. The culture at Calder University may place an even higher premium on preparing students for academic research careers than those of other R1 universities, where interest in faculty careers has been shown to decrease over time (Fuhrmann et al., 2011; Gibbs et al., 2014; Sauermann

& Roach, 2012). However, while providing valuable insights, these quantitative studies

do not address why these career interest patterns shifted over time. And although Gibbs

et al. (2014) did identify differences by race and gender—with White and Asian men

reporting the highest interest in faculty careers—they cannot explain how and why career

interest patterns vary based on social identities. The findings reported on in this chapter

help to fill these important gaps.

After documenting students' career-orientations at the beginning and end of

graduate school, I provide explanations in this chapter for how and why these changes

occurred. For instance, I found that one of the driving factors influencing career

orientations is the student's adviser and the adviser's attitudes towards and support for

academic and non-academic careers. Although there is a common belief that advisers

strongly encourage their students to enter academic careers (Mervis, 2008; Nature, 2011;

Stephan, 2012), very few studies have established this qualitatively (see Sauermann &

Roach, 2012 for a quantitative analysis). In this chapter, I demonstrated that many

advisers conveyed biases towards academic careers, often providing valuable

instrumental support for those students planning to continue in academia. Tenenbaum,

Crosby, and Gliner (2001) define instrumental help as focusing on learning how to do

academic research tasks specific to doctoral study (such as co-writing a paper). I found

that student-adviser relationship difficulties were associated with students receiving less

instrumental support for career advancement. This suggests that students with

challenging adviser relationships may be leaving academia more so due to interpersonal

issues with their adviser, than a lack of ambition or talent.

For students who did ultimately decide to pursue academic jobs, I demonstrated that there are a few critical components—in addition to the adviser relationship—that promote students' desire to remain on the academic track. These include a strong and supportive peer group, a love of teaching, an interest in helping other women succeed in science, and research project success. Likewise, I've shown how a struggle and lack of progress in one's research project, feelings of competition, uncertainty, and disillusionment, and a misalignment with the values of the field, lead to a loss of momentum and a student turning away from academia.

Given the advisers' biases towards academic jobs, it is not surprising that I found students who pursued non-academic careers carried out very independent, self-driven career identification and attainment strategies. These strategies, including internships, coursework, and extracurricular activities, were necessary mechanisms, used by students to identify and successfully secure positions in fields ranging from consulting to policy to media. Unfortunately, students who engaged in a more haphazard job search process were unable to secure satisfactory non-academic positions by their graduation date. These students will likely spend a year or more in a postdoc position trying to figure out a way to pivot out of academic research. Because of the emphasis on technology and innovation in today's global economy, there is an underlying assumption that STEM Ph.D. students at an elite research university will have a plethora of non-academic career opportunities available to them upon graduation. My research suggests that the most desirable jobs, such as those in consulting, biotechnology, and finance, are quite competitive. Students who participated in strategic career planning and exploration did well on the non-academic job market, but with little to no help from their adviser or

doctoral program staff. Thus, the current lack of support for non-academic career searches disadvantages students without the professional savviness to network and identify opportunities.

Based on my analysis of the data, I developed a typology of Four Post-Graduate Career Mindsets: *Academia or Bust*, *Ambivalent about Academia*, *Best of Both Worlds*, and *Opting-Out of Academia.* This framing is important to share with stakeholders in STEM doctoral programs as it helps to explain differences in career outcomes between men and women. Although over 50% of the students in my study are graduating with an *academia-focused* career orientation, most are doing so with some degree of ambivalence. A number of factors account for this. For women, these include self-confidence issues and concerns about work-life balance. A recent study found that stereotypes can cause people to exaggerate actual gender performance gaps, leading to lower self-confidence for women in domains where men typically dominate, such as STEM (Bordalo et al., 2019). The authors also found that stereotypes can play a role in explaining men's confidence, although to a lesser degree than women's lack of confidence.

Interventions aimed at broadening participation in the STEM academic workforce are often based on the assumption that if women and underrepresented minorities progress through the academic pipeline, achieve strong publication rates (van Dijk, et al., 2014), and are well mentored (Rockey, 2014), they will naturally ascend into faculty positions. My research, in combination with Bordalo et al.'s (2019) work on gender stereotypes, suggest that program completion, publication rates, and mentoring are not enough. Doctoral programs should address the gendered stereotypes that are likely

producing large gender gaps in the Four Post-Graduate Career Mindsets typology. I found there were more men than women with an *Academia or Bust* mindset and a *Best of Both Worlds* mindset. Likewise, there were more women than men with an *Ambivalent about Academia* mindset and an *Opting-Out of Academia* mindset. It is possible these mindsets are predictive of who will ultimately succeed in the academic labor-market, a hypothesis that I believe merits further research.

I now move in the next chapter to a more in-depth examination and discussion of the role of advisers on students' professional decision-making. This is followed by a chapter devoted to the role of gender and how men and women experience STEM doctoral programs differently, leading to a gender gap favoring men in academic science research positions.

Chapter 4. The Impact of Advisers on Students' Professional Decision-Making

I. Introduction and Background Literature

In order for doctoral students to succeed on the academic job market, they must first undergo years of training from a caring and committed faculty adviser. The quality of these training years, which colors the entire doctoral program experience, is largely dependent on the nature of a student's adviser-advisee relationship. Positive advising relationships are associated with successful disciplinary and departmental socialization (Hartnett, 1976; Weiss, 1981; Gerholm, 1990) as well as timely degree completion (Long, 1987; Girves & Wemmerus, 1988; Lovitts, 2001). Likewise, a negative advising relationship is predictive of doctoral student attrition and departure from the field (Jacks et al., 1983; Lovitts, 2001; Golde, 2005; Nerad & Miller, 1996). In fact, Golde (2000) found that students who leave their doctoral programs often point to negative adviser relationships as the primary cause.

Although the types of doctoral advising relationships differ greatly between disciplines and across institutions, most programs in the U.S. adhere to the pedagogical "apprenticeship" approach (Golde et al., 2009). Since their founding, American research universities have employed this model, borrowed from the German tradition. It entails a "master" faculty adviser training an "apprentice" doctoral student through frequent one-on-one teaching and learning opportunities, such as close collaboration on research projects and teaching undergraduate and graduate courses together. Typically, students are dependent on a single faculty member for both their training and professional development. The strength of adviser-advisee relationships is highly variable and often depends on the individual personality "fit" of the two individuals involved. This results

in disparate training, grant funding, and career development opportunities across students and often within the same adviser group. This, I find, leads to vast inequities in doctoral education and postdoctoral career outcomes.

This qualitative study makes a distinctive contribution by focusing on an important period in doctoral study, the completion of the Ph.D., when students are deciding their next steps in following an academic research career or diverting from that path. In discussing with students their thought processes around their career planning, it is evident that the relationships students have with their advisers are critical, not only to their training as scientists, but also to their decisions, upon completion of their Ph.D., to stay on the academic path or to stray away from it.

In this chapter, I discuss the impact advisers can have on life and physical science doctoral students' career aspirations and decision-making at one elite research university. I begin with a description of the adviser/lab selection process at Calder University. Next, I discuss the importance of advisers' management style. Lastly, I offer some simple suggestions for how students, faculty, and universities could re-think the adviser-advisee relationship, thus improving students' likelihood of adhering to academic career paths.

II. Findings

The Adviser/Lab Selection Process

During their first year, students in the life sciences at Calder concurrently engage in coursework and a rotation of three laboratories. The lab rotations are intended to expose students to three different sets of potential advisers, research projects, and lab communities. An assigned faculty program adviser matches students with their three lab

rotations. Before the start of their second year, doctoral students in the life sciences must select one of their lab rotations as their thesis lab. While the rotation system is designed as a two-way, six-week long interview process, typically students have a choice in which lab they will join. This is where they will spend the next four to five years learning to become scientists by working on an independent research project that will eventually become their thesis. The faculty member who directs the lab, typically referred to as its principal investigator (or PI), will become the student's adviser and professional mentor, responsible for his or her scientific training while at Calder.

In contrast, the physical sciences doctoral students at Calder are less likely to engage in a formal laboratory rotation system. Most of these students are assigned an adviser upon acceptance into their doctoral program. Others start their degree programs with the goal of finding a good adviser match for themselves as soon as possible. This process and the doctoral program support offered vary widely by department. The size and structure of the labs are also highly variable in both the life and physical sciences at Calder. From my interviews with students, I learned that doctoral students in the physical sciences will work closely with just their adviser/PI, having intensive one-hour meetings once a week. A second common training model at Calder—found in both the physical and life sciences—is one-on-one work with the adviser while simultaneously participating in a tight-knit lab community of other doctoral students and postdoctoral fellows (or postdocs). A third model involves students meeting weekly or bi-weekly one-on-one with their adviser, while also participating in a larger collaboration that may span multiple institutions. These larger collaborations will meet weekly via conference call, giving students additional opportunities to learn from others, to network across labs, and

to occasionally present their own work. A fourth model that occurs at Calder is when doctoral students have sparse interactions with their advisers, who may engage in frequent travel. These students are typically supervised by a postdoc in their adviser's lab instead.

Student Priorities in Selecting an Adviser

Based on my interviews, I learned that Calder students prioritized a prospective adviser's research agenda and its alignment with their own research interests when selecting an adviser and/or lab. Most students arrive at Calder with very specific research interests. In many cases, there might be only one or two faculty members whose research interests align with a particular student. In these cases, the adviser selection process can seem more straightforward. In other cases, where students could see themselves happy with a number of different advisers, it comes down to the type of research projects available to them. Specifically, if the project is interesting and exciting and if it seems likely to yield a good first-author paper or two, doctoral students will be compelled by the opportunity to work with a specific adviser. For instance, Claire, a physical science student, described "meeting with [my adviser] to start graduate school when this [new piece of equipment] was coming online, and he had gotten time with it and that was what he was offering as my first project and I was like, 'this is kind of too good to pass up.'"

Other considerations for students included the adviser's personality and temperament, the size of his or her lab, the lab culture—especially whether doctoral students and postdocs seemed happy to be working there, and the PI's reputation for being a good adviser. Jane, a life science doctoral student, told me she deliberately

sought out a female adviser to avoid any sexual tension or harassment issues, "just so that would never be a question." Additionally, some students recalled being surprised and disappointed to realize that lab size and composition can fluctuate during a student's four or five years in a lab, depending on grant funding and postdocs' departures. Susana chose her life sciences lab because she was "mostly attracted to all the people [she] met who were in the lab, who unfortunately, left after the first year or two." Even the personality and temperament of an adviser can vary, pre/during/post tenure review, or before/after having a baby, as stress levels are heightened and accessibility to students becomes scarce. Katie, a physical science student, was one of her adviser's first doctoral students. She has seen her move up through the faculty ranks:

> *I've seen three different versions of her. I saw her super relaxed as a new faculty member just out of postdoc. Her transition to becoming super PI: getting all the money, getting all the students, getting all the postdocs, and her group tripled. And then now [post tenure review] she's back to this kind of casual… it's like, 'oh, if this is what you're gonna be like, I'm really sad I'm not your student now because you were very high strung and emailing me late at night: 'I need this by tomorrow for a talk!' and now you're like, 'everything's great.' I think those transitions were really the hardest and that kind of carried on throughout my time here.*

While some students mentioned hearing about their adviser's management style through word-of-mouth from a faculty member's former students, none considered this a major influence in choosing their adviser. Yet for the small number of students who were unsatisfied with their adviser-advisee relationships, frequently their adviser's management and communication styles were causing their dissatisfaction. Ultimately, 7 out of 40 students (17.5%) switched advisers. These switches were typically, but not always, made due to management and communication issues.

Switching Advisers

Switching advisers, while sometimes emotionally fraught, is typically an option at Calder, though this seemed more culturally acceptable in some departments than others. In my study, five students in the physical sciences and two students in the life sciences switched advisers. For students in the physical sciences, there is a natural point in the program, just after completion of the first paper, when students can easily switch advisers if they feel they have a poor match. Meanwhile, for students in the life sciences, the point where they can make an adviser switch comes after successfully passing their qualifying exam at the end of their second year. For other students I interviewed, although they were dissatisfied with their adviser relationship, they felt too entrenched in their lab community and too deeply immersed in their project to switch advisers. For these students, the idea of switching seemed too daunting or it was not part of the culture in their department, so they did not seriously consider this option.

Michelle was one of the two students in the life sciences who switched advisers. She said, "I had to completely switch my area of focus, but that was okay, too, because the original area was getting boring for me. This [new adviser's work] was a whole new area that I had to learn from the bottom up." The adviser switch also factored into Michelle's adding an extra year to her Ph.D. program, graduating in six years instead of the expected five. According to Michelle, it was worth it. "The adviser means so much and I always tell people that I was very, very lucky and to be very careful of who you choose [as your adviser] and to go shopping and talk to people and sit down and really get to know them before you choose which one you wanna work with."

Overall, the students in the life sciences who completed the lab rotation program were less likely to consider switching advisers, even if they were dissatisfied. There are several reasons for this. First, it is rare for students to switch advisers in the life sciences; doing so would draw negative attention to both the student and the adviser. Second, the lab rotation system ensures that students are exposed to at least three different possible advisers and lab cultures. Students may be reticent to switch advisers when they know that each adviser and lab culture has its own set of trade-offs. Third, students have invested a lot of time and effort to their research project by the time they may realize their adviser is not a good match for them. As was the case with Michelle, switching advisers can add a year or more to your Ph.D. program and many students are not willing to make that sacrifice.

For students in the physical sciences, their independent research is often divided into two discrete projects. After completing their first research project, physical science doctoral students can choose to pursue a new line of research or to switch to an adviser who is a better personality fit for them. Since switching advisers is something that occurs with some degree of regularity, depending on the department, there is less stigma attached to it than there is when switching advisers in the life sciences.

Advisers' Management Style

One of the hallmarks of doctoral education is its use of the apprenticeship model, whereby a master teacher—the faculty adviser—trains students as scholar apprentices. This model entails advisers giving students opportunities to observe and to practice a set of skills, moving from simple to more complex tasks, while being supported with regular

coaching and candid feedback (Golde, Bueschel, Jones, & Walker, 2009). This

pedagogical approach is unique to doctoral education and differentiates it from other

forms of graduate and undergraduate school, which rely more heavily on classroom

instruction. As Golde, et al. (2009) put it:

> "When the relationship is good, it is very, very good. Outstanding advisers
> challenge their students, set high expectations and standards, generously share
> their expertise, and individually tailor their students' educational experiences to
> meet students' needs. Unfortunately, when the relationship is bad, it can be
> horrid" (p. 54).

The majority of students in this study (71%) came straight from college or from a

master's program with no prior full-time work experience. This was the first time they

were working full-time with a supervisor in a professional, not just academic, setting. In

doctoral education, the traditional metrics of success, such as grades, become less

important. Often students would work hard, logging many hours in the lab only to have

an experiment yield disappointing results. New skillsets in autonomy and self-advocacy

become paramount in a Ph.D. program. For some students, learning these new skills,

working one-on-one with an adviser, and familiarizing themselves with a new culture of

achievement presents a big challenge.

Communication

During their rotations, both advisors and life science doctoral students are on their

best behavior, trying to make a positive impression on one another. Jennifer described

selecting her advisor because she "really enjoyed chatting with him about science." Later

on, she realized that "it's easier to talk to somebody when you just need to make a good

impression initially. It's much harder to maintain that." After she officially joined his

lab and was working with him, Jennifer struggled with her desire to maintain his good opinion of her. That desire ended up "being more important than getting my questions answered," which affected her scientific training and her satisfaction with her project. For Jennifer and several other students, once they started working closely with their adviser, communication problems quickly surfaced. Jennifer described coming into her Ph.D. program "with a lot of hubris because I had already done a lot of research and I felt it had gone well." She anticipated that "everything was going to go beautifully," but quickly realized that:

> *The hardest part of the research is figuring out how to structure your own project and also figuring out how to interact with your adviser…it took a long time for me to figure out the best way to communicate with him and to understand what his expectations were, because they weren't explicitly stated. And so, there were long periods where I would spin my wheels in the research.*

Jennifer went on to explain that while she expected her first project to be "a little project," that would produce "a little paper," her adviser kept asking her to "add one more thing." This back-and-forth process and the mounting frustration that grew with it lasted two-and-a-half years. Eventually, Jennifer said she "figured out how to communicate with him" by learning "to push back as hard as he was pushing and not take anything that he was saying for granted."

Clarity of Expectations

Jennifer and her adviser could have possibly avoided several years of miscommunication and frustration if the expectations of project scope and length were laid out more explicitly at the start. Similarly, Nick, a physical science student was also challenged by his first adviser's "hidden standards." When he started working with his

adviser, he would have weekly check-in meetings where he would consistently receive

positive feedback on his work. He and his adviser decided which results from their

project Nick would present at an upcoming conference. He explains:

> *I present to him a plan and every week we'd meet and I'd present progress
> towards that plan and he would be like, 'this is great, this is great, this is great;
> everything's fine.' And then, two weeks before the conference, he'd be like, 'all of
> this is nonsense. You should really have done X, Y, and Z. This is not ready for
> prime time. You can't present this at the meeting.*

Nick would then "spend two weeks sleeping in the lab" trying to get everything done in

time for the conference. He describes the experience as a "kind of whiplash," where

everything appeared to be on track for weeks and only to abruptly find out that, "I've

done nothing right and everything is trash and nothing will work." In fairness to his

adviser, he concedes that his adviser must have been "giving signals in some kind of

second code," that his other doctoral students were able to pick up on. Nick describes

himself as a more literal person who has trouble picking up on subtle hints or non-verbal

messaging conveyed through body language. He said he prefers people to "tell me what

you want in English, and I'll do it."

Due to the misalignment of communication styles, Nick decided to switch

advisers after the completion of his first project. He described his new adviser as also

hands-off, without a lot of guidance. However, his second adviser was much more

supportive in "backing me, no matter what I did." In the few instances when his adviser

did not agree with what he was doing, he was able to express this clearly and as soon as it

came up rather than waiting for a meeting. Nick describes the contrast between his two

advisers in these terms: "the guidance and feedback I got from [my second adviser] was a

lot more actionable and a lot more aligned. I was able to align his feedback with what I

was doing at all times. Whereas with my old adviser, all the feedback I'd be getting would be positive and then he'd let me go fall off a cliff." Luckily for Nick, the culture in his physical sciences department was supportive and encouraging of students switching advisers to work with different people. I found this to be less true in the life sciences where the rotation system is designed to expose students to three different learning and teaching styles. None of the students in my study identified advisers' communication style as one of the determining factors in selecting their adviser and/or lab. Yet, I found that clear communication is at the foundation of every strong adviser-advisee relationship in this study. It is possible students at age 22- or 23-years-old may not yet be able to identify their preferred communication style with advisers and whether they prefer a hands-on or hands-off style of mentoring.

Hands-off vs. Hands-on

Students typically described their advisers as either hands-off or hands-on in their management style. Twenty-three students (58%) described working with a hands-off adviser, 14 students (35%) described working with a hands-on adviser, 7 students (18%) described working with an adviser who was both hands-off and hands-on at various points[6].

Hands-off advisers were the most common approach used and this seemed to be the default setting for advisers. Since advisers are typically PI's running a lab and overseeing larger research projects, they are incredibly busy, responsible for many direct-report staff, doctoral students, and postdocs. Due to time constraints, most advisers do

---

[6] These numbers include students who were co-advised by two advisers at once and students who switched advisers and had more than one adviser over time.

not have much time to devote to hands-on mentorship of each doctoral student, and several students really thrived working under a hands-off mentoring style. As Claire explains:

> *Looking back at all of my past advisers, I work much better with advisers that tend to be very hands-off. People talk about hands-off versus hands-on all the time. Some people really like to be taught directly and I don't like that at all. I much prefer sort of the advising style in which they throw you in the deep end of the pool and you figure it out. It's frustrating at the time, but I learn a lot more and at the end of it, I tend to do better in terms of actually acquiring a skill.*

Like Claire, Alison also studied physical science and preferred a hands-off adviser. Her first adviser was very hands-on and it was not a good match for her so she switched to a more hands-off adviser. Alison describes her second adviser as "probably one of the least stress-inducing advisers imaginable… he is really not very demanding at all. He's very supportive of whatever any student wants to do, but doesn't really set expectations or enforce expectations and so, that means if you're not self-motivated, it's very easy to just sort of slide into unproductivity, but it also means that you're not stressed out." Alison found with her first, more hands-on adviser, he was very clear with setting expectations. Unfortunately, he also did "not hesitate to let students know when they failed to meet [his expectations]." It is possible that if Alison had a positive experience with her first hands-on adviser, she may have disliked how hands-off her second adviser was. But in comparing the two advisers, she found she preferred working with an adviser who was more supportive and less stress-inducing. Reflecting on her own mentoring approach, "I would definitely want to be a more hands-on adviser than he is because I do think he doesn't strike the right balance, exactly, especially with younger students, it's not gonna work."

