

A Multilevel Analysis to Examine Interdisciplinary Research Experience Among Doctoral
Graduates and Its Effect on Career Outcomes.

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ABSTRACT

This study was designed to explore the impact of interdisciplinary research on the likelihood of a doctoral student obtaining a faculty job upon degree completion. Additionally, this study examined the important individual and institutional components of socialization that contribute to differences in career outcomes. A socialization framework likely substantiates the extent to which doctoral training environments are consequential to careers. Results were obtained from a sample of 28,928 doctoral students who participated in the 2021 Survey of Earned Doctorates. Hierarchical Generalized Linear Modeling was used because it measures the effects of both student characteristics and institutional factors. The findings from this analysis suggest student demographics are an important predictor, but the significance of those characteristics' changes when doctoral field of study is considered. Additionally, there are institutional characteristics that impact the likelihood of obtaining a faculty job related to the proportion of various student backgrounds, faculty backgrounds, and broad field of study, and the prestige of the institution. The independent variable of interest, interdisciplinary dissertation, was not statistically significant at the student level, but the proportion of doctoral students completing an interdisciplinary dissertation at the institution level was statistically significant and negatively associated with obtaining a faculty position adjusting for other institutional factors. These findings show the importance of applying hierarchical models to research questions related to career outcomes for doctoral students. Without a hierarchical model, this important differential finding across levels would have been hidden.

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GENERAL AUDIENCE ABSTRACT

There is currently a surplus in doctoral degree production compared to a shrinking number of faculty jobs in academia. Interdisciplinary research experiences in doctoral education are becoming more popular and it is important to determine how participation in these programs influences a student's career prospects upon receiving their degree. This study was designed to explore the impact of completing an interdisciplinary dissertation on the likelihood of obtaining a faculty job upon degree completion. A model was used which considers characteristics of individual students as well as characteristics of the institutions they attend. Findings of the study show that for a student, completing an interdisciplinary dissertation does not have a statistically significant influence on their likelihood of obtaining a faculty job. However, the proportion of students completing an interdisciplinary dissertation at a particular institution has a statistically significant negative association on the likelihood of obtaining a faculty job. Additionally, student demographics were only significant until the broad field of study was considered in the model. Beyond student characteristics, there are institutional characteristics that impact the likelihood of obtaining a faculty job and these are related to the representation of various student backgrounds, faculty backgrounds, institution prestige, and the proportion of doctoral students in each broad field. These findings show the importance of considering both student and institutional characteristics.

Dedication

To my daughters Olivia and Maxine.

Always remember, you can do hard things and do not let anyone else dictate your dreams.

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Chapter One: Introduction

The National Science Foundation's strategic plan for 2022-2026 specifically calls out the important role cross-disciplinary collaborations play to advance the agency's mission, "...many of the challenging research questions that confront society require convergence of the perspectives and expertise of practitioners from different fields..." (NSF, 2022, p. 19). As part of this plan, NSF will expand partnerships with various entities, including academia. In Strategic Objective 2.2, NSF seeks to advance research in practice and points to the consensus that interdisciplinary approaches in both academia and the private sector are necessary for the most intractable problems in science and they are committed to increasing opportunities for broadening the training of U.S. graduate students (NSF, 2022). In the 2005 report *Facilitating Interdisciplinary Research*, the National Academies argued complex problems such as world hunger, biomedical ethics, sustainable resources, and national security cannot be addressed through the lens of a single discipline. Scholars have argued environmental challenges (Schmidt et al., 2012), climate change (Ledford, 2015), and agricultural system challenges (Hunt & Thornsbury, 2014; Ng & Litzenberg, 2019) must be considered through a disciplinary lens but with interdisciplinary collaboration. The National Science Foundation's *Big Ideas*, specifically the idea of growing convergence research, highlighted similar grand challenges to those above and the need for researchers, including those in academia, from across scientific disciplines to come together in a coordinated way to address complex problems (NSF, n.d.-a).

These complex societal issues are grouped together in what are now known as "wicked problems" (Rittel & Webber, 1973). Such wicked problems cannot be solved with standard scientific approaches and do not have clear boundaries or permanent solutions (Kawa et al., 2021). Due to the nature of these problems, academic researchers can no longer solely produce research to generate new knowledge but must focus on applying research to find solutions for the

important issues facing society now and in the future (Taylor, 2023). The purpose of modern graduate education is to prepare future researchers to respond to the issues of the day, but these issues are getting more complex. In fact, Kawa et al. (2021) argue graduate education is an appropriate framework within which these wicked problems should begin to be addressed.