For Michael, although having a hands-off adviser means "there's almost no guidance," it also forces him to make his own decisions and practice thinking and acting like a PI or assistant professor, within the safety net of graduate school. Michael described his PI as someone who "runs a lot of companies and his academic advice is not the way most PIs work. Most PIs would be like, 'here's the field, here's your contribution, this is how it would fit in. These are the kind of things that people would wanna read about.' I don't get any of that. And so that's a real bummer because I can't always tell where my stuff fits. The advantage is I have to make all those decisions myself and those choices myself…and I think it helps accelerate your navigation of being an assistant professor because you don't have anybody to really help you."

In contrast, Michelle's first adviser in the life sciences was very hands-off and only met with her once her first year, for a 6-minute meeting. During her second year she switched to a more hands-on adviser who "took me step-by-step, 'this is how you start. This is what a lit review is. This is…' [he showed me] all these different things and really mentored me a lot. And I think that patience from him was the best thing. He really taught me how to be a researcher and identified both my strengths and my weaknesses." Likewise, Emily was also appreciative of her hands-on adviser in the life sciences:

> *I really do appreciate his style. It's definitely not for everybody, but it's not like he's peering over your shoulder or he doesn't trust you or he feels like he has to check in all the time because you're not doing good work or anything like that. It's more that he's so genuinely curious and excited about the science like all the time, that he just always wants to know what the results are. He's just always excited to know what's going on. So I think it's felt more encouraging to me rather than…I mean there's definitely times that it's annoying, that it's like, 'woah. We already talked about this yesterday. I don't have any results yet. I need to analyze it.' But I think it was helpful to have kind of frequent back and forth conversations about things and just kind of bounce ideas off of him. And he*

was always willing to talk about things, but also giving me initiative in letting me decide what I…it wasn't like I was just doing what he wanted me to do. I felt like I was able to have freedom to set up the experiments the way I thought were best, but then he's also always there to talk about things. So that's helpful."

One-Size-Fits-All Approach

As their adviser-advisee relationship progressed, most students quickly realized how their advisers' "hands-on" or "hands-off" advising style—and their communication style—was or was not a good fit for their individual learning needs. Due to the multiple competing demands on advisers' schedules, most advisers (58%) defaulted to the less time-consuming "hands-off" approach. Outside of lab, students routinely discussed their advisers' advising approach with other students. Consensus was formed and advisers' reputations were passed on quickly from student-to-student. Some students told me their advisers would give more detailed feedback to students who were struggling. For example, international students who had weaker English language skills would reportedly get more detailed feedback on papers. But more often than not, advisers tended to apply a one-size-fits-all approach in working with students.

Jessica, a doctoral student in the life sciences, had a mixed experience with her adviser. She described her as emotionally volatile and "kinda mean…where she really wants to just needle you and make you feel bad." Jessica attributes this to her adviser wanting "other women to toughen up and be prepared for a man's world of academia." But she also assisted Jessica in applying for prestigious grants and was especially helpful in "thinking about the way to best navigate the environment of getting into different [postdoc] labs." Jessica felt that while her adviser's style ultimately worked for her—she landed a great postdoc and intends to pursue an academic research career—it doesn't necessarily work for everyone. She told me:

Some things will work on some people and some things won't work on them, and you can't just have the same style with everybody because then you're alienating certain people. And that seems so obvious to me, but it's a concept that never occurred to a lot of faculty, that they might need to do things differently with different people. It's like this foreign, alien concept.

Brandi, another doctoral student in the life sciences, plans to leave academia and pursue an industry job after graduation. This is due, in part, to the negative relationship she had with her adviser. When she first joined her adviser's lab, she had a stellar resume, including several years as a competitive Division I college athlete. She thought her adviser took her on because of her resume, that she appeared to be "a gunner," and that she was someone who was "gonna do something." Then "probably my boss realized that I actually needed more [mentoring] than he really wanted to give. And I don't think that the burden would have been so much on him if he'd had a postdoc who was junior and able to take some of my need for guidance. But that wasn't something that was in place in our lab and so, yeah, it unfolded as it did." In Brandi's case, when it became apparent that she needed more hand-on guidance, her adviser was not willing or able to provide that. As a result, Brandi is finishing her program, according to one of her dissertation committee members, looking "downtrodden… like the life has been kicked out of [her]."

Advisers as Negative Role Models

Most students I interviewed said that when they started graduate school, they were either intent on becoming a professor or a PI or at least considered it as a possible outcome. Only two life science students in my study started graduate school intending to work in industry post-Ph.D. Of the students who graduated with the first two Post-

Graduate Career Mindsets, *Academia or Bust* and *Ambivalent about Academia*, three-quarters had positive relationships with their advisers. Meanwhile, around half of the students who fell into the third and fourth career pathways, *Best of Both Worlds* and *Opting-Out of Academia*, either had mixed or negative relationships with their advisers.

Of the students who experienced mixed or negative adviser-advisee relationships, several saw their advisers enduring careers and lifestyles that turned them away from an academic career. This, as mentioned previously, in Chapter 4, was one of the strongest influences dissuading students from pursuing academic careers. Observing lifestyle choices their advisers made, some students became disillusioned and decided that the academic culture was misaligned with their personal values. For instance, Katie, a physical science doctoral student who is in the *Opting-Out of Academia* group watched her adviser, a single woman in her 30s, go up for and receive tenure, all the while working long hours and having very little time for her personal life. Katie initially wanted to become a faculty member at a liberal arts college, but when she "came to Calder, that changed everything." She told me, "I came here and I was like, 'oh my gosh, if this is what being a professor is like, you cannot pay me enough money in the world to be a professor."

Hannah, a doctoral student in the physical sciences who is in the *Ambivalent about Academia* group, lined up a tenure-track faculty job at a state university next year. Her adviser strongly pushed her to apply to the most competitive R1 university jobs, but she was not interested in those and instead set her sights on a public state university or a liberal arts college. She said, "I just see the professors at Calder and they look so stressed all the time and my parents [who teach at a public state university and a small liberal arts

college] are stressed, but not that stressed." Doctoral students at Calder are socialized by

faculty and peers to aspire to R1 professorships. While Calder faculty may view teaching

at a state university or a liberal arts college as a "fall back" option with lower

professional status, students like Hannah did not. Instead, they thoughtfully and

strategically chose to pursue these jobs as a means of doing high-quality research and

teaching in an environment that fostered better work/life balance than the one modeled

for them by faculty at Calder.

David is the physical science student with a *Best of Both Worlds* mindset. In

deciding to pursue an industry postdoc, David was strongly influenced by his adviser who

was denied tenure at Calder. He told me:

> *One of the things that happened that solidified the decision for me was the adviser that I did pick in the start of grad school went up for tenure half-way through my Ph.D. and didn't get tenure, even though he [made this amazing discovery]. It was a big deal but because [he was away doing research], he hadn't been here to build those relationships and stuff. So, then he didn't have a very strong tenure application. So, I was like, well, I saw how hard he worked and put in all that time. And then because he wasn't around in the department during the socializing aspect of trying to get tenure, it didn't really work out for him. So, I said, 'even if I do go all-in on this, it's gonna be pretty hard to actually get to the end of the road anyway.'*

David also received close mentoring and guidance from his adviser's postdoc,

whom he met with informally on a daily basis to talk about his work. He observed this

postdoc go into "an industry job because he didn't have a lot of luck on the faculty job

market." David said, "I basically had a lot of examples of people not really having luck

at various stages of where I was gonna be and it was like, 'okay… maybe I might wanna

do something else." In addition to the highly competitive nature of academia, David was

also concerned with the impact of work on his personal life. While interviewing for jobs,

David would count the number of wedding rings he encountered during the interview

process. He used this as a metric to gauge how much work/life balance he might expect with the various teams he was considering joining.

Jane is a life sciences doctoral student with an *Opting-Out of Academia* mindset. Jane had a mixed experience with her adviser. In hindsight, Jane said she now looks back and appreciates her adviser and all that she has done for her. But there were several bumpy patches in their relationship, including a big disagreement when Jane decided to pursue a master's in science and technology that would require additional coursework, taking her away from her lab responsibilities. Ultimately the disagreement was resolved favorably for Jane, but she remained bitter about the experience. Jane also saw her adviser as a negative role model:

> *The choices that I see her having made to be a PI are not necessarily choices that I would make. She's in lab a lot. She's working all the time. She's super stressed, and lately she's been saying, 'oh, I don't sleep well. I wake up screaming at night,' which is just like, 'oh my God, what are you doing? Just take a break, relax.' But she never takes a break. If that's what it takes to succeed in science, I do not love science anywhere near enough to do that.*

Jane's adviser is married but has no children. She told Jane that if she wanted to have children, she needed to "find a good husband who will take care of your kids for you, so you can succeed in science." The underlying message to students being that academic careers do not allow for much work-life balance or time to raise children.

Tom is a life sciences doctoral student with an *Academia or Bust* mindset. He and his wife met at Calder during their first year in the same doctoral program. He described Calder as a place where people "see their professors struggling and not having work-life balance. That makes them not want to pursue their [adviser's] career. My wife is in the same graduating cohort [as me] and she's definitely not gonna do a postdoc and one of

the reasons is because her professor, who is single and doesn't have a huge amount of personal life, is always stressed. And my wife's like, 'I'm not doing that.'"

Faith, a life sciences doctoral student with an *Opting-Out of Academia* mindset, has a job lined up as a health care consultant next year. She also was turned off by the life of a professor, but not due to the lack of work-life balance. For her, the demands of the day-to-day job just seemed overwhelming and not something she was "necessarily interested in, what with having to balance mentoring students and teaching and running a lab and getting grants. And then, each piece is supposed to be 100% of your time. So, it's like, how can you have 400% of the normal amount of time of anyone else?" Like David, Faith was also influenced by the postdocs in her lab, "who've been there longer than I have and who're struggling to find positions in academia. Many people do two postdocs, each of which lasts five or more years in biology. So, by the time you start your career, it's the time a lot of people are thinking about retirement [chuckle]. Not really, but it just seems like a really prolonged journey, and also very stressful, both mentally and financially."

III. Discussion and Conclusion

Through my analysis, I demonstrated that the Ph.D. adviser is, for STEM graduate students, the most important factor affecting one's post-graduate career plans, and in particular, one's adherence to the academic track. As such, the adviser selection process should be viewed as one of the most important decisions a STEM doctoral student will make in graduate school. However, because it comes at the beginning when most students are just getting their bearings, it is often a decision that students make without

clear consideration of the outcomes and implications that will result from it. It is usually only in hindsight that students realize the full impact of their choice of adviser. In this regard, students often referred to "luck" playing a role in "clicking" with one's adviser. As Adam, a male physical science student put it, "if there's one thing that can sink or swim a graduate career, it's your relationship with your adviser, and that you have very little pre-knowledge about before you show up."

Beyond simply impacting the quality of the doctoral experience as a student, the adviser-advisee relationship also opens up access to resources. These resources can be of instrumental value, such as access to specific lab equipment or unique datasets, or monetary value, such as funding to present at international conferences or to travel abroad for data collection. The advisers' professional network is another resource that is opened up to advisees; by facilitating important introductions, advisers can help their students land job opportunities, such as prestigious postdocs. These findings are consistent with those of Tenenbaum, Crosby, and Gliner (2001). Through a survey of 189 graduate students at UC Santa Cruz, Tenenbaum et al., identified three types of help that advisors might provide to students: instrumental help (learning academic skills), psychosocial help (care of individual's wellbeing), and networking help (connecting with professional contacts). I add to Tenenbaum et al.'s (2001) definition of instrumental help by including financial and non-financial benefits that assist with learning academic skills, such as money to attend conferences (financial) or access to data (non-financial).

Because of the quality of the adviser-advisee relationship and the subsequent access to important resources that can propel a student's career forward, I recommend more attention be paid to the adviser selection process. Many of the students in my study

did not consider the importance of an adviser's communication style and whether a "hands-off" or "hands-on" approach would best suit them. Instead, they prioritized prospective advisers' research agendas, potential projects offered, and lab cultures as they made their decisions. This resulted in the most successful adviser-advisee relationships being attributable to good luck, rather than the individual agency of students and advisers, or the effectiveness of doctoral program administrators. Yet we know that faculty advisors play an essential part in doctoral education (Austin, 2002; Baird, 1992; Golde, 2000; Golde & Dore, 2001).

Since the faculty adviser is the central means of socializing doctoral students, setting the foundation for knowledge and disciplinary values and modeling the roles of academics in the discipline (Baird, 2002), it is no wonder faculty serving as negative role models impacted students' decisions to leave academia. Golde (2000) found that students who leave their doctoral programs often point to challenging relationships with their advisor as the motivating factor for the split. Although my research does not examine attrition, it is looking at how doctoral students make decisions to leave the academy. The adviser selection process is clearly one that can enhance or limit doctoral students' career aspirations. Students who viewed their advisers as negative role models were ultimately turned off by the idea of an academic career trajectory. They realized that they could not see themselves doing their advisers' job and being happy. Other students observed their advisers working hard and yet denied tenure. The career path to become a tenured academic researcher is daunting and laced with uncertainty. With three to six, or more, years of postdoctoral fellowship(s), followed by another five years of being an assistant professor before going up for tenure, the students realized that in order

to stay on that path, they needed to really love what they were doing to make this type of commitment. Several students echoed the sentiment shared by Katie, "I love science, but if this is what it takes to succeed in academia, I don't love it nearly enough."

With the role of advising in career-decision making well established, in the next chapter I delve more deeply into the role of gender on STEM doctoral education. I show how STEM doctoral programs continue to operate in a gendered environment where the norms and expectations of the discipline reproduce differences that continue to privilege men at the expense of marginalizing women.

Chapter 5. The Role of Gender on Students' Professional Decision-Making

I. Introduction and Background Literature

Despite more women obtaining doctorates in the sciences, the proportion of women entering the professoriate has not kept pace (NSF, 2014; NSF, 2017). At the highest faculty ranks, only 22% of STEM full professorships at R1 institutions are held by women (NSF, 2015). Meanwhile, the percentage of STEM Ph.D.s awarded to women in 2017 was 55.3% in the life sciences, 33.1% in the physical sciences, and 25.4% in mathematics and computer sciences (NSF, 2017).

In Ceci and Williams's (2010) analysis of over 400 research studies on biological sex differences, three dominant theories attempt to explain the underrepresentation of women in STEM fields. First, innate ability differences favoring boys and men; second, social and cultural biases and barriers, such as gender stereotypes and gendered cultural expectations; and third, career preferences, including women's preference for time flexible careers that can be adapted to personal and family needs. In their 2010 book, Ceci and Williams describe and analyze the evidence for each of these explanations, finding most credibility in the third theory: women's career preferences.

Although Ceci and Williams's work assesses mathematically intensive scientific professions, including but not specific to faculty careers, it is important to consider their career preferences theory as a possible explanation for the gender gap in the STEM academic labor force. Other studies that attempt to explain this are typically reliant on quantitative datasets to identify national trends (see Lerchenmüller & Sorenson, 2018; Hill et al., 2010). Additionally, quantitative studies have done a good job systematically documenting the publication gap favoring male scientists. These studies demonstrate that

women publish fewer papers (Cole & Zuckerman, 1984; Long, 1992; Xie & Shauman, 1998), publish in less prominent journals (Brooks et al., 2014; Lerchenmüller et al., 2018); are cited less often (Lariviere et al., 2013; King et al., 2016), and appear less frequently as first and/or last author on their publications (West et al., 2013; Filardo et al., 2016). Less, however, is known about the processes and mechanisms that are associated with these differences in publication records. For example, we know that women face discrimination in academia (Litzler, et al., 2005), disparity in the time spent on childcare (Mason & Goulden, 2004; Craig & Mullan, 2011), higher rates of attrition from doctoral education (Ferreira, 2002), insufficient doctoral advising (Seagram, Gould, & Pyke, 1998; Nettles & Millett, 2006; Schroeder and Mynatt, 1993), and work-life balance issues (Holmes, O'Connell, Frey, & Ongley, 2008; Mason & Goulden, 2004; Williams & Ceci, 2012). But we don't yet know which of these may account for the persistent gender gap favoring men in STEM faculty positions.

This chapter extends the literature on the gender gap in STEM faculty careers by examining the experiences doctoral students encounter at one elite research university widely considered an incubator for the next generation of STEM faculty. This analysis extends our understanding, established by Sallee (2010), of the impact of gendered disciplines on doctoral students' career outcomes. It also furthers our knowledge about possible explanations for the underrepresentation of women in STEM faculty careers. By analyzing doctoral students' decision-making at a critical juncture—at or near completion of the Ph.D.—I am able to shed some much-needed light on one of the leakiest points for women in the academic pipeline.

In the section that follows I will describe the literature on two major challenges for women in STEM doctoral programs: advising and work-life balance. These end up being particularly salient issues for the students in my study. Then I will turn to my findings and discuss students' adviser satisfaction. This discussion will include the impact of same-gender advising, the experience of being advised by pre-tenured faculty, the maintenance of clear personal boundaries between advisers and students, and work-life balance and its implications for men as well as women. Other key challenges for women that emerged from the data included messaging around "how to succeed as a woman in science," telling a story with your data, and playing the game/politics of science. I close the chapter by summarizing its key findings and discussing some of their implications for practice.

Challenges Women Face in STEM

Advising

In the sciences, doctoral advising is considered the heart of scientific training (Paglis et al., 2006; Barnes & Austin, 2008). Ample research has demonstrated that improved advising and clear program requirements are associated with reduced attrition and timely graduation rates (Ehrenberg & Kuh, 2009; Lovitts, 2001). However, compared to their male counterparts, women report receiving less faculty guidance in designing research (Nolan et al., 2007), writing grant proposals (Fox, 2001), and co-collaboration on publications (Seagram et al., 1998). Overall, men report more positive experiences with their dissertation advisers than women; women are more likely than men to state in hindsight that they would have used different criteria in selecting their

dissertation adviser, and women are more likely than men to switch dissertation advisers during graduate school (Nolan et al., 2008). Importantly, more men (78.6%) than women (63.4%) sought the advice of dissertation advisers in choosing a postdoctoral appointment (Nolan et al., 2008). Meanwhile, mentoring appears to be more effective for women than men, leading female scientists to increased rates of graduation and successful employment (Preston, 2004). For example, Gilbert and Rossman (1992) found that female students benefit from mentors in three primary ways: exposure to new models for careers, feelings of acceptance and empowerment, and sponsorship by a mentor.

Same-Gender Advising

Research suggests that working with faculty members of the same gender may impact a student's interest in a subject. Female instructors positively influence course selection and major choice in some disciplines, supporting the possibility of a role model effect (Bettinger & Long, 2005). These effects were particularly positive and strong in math and statistics, geology, sociology, and journalism. Additionally, female faculty are more likely to emphasize female participation in laboratory meetings, frequent interactions with faculty, acquisition of a broad range of skills, and higher expectations for female students in seminar presentations (Fox, 2003). These same-gender faculty-student interactions appear to be especially beneficial for women in STEM fields (Hoffman & Oreopoulos, 2009; Carrell et al., 2010). A recent study of chemistry Ph.D. students found that those working with same-gender advisers tended to be more productive during their Ph.D. and were more likely to become faculty members themselves (Gaul & Piacentini, 2017). However, in studies investigating the role model

and mentoring effects on female Ph.D. students in economics, Neumark & Gardecki (1998) found no evidence that initial job placements for female graduate students was aided by having female faculty members on one's committee or by having a female dissertation chair. They did find that female faculty members reduced the time spent in graduate school by female students. This was consistent with Dynan & Rouse (1995)'s findings that female faculty do not affect the probability that males or females continued to study economics as well as Canes & Rosen's (1995) findings that an increase in female faculty had no impact on the percentage of undergraduate females studying science or engineering. This issue is clearly still in need of further research and understanding.

Work-Life Balance

For most women pursuing STEM faculty positions, career-life balance is a well-documented challenge (Holmes et al., 2008; Mason & Goulden, 2004; Williams & Ceci, 2012). This is a key issue impacting persistence and advancement in academic careers that typically affects more women than men. For example, Mason and Goulden (2004) analyzed a nationally representative sample of doctoral recipients as well as 4,459 tenure-track faculty at the nine University of California campuses from 2002-2003. They found that women faculty who have children soon after completing their doctorate are less likely to attain tenure than men who have children at the same point in their careers. Additionally, more fathers (66%) worked more than 60 hours per week than mothers (50%). Overall, women with doctorates reported lower rates of marriage and fewer children; 41% of female academics and 69% of male academics reported being married

with children. Among academics, 28% of women and 11% of men reported to be unmarried, and women experienced higher rates of divorce (144% of the men's rate).

The majority of women scientists cite family issues, such as feeling overwhelmed by academic life after the birth of a child, as a major barrier obstructing their success in science (Holmes et al., 2008). In academia, and especially in the sciences, professors are expected to demonstrate their commitment to the profession through long hours, linear career trajectories, and relentless accessibility and visibility (Acker, 1990; Drago et al., 2006; Jones, 2012; Williams, 2000). In many departments, working 12-hour days, 6-days a week is considered the norm for scientists at all levels, including the doctoral, postdoctoral, and pre-tenured faculty stages (Jones, 2012). Although the challenges in balancing career and life are understood to affect all women and especially mothers (Holmes et al., 2008; Mason & Goulden, 2004; Williams & Ceci, 2012), very little research has focused on how these issues may impact women during their doctoral education, before the start of their post-Ph.D. careers and generally, before they start having children.

II. Findings

Adviser Satisfaction

As Jennifer, a physical sciences student put it, "relationships with advisers are almost always complicated." Every student in this study experienced struggle; many of these struggles were related—either directly or indirectly—to their relationship with their adviser. Yet, most students viewed their overall adviser/PI experience holistically, acknowledging the benefits as well as the drawbacks that came with working with their

particular adviser. Looking back on their experiences, students tended to view their

advisers in a positive light; 67% of men and 58% of women indicated overall satisfaction

with their adviser. Likewise, 35% of women and 25% of men reported being dissatisfied

with at least one of their advisers (students who were the most dissatisfied often switched

advisers and experienced two different advising relationships during their doctoral

program). This is consistent with the research literature on advising satisfaction by

gender (Nolan et al., 2008). However, unlike in previous research, the men (25%) in my

study were more likely than the women (15%) to switch advisers during graduate school.

Although I believe one particular department may be driving this trend, as there is a

natural opportunity—between the first and second research projects—to make an adviser

switch and approximately one in four students in this department choose to do so.

Same-Gender Advising

While the majority of students (75%) had been advised by at least one male

adviser, including students who switched advisers and those who were co-advised by two

advisers, 35% of women and 15% of men worked with a female adviser and 71% of men

and 54% of women worked with male adviser. Unfortunately, women with same-gender

advisers (67%) were more likely to have described their advising relationships negatively

than men with same gender advisers (30%). Caroline is a life sciences student who was

warned by current graduate students that she might have trouble working with her female

adviser. She describes some of the challenges she faced:

> *It became clear that it was very hard to actually use the equipment in her lab.*
> *She was very protective of it. She also oddly didn't want me to take a lot of*
> *classes. So, I realized I could do similar work [to hers] in labs or by taking*
> *classes to learn these things, but she wouldn't let me. So, I made deals with*

professors where I could audit their classes and I would literally sneak to the classes and I would disappear for a few hours every day and she'd be like, 'oh, where were you?' and I'd be like, 'oh. The library.' And I was just taking secret classes. So, at that point, when I was reflecting on the fact that my adviser didn't seem to want me to be learning and that I was doing secret lab work and taking secret classes, I shouldn't be doing these things in secret. I should be getting credit for them. And then I sought out her former graduate students and they all had similar experiences that only seemed to get worse over time as they got higher in graduate school and really needed to be doing research. It just became very clear to me that I should switch advisers or schools.

Of the 6 out of 9 women who described their same-gender advising relationship negatively, two switched to male advisers, with one having a positive experience and one having a negative experience. Of the 3 out of 9 men described their same-gender advising relationship negatively, two switched to other male advisers, both with positive outcomes.

Both women and men described having more positive experiences with male advisers; 69% of students described having an overall positive relationship with a male adviser compared with only 33% of students who described an overall positive relationship with a female adviser. Relatedly, students with male advisers were also more likely to be working with advisers who were tenured; 64% of the male advisers and 33% of the female advisers in this study were tenured at Calder, compared with 25% of male advisers and 50% of female advisers who were not. This is roughly on par with the overall proportion of tenured women across all disciplines at Calder (27%) and the proportion of women on the tenure-track (40%). Within science at Calder, only 18% of tenured faculty are women, while 50% of tenure-track faculty are women. In this study, 4% of male advisers and 17% of female advisers went up for and received tenure during the student's advising relationship. Only one student had an adviser who went up for

tenure and was denied tenure during the advising relationship. This adviser was male.

The remaining advisers who went up for it were promoted with tenure.

The Consequences of Being Advised by Pre-Tenured Faculty

Several students observed their adviser in the years leading up to and during their

tenure application bid. These students described observing this process as stressful and

difficult. It often served for students as a cautionary tale of how an academic research

career can wreak havoc on one's physical and emotional health. For example, Stephanie,

a life sciences doctoral student described her female adviser, who was continuously

working with an eye towards her tenure application,

> *During my fourth year was when things in the lab started to change a little bit, because my adviser sort of felt tenure coming closer and closer, and I think if there's something that determines how much you wanna go into academia, it's watching someone else go through the tenure process. And that's when I started really questioning whether I wanted to stay in academia, just seeing all of the crap that she puts up with and how much she has to sacrifice in other parts of her life.*

Stephanie went on to describe how her adviser manages running a lab, preparing for

tenure, and balancing her family life,

> *My advisor has two young children. When her kids have a day off from school, she will bring them into the lab 'cause she still has to be there and get stuff done. On a typical day, she will leave at 5:00 PM to go pick up her kids and have dinner with them, but then she's back on her email at 10:00 PM. You can expect emails from her any time between 10:00 PM and 5:00 AM, and then all day. It just seems like she doesn't really sleep or have time for herself…so seeing those sacrifices, I was like, "man, I don't know if I want that."*

Stephanie also observed another professor in her department that she "really looked up

to" go up for tenure. She recalled,

> *You just kind of observe people age 10 years in the span of a year when they're going up for tenure. This professor was someone who was engaged [to be*

married] and her engagement ended as she was going through tenure. She probably lost 20-30 pounds because she was just working all the time, and literally, you could see [her] age. And it's like, well, if someone who doesn't have a family, who doesn't have all these other side responsibilities is still clearly giving everything she has to get this, it seems like a lot…and just observing all of this, I was very much like, "this is not what I want in my life. I don't want to be someone who is on her email all the time. I don't wanna be someone who is constantly fighting for funding. I don't wanna be someone who works, works, works.

Advisers Who Maintained Clear Personal Boundaries, Fared Better with Students

Regardless of whether a student was advised by a male or female adviser, I found students had more positive advising experiences when their advisers maintained clear boundaries between their personal and professional lives. Often this manifested into a more formal and professional mentoring relationship. For instance, Lauren, a physical sciences student had a very positive experience with her adviser. Lauren's adviser was a tenured female professor whom she described as keeping her students at arm's length, emotionally:

> *I really like my adviser overall. I really have a lot of respect for her and our relationship has always been primarily professional. We haven't really talked a lot about our personal lives… it's tough to have close conversations with her. So, it's always been very professional, but supportive, and she's great to write papers with. For example, she always responds to emails within hours and she meets with us once a week.*

Despite working closely together for six years, Lauren lamented that her adviser never got to know her on a personal level. As a fellow woman in a heavily male-dominated STEM subfield, Lauren initially hoped that their shared minority status would bring them together. Instead, Lauren's adviser showed concern for her advisees through professional actions, rather than emotional words. For instance, early on in her doctoral program, Lauren was preparing for her first major public talk. Her adviser knew that public

speaking was a skill Lauren felt insecure about. They spent hours practicing together in order to mitigate Lauren's anxiety and build up her confidence.

> *The whole week leading up to that talk, we probably did something like 10 practice talks together, and she was preparing me for how to deal with questions and was just a little bit more frank with me about, "I recognize this is an issue for you. Let's just get through this. You're totally able to get through this." And just seeing her spend time into the evenings, helping prep me, [showed] she clearly cared.*

Lauren considers her adviser to be a professional role model based on the high quality of her research and the way she conducts herself, both at conferences and in her day-to-day work with students. She also describes her adviser as a good manager, which is in stark contrast to most students' description of their advisers' as poor managers. When Lauren's adviser was coaching her in preparation for a big talk she told Lauren, who really enjoys teaching,

> *"You're a good teacher. I need you to just think about this as though you're teaching a group of undergrads about your research." And that framework has actually really helped me and it makes me think that…she's a good manager or is good at treating [advisees] in a very individual way. She makes observations like that, that make me think she's either paying attention or at least knows the right thing to say. [chuckle]*

Another instance when Lauren's adviser knew the right thing to say came after an unpleasant interaction at a dinner with a senior male faculty member from a peer institution. At the dinner, which included several of Lauren's dissertation committee members, the senior faculty member "made some assumptions about me and called into question the fact that I was graduating in a week" without taking "the time to learn about my work." While she "didn't cry in front of him," she did cry later on, in private. After observing the conversation, her adviser took the time to recognize and address the inappropriate comments with Lauren directly.

> *Afterwards she came up and made a comment about just how every time you talk to this particular individual, [he's] kind of like that. And it still feels that way for her, even though she's known him for 15 years. So, I appreciated that she recognized what happened and took the time to talk to me about it.*

Although Lauren likes her adviser and considers her a good manager, she has not always been the best role model in terms of work-life balance. Lauren described her adviser as working "pretty long hours." She also heard, indirectly from other students, that her adviser has expressed the opinion that she would not have reached her level of professional success if she had children. On the other hand, she's told Lauren, directly, that "a postdoc is a good time to have a kid." Luckily, Lauren is optimistic about the future for women in her male-dominated field where, "if you wanna be successful, you would look like a lumber jack, and drink a lot of beer, and be one of the guys." Although Lauren's traditionally feminine appearance is the polar opposite of a lumber jack's, she is pursuing an academic postdoc next, with the hope that "as a field, we need to adapt and the more women we can retain who have families, the better, and things are just going to have to shift and accommodate that." However, Lauren is also "not so wedded to the idea of academia" and possesses an *Ambivalent about Academia* mindset. She told me, "if it just wasn't working, I would probably leave and do something else. And I think that's probably true with a lot of women as well. So, I just hope the field shifts."

Several doctoral students, such as Stephanie and David, observed their advisers go up for tenure during their doctoral program and were disillusioned by this process, ultimately turning away from academia. Thus, it is noteworthy that Lauren had the good fortune of meeting and working with her adviser subsequent to her adviser's promotion to tenure at Calder.

> *I think a huge part that has very much shaped my experience is that [my adviser] had tenure. When I was applying [to Calder] I was talking to other faculty in the department, or actually, just throughout the field. One thing I heard over and over again, which is kinda weird to me now, was, "oh, she's calmed down a lot since she got tenure. She was so stressed out, but she is… you're coming in at a good time." And so, I do think my experience might have been very different if I had been there when all of the pressure was on.*

Advisers Who Blurred the Line between Personal and Work Lives, Fared Worse with Students

Olivia, a physical sciences doctoral student, had an advising relationship that stands out in its stark contrast to Lauren's relationship. Olivia observed her adviser apply for promotion and be denied. She described her adviser to me as "a great scientist, but she's not a good adviser." Unlike Lauren's adviser, who maintained a distant yet professional relationship with her advisees, Olivia's adviser felt at ease crossing personal boundaries at multiple points in their relationship. According to Olivia, the relationship was "incredibly unusual" in that, "I don't think many students have their Ph.D. adviser cry to them and ask them to bring them food, and take care of their children, and buy their kids toys." Olivia accompanied her adviser to a conference where her adviser was taken ill and was bedridden due to complications from her recent childbirth. She sent Olivia out on errands to feed and entertain her children while she was resting at the hotel. Although the care and feeding of her adviser's children was anomalous, Olivia said, "the crying was persistent and the bringing food to her was persistent" throughout their time together. Olivia's adviser "had severe complications from childbirth but started coming into the office two weeks later, when it was clearly not time for her to do that." Olivia explained,

She would make comments about how as a woman, if you spend more time away [from work postpartum] you can't recover [professionally]. And so she would push herself but in these ridiculous ways that would only make everything worse. I think she lost a lot of credibility with a lot of people for doing that, but she felt that you had to. And I didn't ever think that you had to emulate that exactly, but still, even somewhere on the scale from zero to insane, there's something where if your job has to be so all-encompassing like this, where she's not seeing her children 'cause she's crying to me that she doesn't say good night to them in person 'cause she's too busy at work and stuff, that wasn't something that was highly desirable. It seemed like you had to be intensely focused on one thing and I have sort of a more, I guess, shallow and broad interest than she does, so [pursuing an academic career] didn't seem like a great fit.

This example of what it takes to succeed as a woman in science, in her adviser's eyes, ultimately turned Olivia away from pursuing an academic career. She took from her adviser's example that "whatever I was doing, it was not at the appropriate intensity, and for me, that was not sustainable. If this is what it takes to succeed, then I don't think I'll be successful."

The models Lauren and Olivia witnessed may be at extreme ends of a very wide spectrum of the type of STEM academic careers for women experience. However, unless they are co-advised, female doctoral students at Calder, tend to view their female adviser's approach to their careers as the most accurate model for what they themselves should expect. This unintentionally leads talented students to turn away from academia in search of a profession where they can stay in STEM while also achieving a healthy work-life balance.

Work-Life Balance

Several students described observing a negative work-life balance in their advisers' lives. For most students, this entailed receiving emails from their advisers late at night and on weekends. Sometimes these emails were stress-inducing, asking students

to quickly revise documents and send them back immediately. Other students observed

specific instances of what they deemed to be poor work-life balance in their advisers'

lives. For instance, Caroline's adviser slept on a blow-up mattress for a week in her

office during a major snowstorm, rather than be kept away from her work. Michael

described one of his former male PIs who had a wife and four kids. Michael told me,

> *[My PI's] wife slept with a gun under her pillow because [her husband] was gone*
> *most nights… he was really promoting the science and he was really good at*
> *talking. But I realized at that point that I didn't want be that person… [when I'm*
> *a PI] I want to be gone two or three times a year. I don't wanna be that twice a*
> *month person.*

David's second adviser was a successful tenured female faculty member at Calder. She

once gave him the strategic advice to get a "house spouse" to help bolster his career.

Meanwhile, Jessica's adviser had elementary school aged twins and employed two full-

time nannies to help her balance work and family life. Jessica recalled her adviser's

childcare strategy:

> *She would say, 'if one babysitter is sick, you should just have two permanent full-*
> *time babysitters. So that way if one is sick, then the other one can cover.' That is*
> *not financially feasible for most people.*

Jessica went on to describe her adviser modeling poor work-life balance by emailing her

students at 10 or 11 at night demanding work products from them and while she was

supposed to be on vacation with her kids.

> *I don't think she's a great model for work-life balance, but I don't think that any*
> *of the female PIs or male PIs in the department are, either.*

While both male and female advisers demonstrated poor work-life balance, women

advisers, such as Caroline's, Jessica's, Stephanie's, Olivia's, and Jane's (introduced in

Chapter 4) struggled more and revealed more of the imbalance to their female students.

Perhaps, like Jessica's adviser, they were intentionally trying to expose students to the

harsh realities of a demanding academic career. Notably, 28% of students, including

Caroline, David, and Jessica, were partnered with another STEM doctoral student or

Ph.D. These students were confronted with the so-called "two-body problem," which is

when two romantic partners are both seeking academic positions in the same geographic

region. The implication is that in order to stay together, one person's career is

subordinated in favor of the other's, or that the couple must endure a long-distance

relationship. I found, however, that both students with life partners and those who were

single, valued work-life balance irrespective of gender.

Equally Valued by Women and Men. In their 2010 book, Ceci and Williams

(2010) posit that career decisions by women are largely driven by a desire for work-life

balance. In contrast, my findings show that at this stage in their careers, work-life

balance is an aspiration held jointly by both women and men. Both the women and men

in my study expressed an interest in eventually starting a family; 58% were either married

or in a serious co-habitating partnership. Two of the students had children. However,

most students still envisioned starting a family in vague terms and were not yet familiar

with the personal and professional sacrifices involved. For the most part, students were

planning to pursue careers within or outside of academia without regard to the specifics

of how they would balance work and family life. For this Millennial generation of STEM

Ph.D. students, there appears to be a shift in values and priorities.

When students talked about work-life balance, they spoke in terms of wanting to

maintain outside hobbies, get enough sleep, and not feel forced to work at night or on the

weekends. Some students also had experience with mental health challenges while in

graduate school. Due to the heavy workload and interpersonal conflicts with classmates

and/or advisers, many students struggled with anxiety and depression. Several disclosed

they were seeking treatment from campus mental health counselors. For these students, a

healthy work-life balance was paramount, not because of their anticipated future children,

but because of their current physical and mental health well-being.

Some students even described witnessing members of their doctoral community

commit suicide. Isaac is a physical sciences student who was deeply affected by the

suicide of a doctoral student in his lab. The student "definitely wasn't happy and showed

a lot of the signs [that he was suicidal]." Isaac was disappointed with how his department

dealt with the aftermath of the suicide:

> *I don't really think [they] address at all the root cause of why people have these [suicidal] thoughts and why people are so unhappy in grad school, which, I think, a lot of it is pressure from their advisers and expectations related to going into academia or publishing papers.*

At first, Isaac's adviser "handled it really well." She told people that they did not have to

come into work at the lab. She advised her students to take as much time as they needed

to grieve at home. When she returned to the lab, she moved her work station from her

office to a communal group room in order to make herself available to anyone who

wanted to talk about what happened. She also invited students to her home to talk with

her in a more private setting. But then after that, Isaac felt she reverted back to the work

culture that caused much mental anguish within her lab:

> *Kind of within a month, she was repeating a lot of the same habits that I, and others in the lab personally think led to, maybe not directly, [my classmate]'s suicide, but for sure, [led to] him being very upset. And it was hard to see her do these things to [another classmate] who was also, we felt, in a similar situation. Thankfully that person has sought help…and hopefully that's working. But to kind of see her repeat a lot of the same behavior [that contributed to the first suicide] was really tough.*

Isaac describes his adviser as very demanding: "She likes us to work 12-hour days, six days a week. That's not even necessarily a lot of work for her. That's just kind of the minimum amount of work." Expectations around the number of hours students need to work at the lab, in addition to the "constant pressure to produce results," created an unhealthy, high-stress work environment. The intensity of the lab, for many students, can create a level of anxiety that is both mentally unhealthy and physically unsustainable. When students are unhappy, depressed, or anxious in their doctoral studies, it is no wonder they begin to consider what life outside of academia looks like. When the unhappiness and anxiety is being caused by pressure from their advisers, students have to reconcile their desire to become PIs with the negative behavior and lifestyle choices of their own PI.

Other Key Challenges for Women in Science

In examining how students develop their post-graduation plans, several other key challenges presented themselves, generally impacting women more than men. Many women doctoral students struggled with messaging about "how to succeed in science as a woman," storytelling with data, and the role of politics in scientific careers.

How to Succeed as a Woman in Science

A consistent theme that came up repeatedly with several women participants was the idea that in order to succeed in science, women must jettison characteristics that are considered to be traditionally female and adopt traditionally male characteristics. For example, Jane, a life sciences doctoral student, described her female adviser telling her to "put on the [male] persona for a talk" in order to "be confident." She instructed Jane to

"fake it" and "pretend to be the confident type," which, "basically means you have to be a man and do the things that a man does…and fit that personality." Jane feels that "what makes you a valuable person in academia, those things are masculine qualities. If [academia] could value feminine qualities in some way, that would help more traditionally, feminine women." She further elaborated that in order to get papers published, get big grants, and advance up the tenure ladder, "you have to be very competitive and show that you're competent in the certain set of ways that, unfortunately, are more conducive to masculinity and the way men live their lives." Jane feels that the "masculine qualities" that are rewarded in academia include "a more aggressive communication style" and a sense of entitlement that "I am here and this is the place for me and I will achieve things and that is the narrative of my life as a person in this world." Jane reflected, "that's something that I think is missing for me that I think is more associated with masculinity."