There are wicked problems facing society and doctoral education is a means for training individuals to understand and tackle these problems. Socialization is the process by which doctoral students are prepared to conduct research and enter a career where they can work on these issues (Weidman et al., 2001). It is important to understand how graduate students are socialized to address these science-based problems and the career paths doctoral students are prepared to undertake. While historically doctoral recipients have pursued research careers as faculty members in institutions of higher education, now doctoral students pursue careers as researchers in nonprofits, governments, and private industry as well (NCSES, 2022). The increased calls for research focusing on solutions to wicked problems and the dispersion of research careers makes the current landscape of doctoral education in the United States an important ecosystem to study.

History of Doctoral Education in the United States

The roots of the modern doctoral degree date back to 1810 when Wilhelm Von Humboldt founded the University of Berlin, which became the world's first research-focused university (Taylor, 2023). Within this university, a new doctoral degree was introduced and awarded for "making an original contribution to knowledge and understanding in the arts and sciences" (Taylor, 2023, p. 606). This degree was only intended for a small group of individuals and was based on a "master-apprentice" model where a student learns under the supervision of an advisor. In this format, students had to complete a research project, write it in the form of a thesis

and defend it through an oral examination (Taylor, 2023). This milestone continues and is analogous to the dissertation produced by present-day doctoral students as the culminating experience of their education and training.

While most countries across the world resisted this shift in the purpose of the university and the focus on research, universities in the United States embraced it and produced the first doctor of philosophy (PhD) at Yale University in 1861 (Taylor, 2023). Prior to this, American education followed the Humboldtian model that focused on undergraduate education. This shift to doctoral education in the United States launched a new mechanism to spur research and development efforts to increase global competitiveness and bolster national security. In the decades that followed, the social, economic, and political values of the doctoral degree was further evidenced during times of national importance. The introduction of the post-World War II Serviceman's Readjustment Act in 1944, the so-called G.I. Bill, and the competitive environment spurred by the Cold War era accelerated PhD production (NCSES, 2022). Opportunities for doctoral education continued to grow in response to wide-ranging demands in higher education, industry, and government. The number of doctorate-granting institutions in the United States grew from 282 institutions in 1973 to 457 institutions in 2022 (NCSES, 2022).

Current Landscape of Doctoral Education

Despite recent discourse questioning the usefulness of advanced education (Larson et al., 2014; "PhD training is no longer fit", 2023), the growth of doctoral education has continued. Applications to doctoral programs increased by 8.9% from Fall 2020 to Fall 2021 and first-time doctoral enrollment increased by 5.1% during this same time (Zhou, 2022). While recent application and enrollment trends may be impacted by the COVID-19 pandemic and the resulting economic downturn, positive trends are evident over a longer period. Between 2011-2021,

enrollments in doctoral programs increased 2.1% (Zhou, 2022). During the same 10-year time period enrollment in undergraduate education saw a 15% decrease. Further, enrollment is projected to increase by an additional 9% between 2021 and 2031 (NCES, 2023). These trends suggest demand for graduate education will continue in the United States and likely indicate expectations for individuals with advanced education and training are necessary in the labor market.

Similar to the Humboldt “master-apprentice” model, modern doctoral education in the United States is one of social reproduction where advisors train their students to enter a career in academia (Curtin et al., 2016; Sauermann & Roach, 2012). Doctoral education has traditionally focused on training students from a narrow disciplinary perspective with the expectation new scholars will become the next generation of faculty conducting research in institutions of higher education (Boothby and Milojevic, 2020; Curtin et al., 2016; Schillebeeckx et al., 2013). However, as career interests and opportunities change for doctoral recipients (Choe & Borrego, 2020; Curtin et al., 2016; Roach & Sauermann, 2017; Sauermann & Roach, 2012), and the problems of the future become more complex (Hunt & Thornsbury, 2014; Kawa et al., 2021; Ledford, 2015; Ng & Litzenberg, 2019; NRC, 2015; NSF, 2019; Schmidt et al., 2012), the institutions and faculty that train these students are under pressure from funding agencies and industry employers to prepare them to enter a wider range of employment sectors that require transferable skills beyond typical training to conduct academic research (Denecke et al., 2017; NSF, 2019, NSF, 2021). Additional changes and challenges to the landscape of doctoral education include shifting demographics of entering students (Espinosa et al., 2019; Zhou, 2022), increases in cross-disciplinary research teams (National Academy of Sciences, 2005; NRC,

2015; Specht & Crowston, 2022), and a decrease in tenure-track faculty positions (Stein, 2022; Tiede, 2022).