Claire is a physical sciences student who was successful on the academic postdoc job market and hopes to pursue a faculty career. Claire's physical appearance presents as prototypically feminine. She told me when she attends conferences she dresses "much more professionally than the average male [scientist in my field] would." However, she did "in fact, get advice from a female faculty member that was the exact opposite." The faculty member told her:

> *'You should try and blend, so you should wear [a] Hawaiian shirt, and pretend that you're a man.' And she's like, 'yeah, this one woman faculty member [in our department], she's done really well, despite the fact that she wears dresses all the time. She should just wear baggy pants, and look like a man.' And I was like, 'different approaches… okay.' I mean, the culture is just definitely male, and you're gonna spend a lot of time hanging out with a lot of men.*

Since Claire has her own sense of style and a quiet self-confidence, she ignores this advice and instead chooses to "dress professionally" for conference presentations. However, it is not lost on her that in her graduating cohort of doctoral students, "of the women, at least 50% of them are leaving the field; of the men, I think only one is leaving the field." Olivia is another physical sciences student who described a female adviser telling students, "you have to stop wearing dresses because no one will take you seriously if you wear dresses." Olivia's adviser "would give public sessions with the grad students saying, don't wear skirts, don't wear dresses." Olivia also described bringing homemade baked goods to her department to share with her colleagues. She said, "I was told, [by my adviser] 'you have to stop baking things because people will then associate you with a 1950s domesticated wife.'" For women like Jane, Claire, and Olivia, there were certain masculine behaviors such as confidence, competitiveness, and an aggressive communication style, that they were expected to integrate into their professional approach to science, while abandoning traditionally feminine behaviors, such as wearing dresses or baking cookies. This finding echoes Antony (2002)'s critique of the congruence and assimilation orientation embedded in traditional graduate student socialization theory. I find that some of the women in my study felt pressured to adopt their fields' norms and values surrounding communication style and manner of dress, suppressing their own personal preferences in the process. Students, like Jane and Olivia, who rejected this pressure ultimately abandoned the academic career track. Meanwhile, students like Claire were able to develop an awareness of their fields' values without internalizing them, as Antony and Taylor (2001) found in their study of Black graduate students.

Telling a Story

As the women in my study experienced, STEM doctoral education is structured around organizational norms and behaviors that favor masculinity while marginalizing femininity. Another traditionally "masculine" trait embedded in academic science, according to Jane, is the "need to be able to trick yourself into feeling like your work, no matter what it is, is really, really important and closing your eyes to some of the assumptions that are built into it." She told me, "if you took those [assumptions] away, everything would really fall apart. And I'm just really not willing to close my eyes to all that." A common example students cited, with regard to ignoring some of the assumptions in academic research, is found within the practice of "telling a story" with your data. This can be especially hard for students already struggling with confidence issues. According to Jane,

> *I don't really like being in front of people. I don't love giving talks. It's really the most stressful thing I can prepare for, giving a talk. I don't love attention. I'm always questioning everything. So, it's hard to go up and tell a story confidently, because I feel like I'm lying to people. And I don't like to feel that way…. But you just have to somehow convince yourself that you're doing the right thing, and that's very hard to do.*

Meanwhile, Brandi, a life sciences doctoral student, puts the onus squarely on stereotypical male behavior: "men have no problem bullshitting about something." Despite her male adviser's paltry publication record, he was awarded several national research grants. She attributed this to his ability to write convincing grant proposals, rather than his ability to do good science. Accordingly, he tried to coach Brandi into telling a compelling story with her data. Brandi recalled,

> *I generated some data with a couple of figures and he's like, "well, what's the story? You gotta make the story." And I was like, "what do you mean make the story?" Like, yes, I need to generate some more data figures, but I don't wanna*

make a story, right? And it turns out that the story becomes this main motivating factor for doing experiments, and then you design the experiments to give you the right answer for the story. And it's like, "what am I doing?"…Yeah, and I kind of wish I was another way. I understand that having that quality is a pretty useful skill, but I don't think I'm ever gonna be there. Not only am I not comfortable with it, but I don't see the value in it."

Although Brandi does not see the value of "telling a story" with data, Michael, also a life sciences doctoral student, was drawn to a career in science precisely for this reason. He told me, "that's what a scientist is really doing, they're telling stories to different people." Michael saw story telling as the "chance to have an applied outcome" in order to "help humanity move forward with knowledge." For Michael, the challenge was more in the identification of which stories are the most important to tell and the psychological burden of letting go of certain stories.

I've been overwhelmed with the sense of, what are the actual discrete stories here, because we have a lot of thing going on. There's a lot of data. There's a lot of points of view. I'm stuck in a way where we have a lot of things going on and it's not immediately clear to me what the next paper that's coming out, what it's going to contain….it's hard to navigate this process. And I think one way to do it is to just don't care and just get 'em out. We have two stories and each of them has two remaining pieces to do. There's a choice of, is this a more important story so I should finish that part? And the psychological [burden] about that is – is it okay if it's a crummy story?

Unlike Jane and Brandi, Michael is comfortable with the practice of telling stories with his data. Where he feels ambivalent is in the somewhat arbitrary nature of choosing which story is the best to tell, as it is not always a clear choice. Michael described this as a process of "navigating through the hard layer" in order to identify the best stories. He views this navigational skill as pivotal in doctoral students' careers; as a "sieve or filter," sorting between those people who should go on in academia and those who "maybe should find something that they're better at."

Students of both genders view storytelling as an inherent feature of scientific research. However, while some of the women found the act of storytelling in and of itself unsettling, Michael's experience encapsulates what seems to be the typically male attitude towards storytelling: men find it challenging to figure out the most important story to tell but are not opposed to the practice. I found that some of the women in my study, likely due to prior experiences they had before starting graduate school, were predisposed to understand "story telling" with scientific data pejoratively. While the men, socialized in an academic culture that privileges masculinity (Britton, 2000), view storytelling as a necessary communication strategy, useful in generating interest and engagement from others in your work. In other words, women found it problematic to tell a story with your data in order to win grants, present at conferences, and publish papers. They felt that telling a story necessarily involved adding embellishments that would stretch the truth; good data should not need special packaging. I believe these attitudes are likely associated with women's lower levels of self-confidence found in STEM doctoral programs (Ferreira, 2002, Litzler, et al., 2004; Ulku-Steiner, et al., 2000) and relatedly, to the discomfort with public speaking expressed by some women (Jane, Lauren, and Hannah). This aversion to storytelling is problematic when telling stories about your data is a skill needed to write grant applications, present at conferences, and publish. It is also part of a larger narrative about succeeding in academic science that students often referred to as "playing the game."

Playing the Game and The Politics of Science

Throughout my interviews, there were several references to "playing the game," "gamesmanship," and "showboating," especially with regard to the actions and behaviors of one's adviser. Students began graduate school with a passion for science, a knack for research, and a desire to create new knowledge. Some students were interested in improving human health outcomes through medical advancement while others hoped to identify extraterrestrial life on other planets. Few students were knowledgeable about the activities scientists must pursue outside of research in order to be a successful PI. These include networking at conferences, writing grant proposals, developing partnerships with other institutions, and identifying research topics that will yield long-term professional benefits. Playing the game is the disapproving term students used to refer to these types of activities. In general, I found men more comfortable than women with the idea of "playing the game" in order to succeed in science.

Susana, a life sciences doctoral student, talked about the game people played to get published in top tier journals. She described peers in her lab "making mountains out of molehills or mountains out of craters in the ground," suggesting that in order to produce publications, lab members were making more of the data than was there. In Susana's lab, she experienced an underlying pressure, driven by both the competitive job market and the expectations of the PI to "package your data." She explains the publication process with her adviser:

> *You have to send him overly processed data. You have to make grandiose claims. If you show him raw data, he's going to throw it in the trash. If you show him data that's glitz and glam, then he'll send it to a top journal.*

Susana realized that the people in her lab "who were big and bold and grandiose…knew that there was a game to be played, and they were willing to play that

game." Ultimately, Susana decided that she was not willing to play that game. She ended

up finding her postdoc without any assistance from her PI. Meanwhile, Tom, another life

sciences student, did not engage in any nefarious behavior to get his research published.

However, his version of "playing the game" was to tap into his adviser's professional

network to find a desirable postdoc. Tom described his postdoc job search as largely

informal, dependent on "who you know" and, more specifically, who your adviser is

friends with.

> I talked to my mentor, who knew a lot of people, and I also talked to four or five
> different professors within the department, mostly, that I respected and were in a
> similar field…these big labs don't have a call or anything like that, so it's not like
> they're putting up on a billboard that they're looking for [postdocs]. So, when I
> emailed them that I'm looking for a position, I guess two out of the three
> professors, apparently, didn't have positions open. But my [mentor] emailed
> them as well, and they're like, "okay, we'll open a position if it goes well." My
> mentor knows two of them already, so maybe they would've given me an interview
> and might not have given another person a look because of this connection...so
> yeah, there's some politics that are important.

While Tom acknowledged that "the politics is something that I don't really want

to deal with," he is willing to put up with it for now, as he knows senior faculty, such as

his future mentor/postdoc adviser, who "don't give a shit about any of it," now that they

are at a certain point in their careers. "Once you're past the hump, then you get to not

kiss ass and care so much about the politics. Those are some of the pros and cons, from

what I've seen, of this profession." Tom is willing to play the game as long as it benefits

him as he believes that eventually, he will be senior enough in his career where this

becomes unnecessary.

Nick, a physical sciences doctoral student, also referenced the politics involved in

obtaining a good postdoc, alluding to the often "highly incestuous dynamic," whereby

doctoral students go on to work with their adviser's former academic progeny. For

instance, Nick told me, "the person who I'm gonna work with for my postdoc was actually the first [doctoral] student of my current Ph.D. adviser." Although Nick is benefitting from this system, he also sees how inequitable it can be:

> *If you go to Calder, you just end up networked by default with all the best people. And it's really to some degree, in my opinion, unfair, because I know there are people who can do what I do to some degree, better, but their advisers aren't friends with my adviser, and so they never got that opportunity [to access certain postdocs]. And it's just a comfort level thing. The other PI is looking for someone who can do X and they just know that talking to my adviser will get you students who can do X.*

Like Tom, Nick nods to the inequity of the system but ultimately goes along with it as it is in his best interests to do so. However, "playing the game," is not inherently unethical. When students tap into a network of "all the best people" to obtain postdocs and other professional opportunities they are simply accessing their social networks. Granovetter's (1973; 1983) seminal social network theory identifies social networks as developing systems between individuals where ideas, information, and resources are exchanged. While strong ties, consisting of family and friends, develop casually, weak ties between distantly connected people, develop more formally and provide access to information and resources. In the case of STEM doctoral education, students have access to many weak ties through their advisers. If their relationships with their advisers are strong, they stand to benefit a great deal from these professional connections.

Where playing the game becomes less ethical is when students feel the need to "package [their] data" in order to get published. Additionally, students described the non-scientific activities of a PI, such as fundraising and networking at conferences as "playing the game," and thus, less desirable. While the women were not universally opposed to "playing the game," several voiced strong opposition to it. The men, on the

other hand, were more likely to acknowledge it as a necessary part of a PI's role, one they accepted as part and parcel of their future career.

III. Discussion and Conclusion

Key Findings

Much research has documented the gender gap in STEM academic careers. In this chapter, I showed that men and women at an elite research university often experience STEM doctoral education in vastly disparate ways, socializing many women, ultimately, to opt-out of academic careers. These differences result in disproportionately more men than women planning to stay on in academia post-Ph.D. Specifically, I find that more men than women are generally satisfied with their advising experiences at Calder. This is consistent with research by Nolan et al. (2008) and Seagram et al. (1998), who both found, separately, that men were more satisfied with the quality of their advisers than women. Surprisingly, I find that women students reported more positive advising experiences with male rather than female advisers, countering much of the literature that associates women reporting higher quality interactions with same-gender advisers (see Hoffman & Oreopoulos, 2009; Carrell et al., 2010; Gaul & Piacentini, 2017; Schroeder & Mynatt, 1993). However, as I discuss in this chapter, this finding may be related to the fact that many of the women faculty at Calder are tenure-track (rather than tenured). Some students observed the process of watching their female advisers prepare to go up for tenure, which is notoriously difficult for faculty to obtain at Calder. For women faculty who are balancing work with raising young children, the tenure review process can be especially daunting. I argue that the stress and pressure women faculty

experienced during the tenure process were made transparent to their students, with female students being affected more strongly by this close observation.

Counterintuitively, I find that advisers who maintained clearly delineated personal boundaries with their advisees were associated with more positive advising relationships, and subsequently, students who were more likely to stay on in academia post-graduation. While some students whose advisers maintained firm boundaries lamented the impersonal nature of their advising relationship, this type of relationship was ultimately more beneficial for students than those who were privy to some of the messier details of their advisers' personal lives. For instance, Olivia's adviser frequently cried in front of her, sharing details of her struggles balancing a career and family. In contrast, Lauren's adviser maintained firm boundaries, rarely opening up about her personal life. Instead, Lauren's adviser demonstrated her commitment to students through caring actions, such as personalized coaching via co-authoring papers together or preparing one-on-one for a public speaking engagement. While it is important for women doctoral students to go into academia knowing the gender-specific challenges that await them, it's also important to acknowledge that every person's career path is unique. Most of the students in my study will not go on to become faculty members at Calder, and should not necessarily view their adviser's experience as the industry standard or what they themselves will encounter as professors. However, more research on faculty in other institutional settings is needed to verify this.

In examining how students develop their post-graduation plans, I also find that many women doctoral students struggled with self-confidence, messaging about how to succeed in science as a woman, storytelling with data, and the role of politics in scientific

careers. Female doctoral students' struggle with self-confidence has been documented in prior research (see Ferreira, 2002; Ulku-Steiner et al., 2000). It is disheartening that almost 20 years after these prior studies were published, women in STEM academia are still experiencing more negative perceptions of their own abilities throughout their doctoral program. These studies point to processes and mechanisms in doctoral education that negatively affects women's perceptions of their skills and abilities.

It's possible that these insecurities could be driven by gender discrimination and implicit biases (Litzler et al., 1005). Faculty advisers need to be made aware of the potential gender differences with regard to implicit bias, stereotypes, and self-confidence challenges for women. In terms of the other challenges for women, including public speaking, storytelling with data, "playing the game," and the politics of science, I found that my study supports Sallee's theory that the STEM disciplines are dominated by gendered norms. For instance, several women in my study noted a strong aversion to public speaking. But in order to be a successful academic, you must frequently present your work, verbally, in front of both experts and neophytes in your field. This, I found to be a gendered cultural expectation of academia, since several women reported challenges and anxiety related to public speaking, but none of the men had expressed these concerns.

With regard to work-life balance, my research findings are consistent with the literature pointing to STEM faculty struggling to maintain a healthy balance (Holmes, et al., 2008; Mason & Goulden, 2004; Williams & Ceci, 2012). In particular, students described female advisers struggling more than male advisers with work-life balance, consistent with prior research (Mason & Goulden, 2004). Where my research is able to make a new contribution is in how work-life balance factored into career decision-

making at the STEM doctoral level. I found that in observing their advisers navigate

work-life balance, largely unsuccessfully, some students were permanently turned-off

from academia. This was especially true for women. Several women doctoral students

described witnessing egregious acts of work-life imbalance, such as sleeping in one's

office. These observations served as cautionary tales for students to learn from and

strategize ways they could avoid this type of behavior in their own future careers. I

believe two mechanisms further disadvantaging women were at play here. One, the

institution, Calder University, is dominated by gendered norms. For instance, due to

gender discrimination, women have to work twice as hard as men. A second mechanism

disadvantaging women is the anti-role-model effect: seeing women in faculty jobs who

seem unhappy inspires neither imitation nor emulation.

Lastly, challenging Ceci and Williams's (2010) claim that career decisions by

women are largely driven by a desire for time-flexible careers and work-life balance, I

found that *both* women and men in this study prioritized work-life balance as an

important factor when making decisions about their next career move. The majority of

students in the study were not yet parents and were not making career decisions with

future children in mind. Instead, they identified work-life balance as a vehicle to

maintain their mental health and personal happiness.

Chapter 6. Discussion and Conclusion

In this study, I investigated how forty STEM doctoral students at Calder

University made decisions to pursue academic and non-academic careers. By examining

students' career decision-making processes, I hoped to improve our understanding of how

students navigate the pathways both into and away from the professoriate. In particular, I

was looking for explanations that would help account for the lack of diversity among

STEM faculty. This study was guided by the following research questions: How do

STEM doctoral students at Calder University explain their decision-making processes in

choosing to follow academic and non-academic career pathways? Do these explanations

differ across gender? If so, how? What are the processes and mechanisms that enhance

or limit students' career aspirations? Do these processes and mechanisms differ across

gender? If so, how?

In this chapter, I review my key findings and discuss the most important and

unanticipated findings drawn from the participants' experiences. I then discuss the

implications of this research and describe suggestions for future research.

I. Overview of Key Findings

Advisers' Support for Academic and Non-Academic Careers

A key finding of this study is the tremendous impact of advisers on doctoral

students' professional pathways. This finding is in line with previous research on the

impact of doctoral advising (see Austin, 2002; Baird, 1992; Golde, 2000; Golde & Dore,

2001). However, a new contribution this research makes is confirming a common

assumption that advisers are largely predisposed to steer their students towards academic

careers. Sauermann & Roach (2012) found this to be the case analyzing a national survey of Ph.D. students at 39 tier-one research universities. Meanwhile I was able, through qualitative research, to establish some of the mechanisms behind this encouragement. I found that older faculty advisers seemed to discount how competitive today's academic job market is for students. While younger faculty were motivated to establish their own lineage of academic scientists to bolster their tenure and promotion dossiers and their grant applications. Luckily, most students who chose non-academic careers (n = 19) ultimately felt supported in doing so after disclosing their intentions to leave academia to their advisers. Still, their decisions were typically met with initial resistance by their advisers.

I found that advisers' financial and non-financial support for their students' career preparation and planning served as a key mechanism in strengthening students' adherence to the academic path. This is in line with research by Tenenbaum, Crosby, and Gliner (2001) who identified advisers' instrumental help as increasing student productivity. I add to Tenenbaum et al.'s (2001) definition of instrumental help by differentiating between financial and non-financial benefits. The financial instrumental help included obtaining money to attend conferences or purchase specialized equipment for their research. The non-financial instrumental support included access to data or powerful computational software. They also entailed co-writing papers, proposals, and grant applications as well as introductions to a wide network of possible postdoc employers. I found that this type of instrumental support was generally contingent on students' relationship strength with their adviser. Students with weak adviser-advisee

relationships accordingly received less instrumental help to bolster their career training and job search support.

I demonstrate that at Calder University, STEM doctoral students are typically socialized towards academic careers. Thus, the decision to pursue a non-academic career is not always an easy one. In general, advisers were ill-equipped to support students in meaningful ways with their non-academic job searches. Some advisers even served as impediments, blocking students from attending career panels or pursuing outside coursework, if participation in these would interfere with the student's daily lab work. This finding points to a disconnect between how doctoral students are socialized by faculty, departments, and peers to become academic researchers, and how students interested in non-academic careers experience the career planning process. With almost half of the students I interviewed planning to leave academia, the lack of structural support for non-academic careers is highly problematic.

Academic and Non-Academic Career Planning

Throughout this study, I demonstrated that the two most important factors impacting students' desire to stay in academia were one, their relationships with their adviser and two, the success of their independent research projects. Naturally, these two factors were intertwined and mutually reinforcing. Students with strong adviser relationships were associated with successful research projects; students with research project success described earning the trust and respect of their advisers, leading to a further investment of time and career mentoring. Students described the success or failure of their research project impacting their self-confidence. Due to the scarcity of

faculty jobs, students explained that they required a high degree of self-confidence in order to take the calculated risk involved in pursuing an academic career.

Students who were successful in securing non-academic jobs by their graduation date typically engaged in several months' worth of independent career exploration, networking, and job search work. These students were proactive in their job searches, taking the initiative themselves to set up informational interviews with alumni, join graduate student career clubs in biotechnology or consulting, and participate in summer internships. Internships proved especially valuable in serving as a market signal to prospective employers that students were serious about non-academic careers. More importantly, by participating in part- or full-time internships, students could identify how well suited they were for the type of work they could obtain as a Ph.D. holder working in industry. As with the non-academic job search, there was minimal faculty and institutional support given to students to find internships. Instead, students described jumping "through a bunch of hoops" and obtaining one's adviser's support—not always the easiest task—in order to complete an internship during graduate school. In contrast, students who conducted more haphazard non-academic job searches were more likely to end up in a postdoc after graduation. For students interested in non-academic careers, the postdoc turned out to be the path of least resistance.

The Four Post-Graduate Career Mindsets

With regard to academic and non-academic career plans, the students in my study fell into one of four career mindsets: *Academia or Bust* (22%), *Ambivalent about Academia* (30%), *Best of Both Worlds* (10%), and *Opting-Out of Academia* (38%). These

career mindsets are a useful way to understand students' attitudes about their post-graduate career plans. They provide more nuance than the false binary of academic and non-academic career paths being the only choices available to STEM doctoral students. They also allow researchers and policy makers to identify the two most prevalent mindsets: *Ambivalent about Academia* and *Opting-Out of Academia*. It is worth noting that fourteen women (54%) and only one man (7%) are leaving with an *Opting-Out of Academia* mindset and nine women (35%) and only three men (21%) are leaving with an *Ambivalent about Academia* mindset. That ten women in the life sciences (38%) compared with four women in the physical sciences (15%) are *Opting-Out of Academia* is consistent with national trends. One possible reason for this gender imbalance is that the lab culture in the life sciences, which centers the PI in a "CEO" type of role, may be turning some women away. Students, both men and women, who pursued a scientific research career for the love of science were turned off by the business-management side of running a lab. Additionally, advisers who are running life science labs are under immense pressure to keep the funding levels up and, if not already achieved, to get tenure. In this regard, the lab activities which promote funding and tenure promotions, such as frequent international travel, can be at odds with the advising and professional development needs of doctoral students, further alienating students away from the profession.

Gender Differences

Overall, more men than women indicated general satisfaction with their advising experience (67% vs. 58%) and more women than men indicated a dissatisfaction with

their adviser (35% vs. 25%). However, due to my small sample size, these differences are not statistically significant. They are, however, consistent with other research on this topic (Nolan et al., 2008). Additionally, more men (25%) than women (15%) switched advisers during graduate school, although this may have been driven by a trend in one department where switching advisers mid-stream is facilitated by the doctoral program design. Students in this department are required to complete two distinct research projects, which could easily be supervised by two different advisers.

Several women students watched their same-gender advisers sacrifice their physical and emotional health, as well as time with their children, in service to their careers. This caused these students to become disillusioned by the life of a woman in academia. Other students noted a transformation or metamorphosis that occurred before, during, and after the tenure-review process their adviser went through. It may be worthwhile for Calder University to consider a policy that assigns students with junior faculty PIs to be co-mentored by a senior faculty member as well. Co-mentorship is not without its challenges, but a student whose adviser is pre-tenure should not be penalized, emotionally and professionally, because her adviser is gearing up for a tenure review process.

In general, I found that students had more positive advising experiences with advisers who maintained clearly delineated personal boundaries in their relationship with their advisees. Students with this type of advising relationship did lament that they were not more personally connected with their adviser. However, they were also spared the negative impact of knowing too many intimate details about their adviser's personal life. Students who were allowed entry into their adviser's personal and emotional lives were

often turned off by many of their adviser's decisions (e.g. working late at night and on the weekends). Meanwhile, advisers who maintained an emotionally distant relationship, but showed they cared through their actions (e.g. responding to emails quickly, co-authoring papers together, promoting their students at conferences), were often the most successful in building strong adviser-advisee relationships. These strong advising relationships were the cornerstone of every student who ultimately decided to stay on in academia post-graduation.

With regard to work-life balance, I was surprised to find that this issue factored into the career decision-making of both men and women equally. There is much research (see Ceci & Williams, 2010; Hakim, 2006; Leslie, 2007; Lubinski et al., 2006; Mason & Goulden, 2004) that points to women opting out of STEM faculty careers due to lifestyle choices, including the desire for work-life balance. Women traditionally have been viewed as the primary caregivers of both young children and elderly parents. However, I found that this Millennial generation of doctoral students were equally concerned with how to balance work with raising a family. Contrary to gender stereotypes, both women and men expressed equal interest in having children. Most held a wait-and-see attitude about whose career would take a back seat—theirs or their partner's—to serve as the primary caregiver to their future children. Several men stated that they would be willing to take on the primary caregiver role in the future, should their partner's career show more promise than theirs. The same was true for students in long-term partnerships with other academic researchers. They said they would see which partner had the best opportunity and let that partner's job prospects determine their geographic location.

Because most students did not yet have children, their prioritization of work-life balance was also motivated by a need to balance their professional lives with hobbies, healthy sleep habits, and time-off on the weekends. Several students also cited personal experience with mental health struggles due to the long hours required in their graduate work. For these students, including both men and women, maintaining a healthy work-life balance was an especially important priority. They knew it was simply unsustainable to sacrifice their mental and physical health needs in the long-term. This point was further driven home by the fact that some students witnessed doctoral and postdoc colleagues in their labs take their own lives while at Calder.

Women often cited low self-confidence and "imposter syndrome" as major stumbling blocks they had to learn to overcome while in graduate school. Through a series of affirmations and successes, most women slowly became more confident in their abilities and identities as scientists. Women also received messaging, both explicitly and implicitly, and mostly from female faculty, about "what it takes to succeed as a woman in science." These messages included advice to adopt more "masculine qualities," including confidence, competitiveness, a sense of entitlement, and an aggressive communication style. Several women also observed their female advisers return to work shortly after the birth of a child or compromising the time they spend with their children. These behaviors are often condoned or even encouraged in American society for working fathers but not for working mothers. They symbolize the sacrifices women PIs made to pursue academic careers, and many of the women students I interviewed indicated they would try to avoid these choices in the future by eschewing academic careers altogether.

Students of both genders also cited the common practice in research of "telling a story" with one's data, both in written format, such as grant proposals, and orally at conferences. Female students were especially reticent to "tell a story" when they felt it was forcing them to make a set of assumptions about the data without enough evidence to back them up. For instance, Brandi, a life sciences doctoral student, said she did not want the story to bias the research design, thus setting up the experiment in a way that would simply provide the answer you are seeking. Another life sciences student, Jane, told me that telling a story made her feel like she was "lying to people." However, storytelling is an accepted part of academic culture. All doctoral students are taught to develop a compelling narrative about their research in order to attract funding and the interest of academic and non-academic audiences alike. It is also part of the larger political culture of scientific research, which students also referred to as "playing the game."

I found that both men and women doctoral students were turned off by the politics of science and what they referred to as "playing the game." Whether it was observing their adviser denied tenure despite excellent research or seeing peers' papers published due to "grandiose claims," both male and female doctoral students ultimately had to decide for themselves if they were willing to "play the game." The men and women who did play it, identified the postdoc job search as based primarily on "who you know" and the PI names listed on your CV. While they acknowledged themselves as beneficiaries of this system, students also regarded it as perpetuating privilege and inequality. Although both men and women expressed some reservations about "playing the game," women, overall, were less comfortable with this than men. Women were especially uncomfortable with the idea of packaging their data in the service of storytelling.

These attitudinal differences between women and men in "playing the game" are important and rooted in differing mindsets. Men are willing to play the game as long as they benefit from it. They see this as just one phase in a much longer game. Eventually, they will get to a point in their careers where the rules will shift in their favor and they will have more power to play the game in the manner that best suits their personal preferences. The women, on the other hand, were more likely to see the rules as inequitable and at times, played in an unethical manner. I found that the women who accepted the cultural norms of "playing the game" took the approach that they would quietly change the rules from within, once they gained acceptance in the field.

II. Discussion and Implications

The Professional Pathways Paradox

Through graduate socialization theory (Antony, 2002; Antony & Taylor, 2004; Thornton & Nardi, 1975; Stein, 1992; Stein & Weidman, 1989, 1990; Weidman et al., 2001), we understand how and why doctoral students at Calder University are socialized to identify the PI/faculty role as the idealized profession. Their coursework, lab work, milestone requirements, and mentoring are all tailored towards preparing students for this one role. However, challenging the assumption that STEM doctoral students should be socialized and trained in these ways, is the fact that 48% of the students in this study are pursuing post-graduate jobs outside of academia. Of the 52% of students staying in academia, the majority are pursuing postdoctoral fellowships, which, like graduate school, can vary in quality, last anywhere between two and ten years, and are generally low paid (*Nature* This Week Editorials, 2011).

In 1973, 55% of U.S. doctorates in the biological sciences secured tenure-track positions within six years of Ph.D. completion; by 2006, only 15% were in tenure-track positions in the same time frame (Cyranoski, et al., 2011). Many doctoral students will graduate without any firm employment plans. In 2013, this was the case for 42% of U.S. life sciences Ph.D. students (Gould, 2015). As my study found, those who graduate without firm plans are likely to end up in a fall-back postdoctoral position. Some view this as more or less a holding pattern, where they can earn an income while identifying a desirable position outside of academia. Ultimately, the most common paths taken by STEM Ph.D. holders will eventually lead them to non-academic pursuits. The American Institutes for Research found that 61% of STEM Ph.D. holders were working in nonacademic careers in 2010 (Turk-Bicakci et al., 2014). This begs the questions: why are those who seek employment outside of academia considered in pursuit of "alternative" careers?

The commitment by elite research universities, such as Calder, to train STEM doctoral students for academic research positions as the numbers of these positions stagnate or decline is a paradox. The supply of Ph.D. holders has long outpaced the number of academic positions available. Yet the professional-orientation and culture of STEM doctoral programs have not adjusted to these labor market demands. While doctoral program administrators dutifully organize panels on "alternative" careers, the dominant culture is one that positions academic faculty as the highest status career. Anything outside of academia, such as consulting or data science, is perceived by students and faculty as lower status. This cultural norm is internalized when students observe postdocs sneaking away from lab in order to attend a medical writing career

panel. Or when a student is told she is "going to the dark side," by her adviser, when she announces her intention to pursue a position at a pharmaceutical company.

Reform the STEM Ph.D.

Elite universities are not meeting the professional development needs of the 48% of students in this study and the 61% of STEM Ph.D. holders nation-wide pursuing jobs outside of academia. I recommend universities consider the following changes: first, navigating an "alternative" career should not be the independent, divergent job search it currently is. The students in this study who found non-academic jobs did so through a series of multiple, systematic career exploration activities. They each acted as if they were forging their own unique paths, when, in fact, many people have left academia before them, in pursuit of "alternative" careers. It is unnecessary for these students to experience the cultural stigma surrounding leaving academia. It is also burdensome to reinvent a job search process that other students have already created. Most students in this study did not find the university's career services offerings to be of much help. Some attended career panels or information sessions, with mixed results. While every job search is unique, graduate career services at Calder should offer more targeted support and resources to students interested in non-academic careers. It would be worthwhile to investigate ways to embed career exploration activities directly into the doctoral curriculum. Graduate academic affairs professionals should foster partnerships with career services to update curriculum and degree requirements, ensuring that each student is graduating with the skills required for industry positions.

Given that the majority of STEM Ph.D. holders ultimately find themselves in careers outside of academia, more structure and support is needed to guide students into these career opportunities. Doctoral programs should provide students with better access to information about the myriad non-academic professional opportunities available. They should also clarify the types of activities, such as internships, clubs, and certificate programs that will make students competitive applicants for these jobs. Students should not end up like Sam, discussed in Chapter 4, who searched haphazardly for a non-academic job after he was disillusioned by his doctoral research experience. Sam's bid to work at McKinsey failed after his first-round interview and he ended up in a default postdoc. The current non-academic job search process privileges those students who identify early on their desire to leave academia. It also benefits the self-starters who have the know-how or the personal connections to navigate this process alone. Students, like Sam, who are late to identify important opportunities, lose out.

Second, doctoral program curricula should be updated to reflect the job requirements both inside and outside of academia. Doctoral program curricula should be altered to include coursework in communications, management, pedagogy, and leadership. These are skills that students will need as PIs leading their own labs, as well as data scientists, science journalists, museum educators, and venture capitalists. Doctoral programs at large research universities, such as Calder, should better facilitate cross-registration in coursework across the university, such as those offered by schools of management, public policy, communications, and education. Perhaps certificate programs in, for instance, data science or science communications, could be created for

STEM doctoral students. These would signal to prospective employers a job candidate's interest and expertise in working in specific industries.

Third, structural barriers to internships should be removed. The students in this study who were most satisfied with their non-academic career plans were those who completed industry internships while in graduate school. Yet many of these students had to overcome administrative hurdles, such as grant funding restrictions. Others had to face adviser gatekeeping, gaining permission from their PIs to pause their training grant-funded lab work for the summer. The barrier to entry for industry internships is too high. Doctoral programs should consider a curricula re-design that would include a mid-Ph.D. summer or semester-long leave program. This would enable students to pursue work outside of their PI's lab, such as industry internships, teacher training workshops, government fellowships, data collection abroad or participation in another PI's lab.

Fourth, participation in graduate student extra-curricular activities, such as consulting clubs, biotechnology case competitions, and science media publications, should become a normative part of the culture. Students in this study who participated in extra-curricular activities honed their industry-specific skills and explored their interests in non-academic careers. Again, structural and cultural barriers to extra-curricular activities need to be addressed and removed. Students cannot participate in these organizations if their advisers' lab work expectations exceed 50 hours a week. Extra-curricular activities should not be limited to those students who are willing to sneak out of lab unnoticed. Students should also be encouraged to discuss career plans with a host of peers and advisers. Some of the most productive career-planning conversations occurred when students felt they could speak openly about the shortcomings of their field

or subfield. For instance, David joined a career decision-making support group of Ph.D. students across the university, facilitated by licensed therapist. By discussing his personal struggles with regard to his subfield with a group of objective and supportive peers outside of his discipline, David was able to feel confident in making the difficult decision to leave academia and pursue an industry postdoc.

Update Advising and Mentoring Approaches

Improve Adviser Selection Process

This study points to several ways advising could be improved upon in STEM doctoral education. First and foremost, the adviser selection process should be reviewed and revised by each department. Students need better coaching on how to identify an adviser who can best meet their individual learning and communication styles. Advisers should also clearly communicate their typical advising approach (hands-on vs. hands-off) and communication style. Several students in this study reported management and communication issues with their advisers. Seven of these students benefited from switching advisers midway through their program. However, I found that switching advisers in the life sciences, where students typically become members in the PI's lab, is quite rare. Also, none of the students who engaged in a lab rotation before selecting an adviser considered switching advisers. This points to a serious flaw in the adviser matching system, particularly in the life sciences.

Students will not always select the best adviser fit for themselves. Mechanisms should be in place to facilitate a quick adviser switch when needed. One such mechanism is in departments which require two distinct research milestones, such as a qualifying

paper and a thesis. However, because switching advisers can add time to the student's

degree, prudent adviser selection at the start should be advocated by doctoral program

staff. In particular, students should focus on a prospective adviser's communication and

management style and think critically about their own preferences in terms of hands-on

vs. hands-off advising. After collecting information about a prospective adviser from her

current and former students and department staff, a student can then make an informed

decision about the best advising match.

Help Advisers Provide More Individualized Mentoring

From a programmatic perspective, it is easier to try to coach students into

choosing better adviser matches and to "manage up" when needed. However, advisers

must also be given supports to adjust their mentoring to meet the individual learning

needs of their doctoral students. Too many advisers apply a one-size-fits-all approach to

advising, rather than figuring out what strategy will work best with each student.

Overall, students described preferring a more hands-on adviser at the beginning, with

gradually less guidance over time as students mastered a new set of skills. By the end of

their graduate degree, students described wanting very little adviser involvement, as they

saw themselves transitioning into the role of a postdoc or PI

One strategy that may help advisers adjust their mentoring is to require adviser-

advisee pairs to complete written student development plans at the beginning of each

academic year. These plans could outline the goals for each semester, listing the tools

needed to meet those goals, and identify the academic milestone that will be completed at

the end of that year. Then a review of this plan could take place at the end of the year

with an analysis of what worked or did not work, and why. This would enable advisers and program chairs to be held more accountable for a student's progress through the program, ensuring that his goals are being clearly identified early on and that there are plans in place, including specific advising strategies, to meet them.

Another strategy would involve initiating more co-advising opportunities for doctoral students to work with two faculty advisers or a more informal mentoring program where students could pick their own faculty mentor as someone to talk through issues of concern and career questions without the formality or power-imbalance inherent to most adviser/PI relationships.

Challenge Faculty Biases Against Non-Academic Jobs

Advisers should be up front about their biases towards academic careers while acknowledging the competitive nature of these careers. It is also important early on, to spell out for students the long and financially uncertain path towards a professorship. Graduate study and postdoctoral fellowships are low paid compared to the salaries found in industry. And unlike with doctorates in medicine, there is no guarantee of eventually earning a higher salary, since tenure is also hard to obtain. Knowing these uncertainties, it is wise for students to consider "alternative" careers; faculty should actively encourage and support students to learn more about these pathways.

The findings in this study demonstrate that students perceive their advisers to promote academia as the one, legitimate career path to follow. This is both untrue and, ultimately, harmful to students who are not taking the time to prepare appropriately for non-academic careers during graduate school. Unfortunately, faculty face strong external

motivations to encourage their students to follow in their footsteps into academic careers.
Career-training grants from the NIH ask faculty to list the number of doctoral students
who continued in research or related careers (see Appendix E). At Calder, tenure review
applications (see Appendix F) ask faculty to list former students and describe their
accomplishments, including their current position and institution. Although neither
application states explicitly that they are looking to see if your former students are
working in academia, the underlying message is that it will bolster your application if you
can demonstrate that your trainees are successful academic researchers. As one Calder
STEM faculty member told me, "it's important for your trainees to end up with fancy
academic positions when people are reading your CV for tenure" (anonymous personal
communication, April 17, 2019). These are just two examples of external mechanisms
that contribute to the bias towards academic careers in STEM faculty advising.

STEM faculty advisers are also quick to withdraw their career support, once they
are made aware of their students' interest in "alternative" careers. They claim ignorance
about these fields and say they are unable to help students navigate this type of career
exploration process. Yet most STEM faculty are well networked with a large number of
STEM Ph.D. holders, including former students, classmates, and colleagues, who are
now working outside of academia. At the very least, faculty should be making more of
an attempt to introduce their students to the contacts they have working in non-academic
fields who may be able to provide internship opportunities or career advice.

Work-Life Balance for Faculty

Students described witnessing their advisers modeling poor work-life balance by sending emails late at night or while on vacation with their families. Others received messages, both implicitly and explicitly, about how to balance a career in science with raising children. These included hiring two full-time nannies, finding a spouse who is willing to stay at home full-time, or telling students that they would not have gotten tenure if they were mothers. Students with female advisers observed worse modeling of work-life balance than students with male advisers. One reason for this could be that because of unconscious gender biases and discrimination, women do have to work harder than men to succeed in academia. Another reason could be that female faculty wanted to be transparent with their female doctoral students about what it takes to succeed as a woman in academic science. In the future, I would like to add interviews with faculty to this study in order to understand their perspectives on these topics.

In her 2015 book, *I Know How She Does It: How Successful Women Make the Most of Their Time*, time management expert Laura Vanderkam advocates for working mothers to work a "split shift." This involves putting in the requisite 8-hour work day and then getting a couple more hours of work done at night, after the kids are asleep. While some of the doctoral students in this study were dismayed to see their advisers logging back onto email late at night, the advisers may be doing so with the earnest belief that they are modeling work-life balance for their students. Without any data, it is difficult to say anything about the advisers' intentions. However, it is important to note that students are watching, observing, and judging their advisers' lifestyle choices, much more closely than the advisers realize. Advisers should be made aware of this and encouraged to have frank discussions with advisees about how they approach work-life

balance in their lives. For instance, perhaps by emailing late at night, a PI has time in the morning to walk her daughter to school, exercise at the gym, or have lunch with a friend. I urge advisers to be mindful of their role model status with their advisees and also, for those in a lab setting, to be open when they are leaving the lab for personal reasons (e.g. a child's doctor's visit or a quick run to pick up groceries for dinner). It is important for PIs to model a well-rounded, healthy, and balanced lifestyle. They should explain deviations from this norm to their students to counter the perception that their work is all-encompassing.