Calls for change in the way doctoral students are prepared for this changing landscape have come from national organizations such as the National Research Council (2015) and the National Academy of Sciences (2005). The seminal report *Facilitating Interdisciplinary Research* (National Academy of Sciences, 2005), which was a launching point for a move toward interdisciplinary research, was a collaboration between many influential groups made up of faculty and researchers from across a variety of disciplines such as: National Academy of Engineering; Institute of Medicine; Committee on Science, Engineering, and Public Policy; and the Committee on Facilitating Interdisciplinary Research. Despite this call from representatives from a variety of disciplines, tension has remained between the traditional style of preparing doctoral students that focuses solely on the knowledge and methods of a *single* discipline and the emerging style that emphasizes the integration of knowledge and methods from *many* disciplines. Clearly disciplinary understanding is a key aspect of conducting interdisciplinary research (Holley, 2015; Nurius and Kemp, 2019; Repko, 2008); however, universities have struggled to implement the necessary structures to support disciplinary grounding and interdisciplinary experiences at both the faculty and doctoral student levels (Arnold et al., 2021; Klein & Falk-Krzesinski, 2017).

With the changes in the type of research being prioritized and changes in the career outlook it is important to understand the skills necessary to enter this job market. The Council of Graduate Schools (CGS)—its members largely faculty and administrators from graduate schools—is a leading thought and policy organization that views the preparation of doctoral students in the United States as too narrowly focused on academic research skills (Denecke et al., 2017). It has

conducted important work to engage both universities and employers in conversations related to the strengths and skills necessary for doctoral graduates. While the United States PhD is still seen as the gold standard and as an indicator of deep technical expertise, industry hiring professionals are also looking for team experiences to address difficult challenges, communication skills, project management, and business acumen (Denecke et al., 2017). Industry representatives indicate they value PhDs who can look to the future and see where science is going (Denecke et al., 2017). Organizations hiring doctoral recipients see a future of research that is interdisciplinary and expect students to be trained to operate in this manner.

Growth and Diversification of Doctoral Education

In 2021, the most recent year of data collected by the Survey of Earned Doctorates (SED) at the time of this study's design, 52,250 doctorate degrees were awarded in the United States (NCSES, 2022). This number has grown nearly 500% since 1958 and 7% in the last ten years. Coinciding with the continued growth in the number of doctoral degrees awarded annually, there is growth in degrees awarded to groups historically underrepresented in doctoral education such as women and racial and ethnic minorities. Over the last twenty years, women have increased in both the number receiving a doctorate and as an overall share of all doctoral degrees awarded. Between 2001 and 2021, the number of women receiving a doctorate increased by 35% and women increased their share of doctorates awarded from 43.9% to 46.2% (NCSES, 2022). Also, during this time the number and share of doctoral degrees awarded increased for almost all racial minority groups. From 2001 to 2021 the number doctoral recipients identifying as Hispanic or Latino increased by 126%, Asian recipients increased by 42%, Black or African American by 48%, and more than one race by 261% (NCSES, 2022). Large changes occurred in doctoral degree attainment of temporary visa holders (i.e., International students) compared to U.S.

citizens or permanent residents. From 2001 to 2021, the number of international students receiving a doctorate increased by 80% resulting in the share of all doctoral degrees awarded increasing from 24% to 34% (NCSES, 2022).

Job Market for Doctoral Graduates

The Bureau of Labor Statistics (2023a) estimates a 7% growth in jobs requiring a doctoral or professional degree for entry between the years 2022 and 2032. However, there is a gap in the data related to which sectors of employment will see more jobs for doctoral degree holders. One indicator showing where jobs are available is the Survey of Earned Doctorates (SED), which annually surveys doctoral recipients in the semester in which they are receiving their degree on various employment outcomes. Recent trends show employment in academia has been surpassed by jobs in industry or business as the most common employment sector of postgraduation commitment among doctoral recipients (NCSES, 2022). From 2011 to 2021 the proportion of doctoral graduates entering academia decreased by 16 percentage-points while employment in industry or business became the most common employment sector and increased by approximately 16 percentage points during the same period (NCSES, 2022).