It is likely that doctoral students are not seeing the full picture of their adviser's work-life balance and may have skewed perceptions of what they think they are observing. Additionally, advisers should remind their doctoral students that obtaining tenure at Calder University is exceptionally challenging. Most Calder Ph.D. graduates will go on to work at other universities. They should not necessarily view their adviser's stress and workload as normative of a career in academia. However, there are elements of faculty work-life balance at Calder that may be endemic to PIs working in the high achievement culture of an elite institution. Students, ideally, should be made aware of the different types of STEM academic careers offered at all rungs of the institutional hierarchy. That said, this research does suggest that many early career STEM faculty at Calder are operating in unhealthy ways.

Improving Diversity Among STEM Faculty

For the academic affairs and chief diversity officers who aspire to diversify the faculty, the physical and mental health of faculty—especially women and

underrepresented minorities—is subjugated by a faculty culture that rewards high intensity and extreme productivity. Elite universities need to identify ways to mediate the negative consequences of this unhealthy culture. Faculty diversity and work-life balance at Calder will not improve by simply providing faculty with funds for subsidized childcare. There must be a cultural shift that alleviates some of the stress and pressure on faculty at Calder, which I have shown is trickling down and impeding the happiness and well-being of doctoral students.

The fact that both men and women doctoral students have come to see academia as incompatible with raising children, maintaining mental health, and finding work-life balance is highly problematic. Calder University and many of its peer institutions espouse a commitment to increase faculty diversity. However, they view this important work as occurring primarily at the faculty job search stage, when hiring committees are reviewing candidates' CVs. In contrast, this study shines a light on doctoral education as the most critical time when people are making important decisions about whether or not they want to stay in academia. For the students in this study, especially women, their decisions can be largely explained by their experiences working with their advisers. If their advisers appear to be unhappy in academia, the motivation to pursue an academic career is greatly attenuated. This finding points to the urgent need for elite universities to address the expectations and norms that are producing such a high-stress achievement culture for faculty. This may start with reforming some of aspects of the tenure review and promotion process, including rewarding faculty for excellent mentoring and advising rather than focusing solely on research output and celebrity in the field.

Lastly, this study points to the male-dominated STEM academic research profession as one that continues to privilege traditionally male norms and behaviors at the expense of those norms and behaviors thought to be traditionally female. My research has shown that STEM graduate education requires students to conform to the norms that favor traditionally masculine behaviors, such as confidence with public speaking. Seventeen years after Antony's (2002) congruence and assimilation orientation criticisms of socialization theory, I found the women in this study were still being told to adopt the profession's ethics, norms, and values. For example, female doctoral students were advised to stop wearing feminine clothing and "dress like the men." While female faculty were assimilating their values by returning to work immediately after childbirth in order to be consistent with the male standards of parental leave in their field.

Academic vs. Non-Academic Careers: A False Dichotomy

In this study I have identified a typology of Four Post-Graduate Career Mindsets that students leave graduate school with: *Academia or Bust, Ambivalent about Academia, Best of Both Worlds*, and *Opting-Out of Academia*. I found that more men than women left Calder with an *Academia or Bust* mindset, while more women than men left with an *Ambivalent about Academia* mindset. Only men left Calder with a *Best of Both Worlds* mindset, with the belief that they could find future success in either academia or industry without being forced to choose at this point. Correspondingly, women outnumbered men leaving with an *Opting-Out of Academia* mindset, fourteen to one, believing they would never return to academia after earning their Ph.D.

Although those deciding to leave academia were received with varying degrees of adviser enthusiasm, most students ultimately felt that their advisers would support their decision if it was well-reasoned. The messaging students receive throughout graduate school is that once you leave academia, you cannot come back. However, through my identification of the Four Post-Graduate Career Mindsets, it's clear that the *Best of Both Worlds* mindset challenges this assumption. This mindset positions students to engage in work either within or outside of academia, while obtaining the necessary skills and experiences that would enable them to cross over easily to the other side in the future. Mostly, this applies to Ph.D. graduates working in industry postdocs. However, I also found one student, Sam, who fell into a postdoc with the intention of applying again for management consulting positions while also truly enjoying his work in this new lab.

What differentiates Sam from the students leaving Calder with an *Ambivalent about Academia* mindset is that these ambivalent students are cautiously optimistic that they can achieve a successful academic career while also acknowledging that the odds are stacked against them. At this point they are not seriously considering jobs outside of academia. They will only do so when and if it becomes necessary. Sam, on the other hand, is open to finding success in either realm. It is the open-mindedness, optimism, and sense of possibility inherent in the *Best of Both Worlds* mindset that are important. Also, this mindset points to the possibility that STEM graduate programs may be framing the choice between academic and non-academic careers as a false dichotomy. Perhaps students do not necessarily need to choose which path to follow when they complete their Ph.D. Nor do they need to feel a sense of failure if the academic path does not work out. As scientific research continues to change and become more collaborative and as

interdisciplinary research becomes more valued, academic-industry research partnerships are becoming more common. I argue that students with a *Best of Both Worlds* mindset are uniquely poised to take advantage of these professional opportunities.

The Four Post-Graduate Career Mindsets illuminate the ways in which students' frame their careers upon exiting their STEM doctoral studies. I believe that we have too many women (54% in this study) *Opting-Out of Academia*, despite a persistent need to diversity the STEM faculty. The students' narratives detailed throughout this study, reveal why this may be the case. If we wish to diversify the STEM faculty, coaching more women and underrepresented minorities to engage in a *Best of Both Worlds* mindset may yield more diverse STEM Ph.D. holders who will one day hold these positions.

III. Suggestions for Future Research

This study focused on understanding how STEM doctoral students at an elite research university make post-graduate career decisions. I found that the decision-making process for these students is a complex one, which varies across aspects of identity such as gender. Because I began this investigation with an overarching interest in improving faculty diversity, it is important that future research includes larger sample sizes where other aspects of identity, such as race and social class, could be included in the analyses. I was only able to interview five underrepresented minority students in this study, and was unable to identify patterns tied to particular racial identities. In the future, I would like to recruit more underrepresented minority students to participate in interviews. It would be fascinating to examine points of convergence and divergence with regard to the struggles encountered by women doctoral students. I would also like

to work with national survey data to see if there are similar trends in same-gender adviser/advisee pairings and satisfaction rates.

A main limitation of this study is that it took place at one elite research university. It is clear from my findings that institutional context matters a great deal. With regard to the pressure put on faculty members, I wonder if this is especially strong at Calder University or equally intense at other elite universities? It would be ideal to conduct future research at several of Calder's peer institutions to answer this question. I would also like to examine differences in career decision-making in STEM doctoral programs at other types of universities, including those designated by the Carnegie Classification as R1, yielding "very high research activity." Is the intense pressure on faculty, and thus doctoral students, standardized across institutions with high research activity or is it unique to those with the most prestige and status? Previous research on doctoral student career decision-making has not looked across institutions. I believe this line of inquiry would be of great practical benefit to prospective students as they consider which programs to apply and enroll in.

This study included students in the life sciences and physical sciences. While I did not examine individual departments as one of my units of analysis, in the future it would be beneficial to do so. I noticed differing practices between departments, such as a student-led faculty-student mentoring program in one department that students really benefited from. I wonder if this model would work well in other departments? Another department experienced three student and postdoc suicides within a short time period, which undoubtedly impacted students' desire for work-life balance in their careers. Departmental culture also varied with regards to how much encouragement students

received from faculty and peers to pursue academic careers versus careers outside of academia. Comparing doctoral student career development and choice across departments and, subsequently, across disciplines, would be meaningful contributions to the field.

This study identified doctoral advising as a strong contributor to how students experience doctoral education as well as the types of careers they decide to pursue after graduation. In order to improve advising, future research must include data on advising practices. As a next step, I would like to interview STEM faculty at Calder to understand their perspective on advising. I would ask them to describe the tools they use to connect with students and support them in navigating their professional identity development and job search process. We need more research on the variability of adviser-advisee relationships and more generalizable strategies that advisers can use to work with students of various backgrounds and personality types. Future research with faculty at other institutions should examine practices, such as a one-size-fits-all approach, that alienate students as well as identify those practices that draw students into the profession. Other perspectives from important stakeholders, such as department administrators, grant-funding decision makers at the NIH, and industry or government employers of STEM Ph.D.s, should be included as well. These individuals all contribute to the doctoral curriculum and/or the broader culture influencing graduate student career decision-making. Incorporating their perspectives into this research would undoubtedly improve career decision-making and career satisfaction among STEM Ph.D. holders in the future.

IV. Conclusion

Students' explanations of career decision-making in this study reveal the ways in which STEM doctoral education at one elite university encourages and inhibits career preparation towards and away from academia. While more women are needed in the pipeline to STEM graduate education and later, professorships, the findings in this study point to many obstacles that students face while in graduate school. These obstacles, such as difficult adviser relationships, research project struggle, competition, and uncertainty, ultimately dissuade students from staying in academia. Other obstacles, such as structural and cultural barriers to participation in industry-relevant panels, coursework, extra-curricular activities, and internships, impede students' career exploration into non-academic fields. This study demonstrates that both advising practices and doctoral program requirements need to be updated to achieve the dual goals of diversifying the professoriate *and* preparing students for careers in industry, government, and non-profit ventures.

This study also points to several ways in which women are disadvantaged in STEM doctoral education. These include greater challenges with advising—especially same-gender advising—than men faced, pressure to embrace traditionally "masculine qualities" that are embedded in academia, struggles with self-confidence, and difficulties navigating the politics of science. These findings help to explain the conundrum that despite more women obtaining STEM doctorates, the proportion of women in faculty positions has not caught up. Additionally, it challenges Ceci & Williams (2010)'s findings that women are leaving STEM fields due to preferences for time-flexible

careers. In fact, several students pointed out that academia offers more flexibility than industry, given the large degree of control faculty have over their time.

This study shows that both women and men value work-life balance and are prioritizing their mental and physical health needs when making career decisions. As I have demonstrated, the challenges women experience in doctoral education, rather than a desire for time flexibility, are deterring women from academic careers. Given the greater participation by women in STEM doctoral education, it is easy to dismiss the impact of gender on graduate education and career pathways. I propose that STEM doctoral program faculty, administrators, and policy makers pay greater attention to the disparities women are facing. They also must re-examine the elite university culture that rewards obsessive work habits and high stakes competition among faculty. Lastly, the professional aspirations of STEM doctoral students have changed while the academic job market continues to tighten. Elite universities cannot, in good faith, prepare their doctoral students for only one type of career when the majority will go on to pursue exciting scientific careers outside of academia.

Appendix A. Recruitment Email

Hello!
My name is Lisa and I am a doctoral student at the Harvard Graduate School of Education. For my dissertation, I am seeking research participants for an interview-based study on the experiences of STEM doctoral students and the factors that influence their pathways into academic and non-academic careers.

The goal of this study is to create a greater understanding of how doctoral students navigate academic and non-academic career pathways. I hope this study will contribute to programmatic and policy efforts that can better support Ph.D. students, improving both their student experiences and their post-graduate career satisfaction.

I am seeking participants in the Life, Physical, and Applied Sciences at Calder University who:
- Graduated or will graduate in 20XX or 20XX with a doctoral degree
- Are U.S. citizens or permanent residents

Study participation involves one 90-minute interview. Interviews take place at _____ or at a private location of your choosing (or, if necessary, via Skype). Students will be compensated with a $25 Amazon gift card for their time.

If you are interested in possibly participating or learning more about this study, please contact me at lmu848@mail.harvard.edu or 617-216-2834. All inquiries and interviews are confidential and participation in the study is completely voluntary. This study is not endorsed or sponsored by Calder's graduate school in anyway.

Thank you for your interest!

With best wishes,

Lisa Shen

Appendix B. Interview Protocol

Protocol for Semi-structured Interviews

Introduction
Thank you for taking the time to talk with me today. As I mentioned in my email, the purpose of this study is to learn more about how doctoral students make decisions about their post-graduate career plans. In particular, I'm interested in differences across aspects of identity, such as gender and race. Before we get started, I want to mention that there are no "right" or "wrong" answers. I'm interested in learning about *how* and *why* you came to the decisions you made in planning for your post-graduate career, not simply *what* you ultimately decided to do.

Consent, Confidentiality, and Audio Recording
- I want to make sure that I have your consent to participate in this study. This consent form goes over the same things we have just talked about. Once you have read the form, please sign it to document that you have agreed to be part of this research. You should feel free to ask me questions about the research at any time. If you decide that you would not like to participate in the research, you can say "stop," and we will stop at any time.
- I will be the only person who has access to the interview materials in which you are identified. In order to protect your identity from others, I am using a pseudonym for the university's name and will assign all study participants a pseudonym as well in any written communications about my study. I may use the gender and racial identities of participants, along with their department, but the year of data collection will be vague (e.g. 2012-2017) in order to provide for confidentiality. To protect your identity and provide confidentiality, please refer to other people affiliated with the University by their role (e.g. faculty adviser, classmate), not their names.
- With your permission, I would like to audio record this interview. It is important for me to capture your thoughts and ideas and using the recorder will allow me to do this more accurately than writing up your responses as we talk. Do you mind if I record this interview?

Interview Questions
Before we get started, are there any questions you have for me about this study? As I turn the voice recorder on, I just wanted to check with you again to make sure you feel comfortable with me recording the interview.

[Thornton and Nardi (1975) identified three core elements of socialization that map onto the stages and constitute the Weidman et al. (2001) model of graduate student socialization. I used these three central features, knowledge acquisition, investment, and involvement, to frame my initial interview protocol.]

Doctoral Student-Level Questions
1. Background

A. Thinking back, what shaped your decision to apply to graduate school?
   a. PROBE: During the application phase, what types of career goals did you have?
   b. PROBE: Did you have other plans for the future before you started the program?

B. Did you reference these plans in your statement of purpose or when you visited with faculty and students?
C. How did you decide to enroll at Calder? What specifically drew you to Calder? What apprehensions did you have?
D. Overall, how would you describe your experience in your doctoral program?
   a. PROBE: Can you tell me about one of the **highlights** of your experience? (Are there any other highlights that you'd like to share?)
   b. PROBE: Can you tell me about one of the **hardest parts** of your experience? (Are there any other hard parts that you'd like to share?)
E. Can you tell me about your [dissertation] research project(s)? How did it originate? What were the struggles? What were the successes? Who was most helpful to you during this time? How do you feel about it now, looking back on it?

2. Career Planning

A. Can you walk me through your career planning process, from your 1st year to today?

   1. PROBE: What were your thoughts when you started grad school? How have those shifted or changed in the past 5-6 years?
   2. PROBE: At what point did you start to think seriously about your post-Calder career?
   3. PROBE: How did you learn about the types of career options that are available to you?
   4. PROBE: How did you feel about these? Who did you turn to for advice?

B. You told me you would be doing _____ after graduation. How did that come to be?
   1. PROBE: While in your doctoral program, did you consider pursuing any other career paths?
C. Is this your post-graduation "dream job?" If not, what would be your "dream job?"
D. At this point in your career, where do you see yourself professionally long-term (5-10-15 years?).
E. Are your long-term career goals different from your near-term plans? If so, how?
   1. PROBE: Who, if anyone, influenced your long-term career goals?
   2. PROBE: Do you anticipate any possible changes to your long-term career path?
I. What has been most stressful or challenging for you in deciding upon and pursuing post-graduate career plan?

J. What are you most nervous about when you think about starting your new job/postdoc?

K. If leaving academia: do you think you will be able to return to academia? Why or why not?
1. PROBE: Were there any personal constraints, e.g. personal relationships or family concerns that affected your job search?

3. Internalization and Commitment to the Profession

A. Were there any key turning points or major factors that influenced your career plans?
1. PROBE: Was there an "aha" moment for you, when something clicked and you felt strongly about a particular career path?
2. PROBE: What about any moments when you felt strongly *against* a particular path?

B. Is there anything that you know now, that you wished you had learned earlier on in your doctoral program?
1. PROBE: Is there anything that you had to learn "the hard way?"
2. PROBE: What advice would you give to others in their G1 year, who are interested in your academic field?

C. Is there anything you would change or do differently with regard to your career planning?
1. PROBE: Who or what was most helpful to you when making career plans?

4. Advising

A. How would you describe your relationship with your faculty adviser?
a) How has your adviser influenced your career planning, if at all?
2. Can you recall any specific interactions with him/her that shaped your professional aspirations? How frequently did you interact? How often did you meet? How would you describe the quality of the interactions?
a) How open is he/she towards his/her advisees considering non-academic careers?
3. How did you pick your adviser? What made you decide to work in his/her lab?
a) Does he/she have "favorites" and would you consider yourself one of them?
4. Tell me about what activities (e.g., labs, writing articles), if any, you have been involved in with your advisor?
a) If applicable, can you describe the culture of his/her lab or research team?
5. What was his/her advising and mentoring style like?
a) What is his/her teaching style like?
b) Is he/she hands-on? Or hands-off?
6. Would you consider him/her to be a professional role model? Why or why not?
a) Can you describe his/her work/life balance?

          b) What aspects or characteristics of your adviser will you replicate when you are an adviser or supervisor yourself?

          c) What aspects or characteristics will you definitely change?

7. Do you see anyone else within your doctoral program as a role model? Tell me about this person/people.

8. Besides your advisor, was there anyone else who strongly influenced your plans after graduation?

          a) PROBE: Administrative staff, peers, family?

Disciplinary/Department-Level Questions

5. Professional Culture

A. Has your department offered special programming aimed at career development?
1. If yes, what aspects of that programming were useful?
2. Did you access information about career development from any other places? [Probes: other departments, disciplinary meetings, professional associations]

B. If applicable, has your department offered any special programs aimed at students of color? Women?
    a. PROBE: Did you find it helpful? Why or why not?

6. Departmental/Disciplinary Involvement

A. What aspects of your involvement (e.g. activities, such as TF-ing, going to job talks, presenting your work) with your department have been most helpful in your career planning? What about aspects of your involvement with your discipline?

B. Based on your experience, how, if at all, do students within the department support one another in career planning?

C. Can you describe your involvement in any professional activities, such as professional associations, student organizations, **conferences**, writing groups, etc.
    a. PROBE: How did this involvement impact your career planning, if at all?
    b. PROBE: How did it impact your professional identity?
    c. PROBE: How did it impact your commitment to your profession, if at all?

7. Individual Identity

A. Have any aspects of your personal identity played a significant role during graduate school (e.g. race, gender, class, sexuality, geography)?
    a. PROBE: For example, what impact, if any, has your racial identity had on your academic experiences?
    b. PROBE: Your professional development experiences?
    c. PROBE: Your experiences with advising?
    d. PROBE: Your experiences with your peers?

B. Was there ever a time when you felt conscious of being in the minority/majority in your doctoral program? What was that experience like for you? Did you feel included/excluded?

C. If not already answered, what impact, if any, has your identity/identities had on your approach to job seeking and your career?

      D. Are there any other aspects of your identity that have had a significant impact on your career planning (e.g. age, social class, role as a parent)

      E. When you think about your own racial/gender/sexual identity, do you think your experiences are different or similar to others with your racial/gender/sexual identity?

          a. PROBE: In what ways? Why do you think that is?

8. Conclusion

    A. In what ways would you recommend Calder to change, in order to improve the experiences of doctoral students?

    B. Is there anything else you would like to add that we didn't discuss?

    C. Is there anything you would like to ask me?

    D. Is there anyone else you think I should interview?

As I mentioned at the beginning of the interview, I would be happy to send you any reports that come out of this work. Would you like that? Is email the best way to reach you?

Thank you very much for participating in this interview.

Appendix C. Demographic Questionnaire

First name: Preferred pseudonym
(optional):

Doctoral degree program: Graduation date:

Semester and year you began doctoral study (e.g. Fall 2010):

Adviser Relationship
☐ Satisfactory   ☐ Unsatisfactory   ☐ Mixed

Career plans following graduation:
☐ Academic Postdoc   ☐ Industry Postdoc   ☐ Government Postdoc
☐ Teaching Postdoc   ☐ Field-Specific Postdoc ☐ Self-made Postdoc
☐ Consulting   ☐ Industry position   ☐ Public policy position

        ☐ Tenure-track faculty position   ☐ Lecturer teaching position
        ☐ Other _____

Would you be willing to share your personal statement/essay from your doctoral
program application with me?
        ☐ Yes   ☐ No

Would you be willing to share your C.V. with me?
        ☐ Yes   ☐ No

Demographic Questions

1. What is your date of birth? _____

2. What is your sex?
        ☐ Cisgender male   ☐ Cisgender female
        ☐ Transgender male   ☐ Transgender female   ☐ I prefer not to
respond

3. What is your ethnicity/race? (Please check ALL that apply.)
        ☐ American Indian or other Native American
        ☐ Asian, Asian American, or Pacific Islander
        ☐ Black or African American
        ☐ Mexican or Mexican American
        ☐ Puerto Rican
        ☐ Other Hispanic or Latino

☐ White, Non-Hispanic
☐ Multi-racial
☐ Other: _____
☐ I prefer not to respond

4. What is your citizenship?
☐ U.S. Citizen
☐ Permanent U.S. Resident

5. In what country or countries were your parents (or legal guardians) born?

6. Did you grow up speaking a language other than English at home?
☐ Yes
☐ No

If yes, what language(s) other than English did you speak at home?