The purpose of doctoral education has traditionally been to prepare the next generation of scientists to conduct research within academia. However, many researchers argue doctoral degree production is in an oversupply in comparison to jobs available in postsecondary institutions across all broad fields (Larson et al., 2014; “PhD training is no longer fit”, 2023). As a result, doctoral graduates will face fierce competition for jobs in academia upon graduation (AAUP, 2021; Humanities Indicators Project, 2015; Janschik, 2017; Xue & Larson, 2015). Additional research has pointed to a declining interest in academic jobs among recent doctoral recipients (Choe & Borrego, 2020; Curtin et al., 2016; Roach & Sauermann, 2017; Sauermann &

Roach, 2012). This research documents an emerging shift in the purpose of doctoral education. The combination of fewer academic jobs and rising interest in non-academic career paths may result in an expansion in the approach to graduate education. Doctoral students will need to be prepared for a variety of current and emerging career paths, but they will also need to be trained in a way that addresses the complexity of the issues they will be asked to research. Job market competitiveness and diversity of career options must be considered in graduate education through the types of knowledge, skills, and values gained through the process of socialization. It is essential to understand what kinds of socialization experiences lead students to be better prepared for their chosen career. Interdisciplinary research is one such experience to prepare graduate students for novel science and to connect to changing labor markets.

Interdisciplinarity in Graduate Education

A rise in interdisciplinary research opportunities is driven by the funding priorities of federal agencies as a method to transform graduate education and develop researchers ready to solve complex problems. National and international organizations are leading the call for institutions of higher education to develop interdisciplinary programs to prepare students for their future careers and stress the important role higher education must play in developing the structure to provide this type of learning experience (National Academy of Sciences, 2005; NRC, 2015). In response, universities are creating new interdisciplinary degrees, transformative graduate education programs, innovation hubs, and interdisciplinary research centers (Buchanan, 2018; Crow & Dabars, 2019; Hunt & Thornsbury, 2014; Schmidt et al., 2012). Additionally, doctoral students are intentionally seeking out interdisciplinary doctoral programs and have reported enjoying the flexibility and independence of interdisciplinary experiences (Reisman et

al., 2022). However, there is little evidence to show how these experiences are related to career outcomes upon degree completion.

Interdisciplinary Research Defined

The definition of interdisciplinarity varies across published studies making the literature on this subject vague. Several preeminent scholars on interdisciplinarity and a federal funding agency provide context for this study and their definitions will be used to frame it.

Interdisciplinary can be used to define a type of research or to describe a person doing the work.

Julie Thompson Klein (2013), for example, describes interdisciplinarity as a type of collaborative research defined by the synthesis of ideas, data and information, methods, tools, concepts, and theories from two or more disciplines. Allen Repko (2008) focuses on the skills and traits of individuals that make them an interdisciplinary researcher. He describes nine essential traits of interdisciplinarians which are: enterprise, love of learning, reflection, tolerance for ambiguity and paradox in the midst of complexity, receptivity to other disciplines, willingness to achieve adequacy, appreciation of diversity, willingness to work with others, and humility (Repko, 2008). Additionally, Repko (2008) describes six individual skills which include: ability to communicative competence, abstract thinking, dialectical thinking, nonlinear thinking, creativity, and holistic thinking. The National Science Foundation (NSF) draws from the National Academies report *Facilitating Interdisciplinary Research* (2005) to describe interdisciplinary research as research that “integrates information, data, techniques, tools, perspectives, concepts or theories from two or more disciplines; can be done by teams or by individuals; and advances fundamental understanding or solves problems whose solutions are beyond the scope of a single discipline or area of research practice” (National Science Foundation, n.d.). Additionally,

scholars on team science and collaboration define interdisciplinary teams as composed of members with different expertise, a variety of perspectives (Vestal & Mesmer-Magnus, 2020).

Interdisciplinary Research Trends

The primary outcome of interdisciplinary research teams is the creation of new knowledge or understanding to be applied as solutions to complex problems (Specht & Crowston, 2022; Vestal & Mesmer-Magnus, 2020). Several studies found research teams with disciplinary diversity had a positive relationship with scientific impact (Leahey et al., 2017; Specht & Crowston, 2022; Wang et al., 2015) and on novelty of research (Fontana et al., 2020; Lee et al., 2014). Novelty as a measure of innovation goes beyond scientific impact to look at unprecedented combinations of knowledge that are distinct in their disciplinary focus. Fontana et al. (2020) were able to take the measurement even further to look at specific traits of interdisciplinary work and show the correlation between commonly used measures of novelty and an article's interdisciplinary traits. Taken together, these measures show interdisciplinary research teams produce innovative research in a measurable way.