7. What is your mother/parent/guardian's highest level of education?

☐ Unsure   ☐ Master's degree
☐ H.S. diploma   ☐ Professional degree (e.g. JD or MD)
☐ Associate's degree   ☐ Doctoral degree (e.g. Ph.D.)
☐ Bachelor's degree   ☐ Other_____

8. What is your father/parent/guardian's highest level of education?

☐ Unsure   ☐ Master's degree
☐ H.S. diploma   ☐ Professional degree (e.g. JD or MD)
☐ Associate's degree   ☐ Doctoral degree (e.g. Ph.D.)
☐ Bachelor's degree   ☐ Other_____

9. Which of the following best describes you?

☐ Heterosexual (straight)   ☐ Transgender
☐ Gay or Lesbian   ☐ I prefer not to answer
☐ Bisexual   ☐ Other: _____
☐ Asexual

10. What is your marital and family status (check all that apply)?

☐ Single   ☐ Married
☐ Divorced   ☐ Long-term cohabitating partnership
☐ Parent

Appendix D. Preliminary Codes

Etic Codes

Career
- Goals
- Opportunities awareness
- Norms
- Programming
- Uncertainties

Disciplinary
- Advantages
- Challenges
- Culture

Departmental
- Advantages
- Challenges
- Culture

Financial
- Investment
- Support

Identity
- Conflicts

Influential others
- Faculty
- Peers
- Postdocs
- Staff

Institutional
- Advantages
- Challenges
- Culture
- Support

Mentoring
- From advisor
- From others
- To others

Professional culture
- Within lab
- Within department
- Within discipline
- Norms

Program highlights
Program lowlights
Metamorphosis
Sacrifice
Turning point

Emic Codes

Advising Advisor
- Advising your advisor
- Attitudes towards leaving academia
- "Back in my day…"
- Communication
- Hoped for/feared for self
- Management training
- Selection process

Career
- Academia or bust
- Bench research
- Big decisions
- "Coming out"
- Consulting
- Industry
- Internships
- Options
- Planning Proactively
- Postdocs (fallback option)
- Qualifications/competency

Collaboration/lack of

Department Culture
- Achievement-oriented
- Imposter syndrome
- Openness to non-academic paths
- Politics
- Student gossip

Dissertation
>   Dissertation Advisory Committee

Disillusionment

Diversity

Excitement

Extracurricular activities

Frustration
- Spinning your wheels

Fulfillment/Satisfaction

Impact
- Helping mankind

Isolation

Labs
- Culture
- Selection process

Lifestyle
- Work/life balance

Luck

Peer effects

Motivation/Drive

Naiveté

Passion

Partner/spouse
- Two body problem

Postdoc

(Being) Practical/realistic

Publishing

Race & Racism
- Black scientists
- Microaggressions

Regret

Research project
- Luck
- Struggle
- Success
- Thesis

Self-knowledge

Self-reflection

Sexism

Teaching

Transitions
- Undergrad => Grad

Uncertainty

Women in Science

Appendix E. NIH Training Grant Application Table

Instructions

Mentoring Record (Items 7-12). For the last 10 years, provide the record for mentoring pre-doctorates <u>and</u> post-doctorates who have been or are currently engaged in research training under your primary supervision. Exclude pre-doctorates doing research rotations, and clinical interns and residents unless they have been or are currently engaged in full-time, mentored research training in your research group.

7. **Pre-doctorates in Training.** Provide the number of pre-doctorates who are currently in training.
8. **Pre-doctorates Graduated.** Provide the number of pre-doctorates who were awarded their doctoral degree during the last 10 years. Do not include anyone who received the terminal degree prior to January 1, 2008.
9. **Pre-doctorates Continued in Research or Related Careers.** Provide the number of pre-doctorates who were awarded their doctoral degree during the last 10 years <u>and</u> who currently are engaged in a research-intensive or research-related career. Research-related positions generally require a doctoral degree, and may include activities such as teaching, administering research or higher education programs, science policy, and technology transfer. Do not include anyone who received the terminal degree prior to January 1, 2008.
10. **Post-doctorates in Training.** Provide the number of post-doctorates who are currently in training in your laboratory.
11. **Post-doctorates Completed Training.** Provide the number of post-doctorates who completed postdoctoral training in your laboratory during the last 10 years.
12. **Post-doctorates Continued in Research or Related Careers.** Provide the number of post-doctorates who completed postdoctoral training during the last 10 years <u>and</u> who currently are engaged in a research-intensive or research-related career

Name	Degree(s)	Rank	Primary Department or Program	Research Interest	Training Role	Pre-doctorates in Training	Pre-doctorates Graduated	Pre-doctorates Continued in Research or Related Careers	Post-doctorates in Training	Post-doctorates Completed Training	Post-doctorates Continued in Research or Related Careers
John Smith	Ph.D.	Assoc. Prof.	Biology		Mentor	1	3	3	7	9	9

Appendix F. Excerpt from the General Instructions for Preparation of the Faculty C.V. used during the evaluation of candidates for promotion to tenure.

Formally Mentored Calder Graduate Students:
• Note students who have worked with you on their scholarly project, master's thesis or dissertation. For each mentored student, note the students' names, the years in which they worked with you, the titles of their projects, the outcomes of their work, and any scholarship or presentations resulting from the project.

• Include the names of students on whose Dissertation Advisory Committee (DAC), Preliminary Qualifying Exam (PQE) Committee, and/or Thesis Advisory/Defense Committee you have served as a member.

Describe the accomplishments of your mentee as a direct result of your mentorship (maximum one sentence)
2012-2014
Susanna Wright, Calder University, Class of 2015
Currently conducting thesis research in my laboratory. Presented a poster titled "Plasticity of specific inhibitory inputs in the auditory cortex" at the 2013 Society for Neuroscience conference.

Other Mentored Trainees and Faculty:
• Individuals reported in this section should be those mentored in a research, teaching, or clinical setting other than those described in the section above. List only those trainees or faculty on whose careers you have had a significant impact.

• Dates refer to a period of mentorship; end dates should be indicated for individuals who are no longer mentees.

Example Year(s) Name and degrees / Current position, Institution

Note the mentee's career stage during the mentorship period and your mentoring role.

Please describe the accomplishments of your mentee as a direct result of your mentorship (maximum one sentence)

1998-2003 Mary Jones, MD, MPH / Associate Professor of Preventive Medicine, Northwestern University Career stage: resident, fellow. Mentoring role: research advisor. Accomplishments: multiple first-authored scholarship of mentored research; Calder University.

2013-2015 Mario G. Woodruff, MD / Assistant Professor of Radiology, University of California, San Francisco Career stage: fellow. Mentoring role: fellowship mentor Accomplishments: new quality improvement protocol; presented at Radiological Society of North America.

Bibliography

Acker, J. (1990). Hierarchies, jobs, bodies: A theory of gendered organizations. *Gender and Society, 4*(2), 139-158.

Alberts, B., Kirschner, M. W., Tilghman, S., & Varmus, H. (2014). *Rescuing U.S. biomedical research from its systemic flaws.* Proceedings of the National Academy of Sciences, 111(16): 5773-5777.

American Association of University Professors (AAUP). 2013. Trends in faculty employment status, 1975-2011. Available at http://www.aaup.org/sites/default/files/faculty_trends_0.pdf

Antonio, A. I. (2003). Diverse student bodies, diverse faculties. *Academe, 89*(6).

Antonio, A. I. (2000). Faculty of color and scholarship transformed: new arguments for diversifying faculty. *Diversity Digest, 2,* 6-7.

Antony, J. S. (2002). Reexamining doctoral student socialization and professional development: Moving beyond the congruence and assimilation orientation. In J. C. Smart (Ed.), *Higher Education: Handbook of theory and research,* (Vol. 17, pp. 349-380. New York: Agathon Press.

Antony, J. S. & Taylor, E. (2001). Graduate student socialization and its implications for the recruitment of African American education faculty. In W. G. Tierney (Ed.), *Faculty work in schools of education: Rethinking roles and rewards for the 21st century* (pp. 189-209). Albany: State University of New York Press.

Antony, J. S. & Taylor, E. (2004). Theories and strategies of academic career socialization: Improving paths to the professoriate for Black graduate students. In D. H. Wulff, A. E. Austin, & Associates (Eds.), *Paths to the professoriate: Strategies for enriching the preparation of future faculty* (pp. 92-114). San Francisco, CA: Jossey Bass.

Astin, A. W. (1977). *Four critical years: Effects of college on beliefs, attitudes and knowledge.* San Francisco: Jossey-Bass Publishers.

Austin, A. E. (2002). Preparing the next generation of faculty: Graduate school as socialization to the academic career. *The Journal of Higher Education, 73,* 94-122.

Baird, L. L. (1992). The stages of the doctoral career: Socialization and its consequences. San Francisco: Paper presented at the annual meeting of the American Educational Research Association. ERIC Document Number ED 348 925.

Baird, L. L. (1993). Using research and theoretical models of graduate student progress. In L. L. Bair (Ed.), *Increasing graduate student retention and degree attainment* (pp. 3-12). San Francisco: Jossey-Bass.

Bancroft, S. F., Bendon, S. K., & Johnson-Whitt, E. (2016). McNair Scholars' Science, Technology, Engineering, and Mathematics (STEM) Graduate Experience: A Pilor Study. *Mid-Western Educational Researcher, 28* (1), 83-98.

Barnes & Austin (2008).

Becher, T. (1989). *Academic tribes and territories: Intellectual enquiry and the culture of disciplines.* Bristol, PA: SRHE and Open University Press.

Becher, T. & Trowler, P. (2001). *Academic tribes and territories: intellectual enquiry and the culture of disciplines,* 2nd ed. Philadelphia, PA: Society for Research into Higher Education & Open University Press.

Berelson, B. (1960). *Graduate education in the United States.* New York, NY: McGraw-Hill.

Berg, H. M. & Ferber, M. A. (1983). Men and women graduate students: Who succeeds and why? *Journal of Higher Education, 34(6), 629-648.*

Bernstein, B. L. (2011). Managing barriers and building supports in science and engineering doctoral programs: Underpinnings for a new online training program for women. *Journal of Women and Minorities in Science and Engineering, 17*, 29-50.

Bettinger, E. & Long, B. T. (2005). Do faculty members serve as role models? The impact of faculty gender on female students. *American Economic Review, 95*(2).

Blackwell, J. E. (1990). Current issues affecting Blacks and Hispanics in the educational pipeline. In G. Thomas (Ed.), *U.S. Race Relations in the 1980s and 1990s: Challenges and Alternatives.* New York, NY: Hemisphere.

Blank, R., Daniels, R. J., Gilliland, G., Gutmann, A., Hawgood, S., Hrabowski, F. A., Pollack, M. E., Price, V., Reif, L. R., Schlissel, M. S. (2017). A new data effort to inform career choices in biomedicine. Science, 358, 6369; 1388-1389.

Bordalo, P., Coffman, K., Gennaioli, N., Shleifer, A. (2019). Beliefs about gender. *American Economic Review, 109*(3), 739-773.

Bowen, W., & Rudenstine, N. (1992). *In pursuit of the Ph.D..* Princeton, NJ: Princeton University Press.

Bragg, A. K. (1976). The socialization process in higher education. ERIC/Higher Education Research Report, No. 7. Washington, DC: The American Association of Higher Education.

Brim, O. G., Jr. (1966). Socialization through the life cycle. In O. G. Brim, Jr., and S. Wheeler (Eds.), *Socialization after childhood: Two essays* (pp. 1-49). New York: Wiley.

Britton, D. M. (2000). The epistemology of the gendered organization. *Gender and Society, 14,* 418-434.

Brooks, C., Fenton, E. M., Walker, J. T. (2014). Gender and the evaluation of research. *Research Policy, 43*(6): 990-1001.

Bullis, C. & Bach, B. (1989). *Socialization turning points: An examination of change in organizational identification.* Paper presented at the annual meeting of the Western Speech Communication Association, Spokane, WA.

Cahn, S. (1986). *Saints and scamps.* Totowa, NJ: Rowman & Littlefield.

Canes, B. J. & Rosen, H. S. (1995). Following in her footsteps? Faculty gender composition and women's choices of college majors. *Industrial and Labor Relations Review, 48*: 486-504.

Carrell, S. E., Page, M. E., & West, J. E. (2010). Sex and science: how professor gender perpetuates the gender gap. *Quarterly Journal of Economics, 125*(3), 1101-1144.

Ceci, S. J. & Williams, W. M. (Eds.) (2007). *Why aren't more women in science? Top researchers debate the evidence.* American Psychological Association, Washington, DC.

Ceci, S. J. & Williams, W. M. (2010). Sex differences in math-intensive fields. *Current Directions in Psychological Science, 19*(5), 275-279.

Ceci, S. J. & Williams, W. M. (2015). Women have substantial advantage in STEM faculty hiring, except when competing against more-accomplished men. Front Psychology, 6: 1532.

Chait, R. & Trower, C. A. (2002). Faculty diversity: too little for too long. *Harvard Magazine, 104*(4). Retrieved from http://harvardmagazine.com/2002/03/faculty-diversity.html

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). London: Sage Publications.

Clarke, C. & Antonio, A. (2012). Rethinking research on the impact of racial diversity in higher education. *Review of Higher Educaiton, 36*(1), 25-50.

Clauset, A., Arbesman, S., & Larremore, D. B. (2015). Systematic inequality and hierarchy in faculty hiring networks. *Science Advances, 1*(1). doi: 10.1126/sciadv.1400005

Cole, D. & Griffin, K. A. (2013). Advancing the study of student-faculty interaction: A focus on diverse students and faculty. In *Higher Education: Handbook of Theory and Research,* pp. 561-611. Springer: Netherlands.

Cole, J. R. & Zuckerman, H. (1984). The productivity puzzle: persistence and change in patterns of publication of men and women scientists. *Advances in Motivation and Achievement, 2*: 217-258.

Council of Graduate Schools (2005). *Ph.D. Completion and Attrition: Policy, Numbers, Leadership, and Next Steps*; Council on Graduate Schools: Washington, DC.

Craig, L. & Mullan, K. (2011). How mothers and fathers share childcare. *American Sociological Review, 76*(6): 834-861.

Crawford, M. & MacLeod, M. (1990). Gender in the college classroom: An assessment of "chilly climate" for women. *Sex Roles, 23,* 101-122.

Cresswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches.* Los Angeles, CA: Sage Publications.

Cresswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches.* Los Angeles, CA: Sage Publications.

Cyranoski, D., Gilbert, N., Ledford, H., Nayar, A., & Yahia, M. (2011). The PhD Factory: The world is producing more PhDs than ever before. Is it time to stop? *Nature,* April 21 (472), 276-279.

Daniel, C. (2007). Outsiders within: Critical race theory, graduate education, and barriers to professionalism. *Journal of Sociology and Social Work, 34*(1), 25-42.

Daniels, R. J. (2015). A generation at risk: Young investigators and the future of the biomedical workforce. *Proceedings of the National Academy of Sciences, 112* (2), 313-318.

Drago, R., Colbeck, C., Stauffer, K. D., Pirretti, A., Burkum, K., Fazioli, J., Lazarro, G., & Habasevich, T. (2006). The avoidance of bias against caregiving. *American Behavioral Scientist, 49*(9), 1222-1247.

Dynan, K. E. & Rouse, C. E. (1997). The underrepresentation of women in economics: a study of undergraduate economics students. *The Journal of Economic Education, 28*(4), 350-368.

Ehrenberg, R. G. (1991). Academic labor supply. In C. Clotfelter, R. Ehrenberg, M. Getz, & J. Siegfried (Eds.), *Economic challenges in higher education.* Chicago, IL: University of Chicago Press.

Ehrenberg, R. G. & Kuh, C. V. (2009). *Doctoral Education and the faculty of the future.* Ithaca: Cornell University Press.

Feldman, S. (1974). *Escape from the doll's house: Women in graduate and professional education.* New York: McGraw-Hill.

Felder, P. & Barker, M. (2013). Extending Bell's concept of convergence: A framework for understanding the African American doctoral student experience. *International Journal of Doctoral Studies, 8,* 1-20.

Felder, P., Stevenson, H., & Gasman, M. (2014). Understanding race in doctoral student socialization. *International Journal of Doctoral Studies, 9,* 21-42.

Ferreira, M. M. (2002). Context factors related to women attrition from a graduate science program: A case study. *Advancing Women in Leadership Journal,* 1-10.

Figueroa, M. A. (2004). Doctoral student socialization and faculty career choice. Ph.D. Dissertation. Claremont Graduate University.

Filardo, G., da Graca, B., Sass, D. M., Pollock, B. D., Smith, E. B., Martinez, M. A. (2016). Trends and comparison of female first authorship in high impact medical journals: observational study (1994-2014). The British Medical Journal, 352. Retrieved from http://dx.doi.org/10.1136/bmj.i847.

Finn, M. G. (2010). *Stay rates of foreign doctorate recipients from U.S. universities, 2007.* Oak Ridge, TN: Oak Ridge Institute for State and Education (ORISE). Retrieved from http://orise.orau.gov/files/sep/stay-rates-foreign-doctorate-recipients-2007.pdf

Fix the Ph.D. (2011). *Nature, 472:* 259.

Fox, M. F. (1998). Women in science and engineering: Theory, practice, and policy in programs. *Signs, 24,* 201-223.

Fox, M. F. (2001). Women, science, and academia: Graduate education and careers. *Gender & Society, 15*, 664-666.

Fox, M. F. (2003). Gender, faculty, and doctoral education in science and engineering. In L. Hornig (Ed.), *Equal rites, unequal outcomes: Women in American research universities,* pp. 91-109. New York: Kluwer/Plenum.

Fuhrmann, C. N., Halme, D. G., O'Sullivan, P. S., Lindstaedt, B. (2011). Improving graduate education to support a branching career pipeline: recommendations based on a survey of doctoral students in the basic biomedical sciences. CBE Life Sciences Education, 10: 239-249.

Gardner, S. K. & Mendoza, P. (Eds.) (2010). *On becoming a scholar: Socialization and development in doctoral education.* Sterling, VA: Stylus Publishing.

Gaul, P. & Piacentini, M. (2017). An adviser like me? Advisor gender and post-graduate careers in science. IZA Discussion Papers, No. 10828. Institute of Labor Economics (IZA), Bonn.

Gerholm, T. (1990). On tacit knowledge in academia. *European Journal of Education, 25*(3), 263-271.

Gibbs, K. D. Jr., McGready, J., Bennett, J. C., & Griffin, K. (2014). Biomedical science Ph.D. career interest patterns by race/ethnicity and gender. *PLoS ONE, 9*(12), e114736.

Gilbert, L. A. & Rossman, K. M. (1992). Gender and the mentoring process for women: Implications for professional development. *Professional Psychology: Research and Practice, 23*(3), 233-238.

Gilligan, C. (1978). *In a different voice: Psychological theory and women's development.* Cambridge, MA: Harvard University Press.

Girves, J. E. & Wemmerus, V. (1988). Developing models of graduate student degree progress. *Journal of Higher Education, 59*(2), 163-189.

Gopaul, B. (2011). Distinction in doctoral education: Using Bourdieu's tools to assess the socialization of doctoral students. *Equity & Excellence in Education, 44*(1), 10-21.

Gopaul, B. (2016). Applying cultural capital and field to doctoral student socialization. *International Journal for Researcher Development, 7*(1).

Golde, C. M. (1998). Beginning graduate school: Explaining first-year doctoral attrition. In M. S. Anderson (Ed.), *The experience of being in graduate school: An exploration* (pp. 55-64). San Francisco: Jossey-Bass.

Golde, C. M. (2000). Should I stay or should I go? Student descriptions of the doctoral attrition process. *The Review of Higher Education, 23,* 199-227.