Recent analyses of citations show an increase in interdisciplinary publications. In his summary of the impact of interdisciplinary research for *Nature's* special issue, Van Noorden (2015) found an increase in the proportion of citations in research papers that reference other disciplines, an increase in the percent of papers with interdisciplinary* in the title, and evidence that in the long-term citations increase as a paper's level of interdisciplinarity increases. This is further substantiated by a finding that 90% of papers in science and engineering journals were written by teams (NRC, 2015). Additional research has shown a notable increase in journal articles with multiple authors (Uzzi et al., 2013).

This trend towards interdisciplinary research is mirrored in doctoral education with incoming doctoral students indicating they expect to have meaningful opportunities to work across disciplines (Mayhew et al., 2021). Studies have found that interdisciplinary dissertation research has increased over time, but most research is still done between two closely related fields. Falkenheim (2010) and Millar and Dillman (2012) examined data across all broad fields while Golembiewski, et al. (2018) and the Humanities Indicator Project (2015) looked at dissertations within public health and the humanities, respectively. Researchers have found that formal institutionalized interdisciplinary research structures lead to positive outcomes for doctoral students (Borrego et al., 2014; Kniola et al., 2012; Leahey & Barringer, 2020; Schmidt et al., 2012). These types of structures help socialize graduate students in a way they may be missing within their home discipline.

Gap in Interdisciplinary Literature

Researchers have addressed how interdisciplinary programs can be integrated into the graduate degree structure (Arnold et al., 2021; Borrego & DePauw, 2012; Hein et al., 2018; Noble et al., 2016; Pryor & Steinberg, 2023) and the benefits of institutionalizing interdisciplinary graduate education (Borrego et al., 2014; Kniola et al., 2012; Leahey & Barringer, 2020; Schmidt et al., 2012). Additionally, studies have described the student experience in interdisciplinary programs (Graybill et al., 2006; Holley, 2015) and explored teaching practices in interdisciplinary programs (Marbach-Ad & Marr, 2018). However, there is little research evaluating whether these initiatives influence participating students' career outcomes. With the continued surplus of doctoral degree production compared to a shrinking number of jobs in academia it is important to determine how participation in interdisciplinary research experiences influence a student's career choice upon receiving their degree.

Statement of the Problem

Interdisciplinary research has been promoted by federal funding agencies in the United States as a necessary mechanism for addressing the complex problems of a modern society. In response to this call, research universities across the United States have taken steps to incorporate interdisciplinarity through new degree programs, transformative graduate education programs, innovation hubs, and interdisciplinary research centers (Buchanan, 2018; Crow & Dabars, 2019; Hunt & Thornsbury, 2014; Schmidt et al., 2012). However, many barriers still exist in overcoming the traditional disciplinary structure of doctoral education that defines the socialization process for doctoral students. This includes the lack of socialization of doctoral students to the breadth of potential professional pathways (Gardner & Doore, 2020; St. Clair et al., 2017; Thiry et al., 2015). Existing research has focused on how to overcome these barriers, but little research has focused on how socializing influences of interdisciplinary experiences impact career outcomes upon graduation.

Purpose of the Study

Interdisciplinary doctoral programs are increasing in popularity as a form of competitiveness and a progressive mechanism to prepare graduates with a unique set of research skills. However, there remain limited and rudimentary ways to measure if they are effective in achieving career outcomes. This study will bring up to date prior research looking at interdisciplinary dissertation production (Falkenheim, 2010; Golembiewski et al., 2018; Millar & Dillman, 2012) and whether there is an effect on career outcomes in academia (Holley, 2018; Millar, 2013; Schmidt et al., 2012; Weissman, 2014). Additionally, it will look at the important characteristics of individual students and doctoral institutions that may influence the likelihood of obtaining a faculty position. While doctoral students may have many different types of

interdisciplinary experiences throughout their preparation, this study will focus on completing an interdisciplinary dissertation as a measure of a student having been socialized to interdisciplinary research during their doctoral education.