Golde, C. M. (2005). The role of department and discipline in doctoral student attrition: lessons from four departments. *Journal of Higher Education, 76*(6), 669-700.

Golde, C.M. & Dore, T. M. (2001). *At cross purposes: What the experiences of today's doctoral students reveal about doctoral education.* Philadelphia, PA: The Pew Charitable Trusts.

Golde, C. M. & Dore, T. M. (2004). The survey of doctoral education and career preparation: the importance of disciplinary contexts. In D. Wulff, A. Austin, & Associates (Eds.), *Paths to the professoriate: Strategies for enriching the preparation of future faculty* (pp. 19-45). San Francisco, CA: Jossey Bass.

Golde, C. M., Bueschel, A. C., Jones, L., & Walker, G. E. (2009). Advocating apprenticeship and intellectual community: Lessons from the Carnegie initiative on the doctorate. In R. G. Ehrenberg & C. V. Kuh (Eds.) *Doctoral Education and the Faculty of the Future.* Ithaca and London: Cornell University Press.

Gould, J. (2015). How to build a better PhD. *Nature, 528,* 22-25.

Granovetter, M. (1983). The strength of weak ties: A network theory revisited. *Sociological Theory, 1,* 201-233.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360-1380.

Griffin, K. A., Muniz, M., & Smith, E. J. (2016). Graduate diversity officers and efforts to retain students of color. *Journal of Student Affairs Research and Practice, 53*(1), 26-38.

Gumport, P. J. (1993a). Graduate education and organized research in the United States. In B. R. Clark (Ed.), *The research foundations of graduate education: Germany, Britain, France, United States, Japan* (pp. 225-260). Berkeley: University of California Press.

Gumport, P. J. (1993b). Graduate education and research imperatives: Views from American campuses. In B. R. Clark (Ed.), *The research foundations of graduate education: Germany, Britain, France, United States, Japan* (pp. 261-296). Berkeley: University of California Press.

Hagedorn, L. S. & Laden, B. V. (2002). Exploring the climate for women as community college faculty. *New Directions for Community Colleges, 118,* 69-78.

Hakim, C. (2006). Women, careers, and work-life preferences. *British Journal of Guidance and Counseling, 34,* 279-294.

Hall, R. M., & Sandler, B. R. (1982). *The classroom climate: A chilly one for women? Project on the status and education of women.* Washington, DC: Association of American Colleges.

Handelsman, J., Cantor, N., Carnes, M., Denton, D., Fine, E., Grosz, B., Hinshaw, V., Marrett, C., Rosser, S., Shalala, D., and et al. (2005). More women in science. *Science, 309*, 1190-91.

Hartnett, R. T. (1976). Environment for advanced learning. In J. Katz & R. T. Hartnett (Eds.) *Scholars in the making: the development of graduate and professional students.* Cambridge: Ballinger Publishing, 49-84.

Hartocollis, A. & Bidgood, J. (2015). Racial discrimination protests ignite at colleges across the U.S. *The New York Times.* Retrieved from http://www.nytimes.com/2015/11/12/us/racial-discrimination-protests-ignite-at-colleges-across-the-us.html?_r=0

Hill, C., Corbett, C., St. Rose, A. (2010). Why so few? Women in science, technology, engineering, and mathematics. American Association of University Women, Washington, DC. Retrieved from www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf

Hoffman, F. & Oreopoulos, P. (2009). A professor like me: the influence of instructor gender on college achievement. *Journal of Human Resources, 44*(2), 479-494.

Holley, K. A. & Joseph, J. (Eds.). (2013). *Increasing diversity in doctoral education: implications for theory and practice.* New Directions for Higher Education, *163*. San Francisco: Jossey-Bass.

Holmes, M. A., O'Connell, S., Frey, C., & Ongley, L. (2008). Gender imbalance in U.S. geoscience academia. *Nature Geoscience, 1*, 79-82.

Hune, S. (1998). *Asian Pacific American women in higher education: Claiming visibility and voice.* Washington, DC: Association of American Colleges and Universities.

Jacks, P., Chubin, D. E., Porter, A. L. & Connolly, T. (1983). The ABCs of ABDs: a study of incomplete doctorates. *Improving College and University Teaching, 31*(2), 74-81.

Jaschik, S. (2013). Tenure track as alt-ac. *Inside Higher Ed.* Retrieved from http://www.insidehighered.com/news/2013/02/19/research-aaas-meeting-notes-difficult-job-market-academic-science

Johnson, S. D., Kuykendall III, J. A., & Winkle-Wagner, R. (2009). Financing the dream, the impact of financial aid on graduate education for underrepresented minority students. IN M. Howard-Hamilton, C. Morelon-Quainoo, S. Johnson, R. Winkle-Wagner, & L. Santiague (Eds.), *Standing on the outside looking in: Underrepresented students' experiences in advanced degree programs* (pp. 45-62). Sterling, VA: Stylus Publishing.

Jolliff, L., Leadley, J., Coakley, E., Sloane, R. (2012). American Association of Medical Colleges: Women in U.S. Academic Medicine and Science: Statistics and Benchmarking Report (2011-2012).

Jones, J. B. (2012). Working hours for graduate students [Blog post]. Retrieved from: https://www.chronicle.com/blogs/profhacker/working-hours-for-graduate-students/43912

Kahn, S. & Ginther, D. K. (2017). The impact of postdoctoral training on early careers in biomedicine. *Nature Biotechnology, 35*(1), 90-94.

Ketefian, S. (1993). Essentials of doctoral education: Organization of programs around knowledge areas. *Journal of Professional Nursing, 9*(5), 255-261.

Kim, C. J. (1999). The racial triangulation of Asian Americans. *Politics & Society, 27*(1), 105-138.

King, M. M., Bergstrom, C. T., Correll, S. J., Jacquet, J., West, J. D. (2016). Men set their own cites high: gender and self-citation across fields and over time. Socius: Sociological Research for a Dynamic World, 3: osf.io/de853

Kirk, D. & Todd-Mancillas, W. R. (1996). Turning points in graduate student socialization: Implications for recruiting future faculty. In D. E. Finnegan, D. Webster, and Z. F. Gamson, (Eds.), *Faculty and faculty issues in colleges and universities,* (2nd ed.) (pp. 541-550). Needham Heights, MA: Simon & Schuster.

Lariviere, V., Ni, C., Gingras, Y. Cronin, B., Sugimoto, C. R. (2013). Global gender disparities in science, *Nature, 504:* 211-213.

Lerchenmüeller, M. J. & Sorenson, O. (2018). The gender gap in early career transitions in the life sciences. *Research Policy*, 47(4), 1007-1017.

Leslie, D. W. (2007). The reshaping of America's academic workforce. TIAA-CREF Institute, #87. Retrieved from www.tiaa.crefinstitute.org.

Light, R. J., Singer, J. D. & Willett, J. B. (1990). *By design: Planning and research on higher education.* Cambridge, MA: Harvard University Press.

Lindholm, J. A. (2004). Pathways to the professoriate: the role of self, others, and environment in shaping academic career aspirations. *The Journal of Higher Education, 75*(6).

Litzler, E., Edwards Lange, S., & Brainard, S. G. (2005). *Climate for graduate students in science and engineering departments.* Proceedings of the 2005 American Society for Engineering Education annual conference & exposition, Center for Workforce Development, University of Washington.

Long, J. B. (1987). *Factors related to attrition and success in degree and non-degree doctoral students in education.* Unpublished Ed.D. dissertation, Northern Arizona University.

Long, J. S. (1992). Measures of sex differences in scientific productivity. *Social Forces, 71,* 159-178.

Lovitts, B. E. (2001). *Leaving the ivory tower: the causes and consequences of departure from doctoral study.* New York: Rowman & Littlefield Publishers.

Lubinski, D., Benbow, C. P., Webb, R. M., Bleske-Rechek, A. (2006). Tracking exceptional human talent over two decades. *Psychological Science, 17,* 194-199.

Mack, K., Rankins, C. & Woodson, K. (2013). From graduate school to the STEM workforce: an entropic approach to career identity development for STEM women of color. *New Directions for Higher Education, 163*, 23-34.

Marshall, M. N. (1996). Sampling for qualitative research. *Family Practice, 13*(6), 522-525.

Mason, M. A. & Goulden, M. (2004). Marriage and the baby blues: Redefining gender equity and the academy. *Annals of American political and Social Scientist, 596,* 86-103.

Maxwell, J. A. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks, CA: Sage Publications.

McGaskey, F. G. (2011). The relationship between racial identity and the socialization of black Ph.D. students at predominantly white institutions. (Unpublished doctoral dissertation). University of Tennessee, Knoxville, TN.

Mendoza, P. (2007). Academic capitalism and doctoral student socialization: A case study. *The Journal of Higher Education, 78*(1), 71-96.

Mendoza, P., Villarreal III, P., & Gunderson, A. (2014). Within-Year Retention among Ph.D. students: The effect of debt, assistantships, and fellowships. *Research in Higher Education, 55*(7), 650-685.

Menges, R. J. & Associates (1999). *Faculty in new jobs: A guide to settling in, becoming established, and building institutional support.* San Francisco: Jossey-Bass.

Mervis, J. (2008). And then there was one. *Science, 321:* 1622-1628.

Miles, M. B. & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. Thousand Oaks, CA: Sage Publications.

Moore, L. C. (2007). *The career choices of underrepresented doctoral recipients* (Unpublished doctoral dissertation). Claremont Graduation University, Claremont, CA.

National Institutes of Health, Biomedical Workforce Working Group Report (2012). National Institutes of Health, Bethesda, MD.

National Science Board (2006). *Science and engineering indicators 2006,* Vol. 1 and 2, NSB 06-01, 06-01A). Arlington, VA: National Science Foundation.

National Science Board (2014). Science and engineering indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01).

National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) of the 1973-2013 Survey of Doctorate Recipients.

National Science Foundation (2017), National Center for Science and Engineering Statistics, *Doctorate Recipients from U.S. Universities*.

National Science Foundation (2015). Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015. Special Report NSF 15-311. Tech. Rep. National Center for Science and Engineering Statistics, Arlington, VA. https://www.nsf.gov/statistics/2017/nsf17310/.

National Science Foundation, National Center for Science and Engineering Statistics (2017). Women, minorities, and persons with disabilities in science and engineering: 2017. Special Report, NSF 17-310. Arlington, VA. Available at www.nsf.gov/statistics/wmpd/.

Nature Magazine (2011). This Week: Editorial. April 21. Vol. 472.

Nelson, D. J. & Brammer, C. N. (2007). A National Analysis of Minorities in Science and Engineering Faculties at Research Universities, Norman: University of Oklahoma.

Nerad, M. & Cerny, J. (1999). Postdoctoral patterns, career advancement, and problems, in American Association for the Advancement of Science, *Science, 285,* 1533-1535.

Nerad, M. & Miller, D. S. (1996). Increasing student retention in graduate and professional programs. *New Directions for Institutional Research, 92,* 61-76.

Nettles, M. T. & Millett, C. M. (2006). *Three magic letters: getting to Ph.D.*. Baltimore, MD: The Johns Hopkins University Press.

Neumark, D. & Gardecki, R. (1998). Women helping women? Role-model and mentoring effects on female Ph.D. students in economics. *Journal of Human Resources, 33*(1), 220-246.

Nolan, S. A., Buckner, J. P., Marzabadi, C. H., Kuck, V. J. (2007). Training and mentoring of chemists: a study of gender disparity. *Sex Roles, 58,* 235-250.

Nyquist, J. D., Manning, L., Wulff, D. H., Austin, A. E., Sprague, J., Fraser, P. K., Calcagno, Ca., & Woodford, B. (1999). On the road to becoming a professor: The graduate student experience. *Change,* pp. 18-27.

O'Brien, S. A. (2016). Stanford students demand more diverse faculty. *CNN Money.* Retrieved from http://money.cnn.com/2016/04/08/technology/stanford-whos-teaching-us-diversity/

O'Toole, J. (1996). *Forming the future: Lessons from the Saturn Corporation.* Cambridge, MA: Blackwell Publishers.

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, 451-476.

Pascarella, E. & Terenzini, P. (1991). *How college affects students*. San Francisco, CA: Jossey-Bass.

Patel, V. (2016). Diversifying a discipline. *The Chronicle of Higher Education.* Retrieved from http://chronicle.com/article/Diversifying-a-Discipline/235851

Preston, A. E. (2004). Leaving science: occupational exist from scientific careers. Russell Sage Foundation: New York, NY.

Prinster, R. (2015). Mizzou protests set off wave of student activism on college campuses. *Insight into Diversity.* Retrieved from http://www.insightintodiversity.com/mizzou-protests-set-off-wave-of-student-activism-on-college-campuses/

Roach, M. & Sauermann, H. (2017). The declining interest in an academic career. *PLoS ONE,* 12: e0184130.

Rockey, S. J. (2014). Mentorship matters for the biomedical workforce. *Nature Medicine* (20), 575.

Rowley, L. L. (2014). The socialization of African American Ph.D. Students: Race, sociology, knowledge, and historical concepts for contemporary contexts. In P. P. Felder & E. P. St. John (Eds.) *Supporting graduating students in the 21ˢᵗ century:*

Implications for policy and practice, (pp. 151-175). Readings on Equal Education, 27. Brooklyn, NY: AMS Press.

Rubin H. J., & Rubin, I. S. (2005). *Qualitative interviewing: The art of hearing data* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Sallee, M. W. (2010). The individual and the institution: socialization and gender, in S. K. Gardner & P. Mendoza (Eds.) *On Becoming a Scholar: Socialization and Development in Doctoral Education*, (pp. 137-155)*.* Sterling, VA: Stylus Publishing, LLC.

Sallee, M. (2011). Performing masculinity: Considering gender in doctoral student socialization. *Journal of Higher Education, 82*(2), 187-216.

Sauermann, H. & Roach, M. (2012). Science Ph.D. career preferences: levels, changes, and advisor encouragement. *PLoS ONE 7*(5)*:* e36307. doi: 10.1371/journal.pone.0036307

Sauermann, H. & Roach, M. (2016). Why pursue the postdoc path? *Science, 352*(6286), 663-664.

Schapiro, M. O., O'Malley, M. P., & Litten, L.H. (1991). Progression to graduate school from the 'elite' colleges and universities: Understanding the past and influencing the future. *Economics of Education Review, 10*(3).

Schroeder, D. S. & Mynatt, C. R. (1993). Female graduate students' perceptions of their interactions with male and female major professors. *The Journal of Higher Education, 64,* 555-573.

Schuster, J. H., Wheeler, D. W., & Associates, (1990). *Enhancing faculty careers: Strategies for development and renewal.* San Franscisco, CA: Jossey-Bass.

Seagram, B. C., Gould, J., & Pyke, S. W. (1998). An investigation of gender and other variables on time to completion of doctoral degrees. *Research in Higher Education, 39,* 319-335.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (3rd ed.). New York, NY: Teachers College Press.

Sheltzer, J. M. & Smith, J. C. (2014). Elite male faculty in the life sciences employ fewer women. Proceedings of the National Academy of Science, 111, 10107-10112.

Shen, L. U. (2018, April). The Impact of Advisers on Life and Physical Science Doctoral Students' Professional Decision-Making at an Elite Research University. Paper

presented at the American Educational Research Association National Conference, New York, NY.

Smallwood, S. (2004). Doctor dropout. *The Chronicle of Higher Education.* Retrieved from http://chronicle.com/article/Doctor-Dropout/33786

Smith, D. G., Wolf, L. E., Busenberg, B. and Associates. (1996). Achieving faculty diversity: Debunking the myths. A Research Report of a National Study. Washington, DC: Association of American Colleges and Universities.

Solorzano, D. G. (1998). Critical race theory, race and gender microaggressions, and the experience of Chicana and Chicano scholars. *International Journal of Qualitative Studies in Education, 11*(1), 121-136.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage Publications.

Staton, A. (1990). *Communication and student socialization.* Norwood, NJ: Ablex.

Stein, E. L. (1992). *Socialization at a protestant seminary.* Ph.D. dissertation, University of Pittsburgh.

Stein, E. L. & Weidman, J. C. (1989). *Socialization in graduate school: A conceptual framework.* Paper presented at the annual meeting of the Association for the Study of Higher Education, Atlanta, GA.

Stein E. L. & Weidman, J. C. (1990). *The socialization of doctoral students to academic norms.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Stephan, P. (2012). *How economics shapes science*. Cambridge, MA: Harvard University Press.

Sue, D. W., Bucceri, J., Lin, A. I., Nadal, K. L., & Torino, G. C. (2007). Racial microaggressions and the Asian American experience. *Cultural Diversity and Ethnic Minority Psychology, 13*(1), 72-81.

Tenenbaum, H. R., Crosby, F. J, & Gliner, M. D. (2001). Mentoring relationships in graduate school. *Journal of Vocational Behavior, 59,* 326-341.

Thornton, R. & Nardi, P. M. (1975). The dynamics of role acquisition. *American Journal of Sociology, 80*(4), 870-885.

Tierney, W. G. (1997). Organizational socialization in higher education. *The Journal of Higher Education, 68*(1), 1-16.

Tinto, V. (1993). *Leaving college: Rethinking the causes and cures of student attrition* (2nd ed.). Chicago: The University of Chicago Press.

Turk-Bicakci, L., Berger, A., & Haxton, C. (2014). The nonacademic careers of STEM PhD Holders. Issue Brief: STEM at American Institutes for Research.

Ülkü-Steiner, B., Kurtz-Costes, B., & Kinlaw, C. R. (2000). Doctoral student experiences in gender-balanced and male-dominated graduate programs. *Journal of Educational Psychology, 92,* 296-307.

van Dijk, D., Manor, O., Carey, L. B. (2014). Publication metrics and success on the academic job market. *Current Biology, 24*(11), R516-R517.

Vanderkam, L. (2015). *I Know How She Does It: How Successful Women Make the Most of Their Time.* New York: Penguin/Portfolio Press.

Walker, G. E., Golde, C. M., Jones, L., Conklin Bueschel, A., & Hutchings, P. (2008). *The formation of scholars: Rethinking doctoral education for the twenty-first century.* San Francisco: Jossey-Bass.

Warner, J. & Clauset, A. (2015). The academy's dirty secret. *Slate.* Retrieved from http://www.slate.com/articles/life/education/2015/02/university_hiring_if_you_didn_t_get_your_ph_d_at_an_elite_university_good.html

Washburn, M. H. & Miller, S. G. (2006). Still a chilly climate for women students in technology: A case study. In M. F. Fox, D. G. Johnson, & S. V. Rosser (Eds.), *Women, gender, and technology* (pp. 60-79). Urbana, IL: University of Illinois.

Waters, M. C. (1999). *Black identities: west Indian immigrant dreams and American realities.* Cambridge, MA: Harvard University Press.

Weidman, J. C., Twale, D. J., & Stein, E. J. (2001). *Socialization of graduate and professional students in higher education: A perilous passage?* ASHE-ERIC Higher Education Report, Volume 28, No. 3, San Francisco: Jossey-Bass.

Weiss, C. S. (1981). The development of professional role commitment among graduate students. *Human Relations, 34*(1), 13-31.

Weiss, R. S. (1994). *Learning from strangers: The art and method of qualitative interview studies.* New York, NY: The Free Press.

West, J. D., Jacquet, J., King, M. M., Correll, S. J., Bergstrom, C. T. (2013). The role of gender in scholarly authorship, PLoS ONE, 8(7), e66212.

Williams, J. (2000). *Unbending gender: Why family and work conflict and what to do about it.* New York, NY: Oxford University Press.

Williams, W. M. & Ceci, S. J. (2012). When scientists choose motherhood. *American Scientists, 100*(2), 138. Retrieved from: https://www.americanscientist.org/article/when-scientists-choose-motherhood

Winkle-Wagner, R., & McCoy, D. (2016). Entering the (postgraduate) field: Underrepresented students' acquisition of cultural and social capital and social capital in graduate school preparation programs. *Journal of Higher Education, 87*(2), 178-205.

Wong, A. & Green, A. (2016). Campus politics: A cheat sheet. *The Atlantic.* Retrieved from http://www.theatlantic.com/education/archive/2016/04/campus-protest-roundup/417570/

Woodrow Wilson Foundation. (2005). *The responsive Ph.D.: Innovations in doctoral education.* Princeton, NJ: Author.

Xie, Y. & Shauman, K. (1998). Sex differences in research productivity: New evidence about an old puzzle. *American Sociological Review, 63*(6), 847-870.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Los Angeles, CA: Sage Publications.