The purpose of this study is to examine the impact of interdisciplinary research experiences during doctoral education on career outcomes. Specifically, this study will examine the likelihood of obtaining a faculty job upon degree completion for doctoral recipients who report they completed an interdisciplinary dissertation. Additionally, this study will examine the important individual and institutional characteristics that contribute to differences in career outcomes among doctoral graduates. The Survey of Earned Doctorates will be used because it is one of the only data collection mechanisms that asks doctoral students about their interdisciplinary experiences. This survey operationalizes interdisciplinary research experiences through measuring whether the student conducted an interdisciplinary dissertation. Millar and Dillman (2010) found this question is a reasonable indicator of interdisciplinary research by comparing student responses to various iterations of the survey question with their self-described interdisciplinary research status. The dissertation is an important unit of measurement because it is the culminating experience of doctoral education reflecting the student's experiences and indicating whether they have demonstrated the necessary skills to enter their career field and conduct research on their own.

There are many factors that influence the career sector a doctoral student enters upon completion of their degree. Socialization theory allows researchers to better understand the way doctoral students are prepared to become scholars and are prepared for their future careers. Socialization in the context of doctoral research is defined as the process through which students develop the knowledge, skills, and values that will equip them to be producers as well as

consumers of research (Weidman, 2010). Many scholars argue there is a lack of socialization of graduate students to the breadth of potential professional pathways (Gardner & Doore, 2020; St. Clair et al., 2017). Additionally, differences in socialization exist based on individual characteristics such as gender (Sallee, 2010), race and ethnicity (Felder et al., 2014; Gardner & Doore, 2020; Garcia et al., 2020; Perez et al., 2023; Phelps-Ward, 2020; Robbins et al., 2023; Twale et al., 2016; Winkle-Wagner et al., 2020), and in which discipline the student is studying (Roksa et al., 2022; Wofford & Blaney, 2021). Socialization theory shows that not all doctoral students have the same experiences, and it is therefore important to account for these differences when predicting the likelihood of certain career outcomes upon graduation. This study will use a hierarchical design to examine the influence of individual-level and institutional-level characteristics on obtaining a faculty job.

Research Questions

This study will explore the following questions:

1. What are the characteristics of doctoral graduates that are most likely to complete an interdisciplinary dissertation?
2. Does completing an interdisciplinary dissertation influence the likelihood of obtaining a faculty job in academia upon graduation compared to completing a single discipline dissertation?
3. What individual characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?
4. What institution characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?

Significance of the Study

This study will build on previous research looking at interdisciplinary dissertation production and whether there is an effect on career outcomes in academia. It will look at the important characteristics of individual students and doctoral institutions that may influence the likelihood of obtaining a faculty position. Additionally, this study frames these career outcomes within a socialization framework signaling the importance of how doctoral students are trained and the influence on their future careers. There has been much discussion about interdisciplinary research experiences as a mechanism for addressing the wicked problems facing society and training doctoral students with the skills required to enter an expanding variety of careers. However, little empirical evidence has been found that investigates the influencing factors of a doctoral student's likelihood of obtaining a faculty job in academia upon completion of their degree. This study is designed to operationalize interdisciplinary research experiences through the completion of an interdisciplinary dissertation and then investigate the individual and institutional characteristics that influence career outcomes. This study will be important to doctoral students considering interdisciplinary research experiences, faculty across the disciplines responsible for training doctoral students, graduate school deans and other university leaders charged with institutionalizing responsive degree programs, and federal agencies setting and supporting an interdisciplinary research agenda through influential funding mechanisms. For ease of reading, the terms doctoral and PhD are used interchangeably through this document. However, multiple types of doctoral degrees exist, including the EdD, PsyD, DSW, and DPH among others.

Chapter Two: Literature Review

Doctoral degree recipients face fierce competition for jobs in academia in the United States when they graduate, no matter the discipline. In response, students look for experiences in their doctoral education that will be a competitive advantage in the job market. Similarly, universities engage in organizational behaviors to advance education and research programs that bolster indicators of prestige and secure necessary resources to advance myriad goals of higher education.

It is therefore important to understand individual and institutional factors that influence the socialization of doctoral students and lead to successful obtainment of a faculty position. Socialization is the way doctoral students are prepared to become scholars and are prepared for their future careers. The knowledge, skills, and values that doctoral students learn through socialization are how they will set themselves apart. These are typically learned through a disciplinary lens which is one of the defining elements of the socialization process. One potential differentiating socialization mechanism is through conducting interdisciplinary research which would expose students to multiple disciplinary perspectives. This type of research has been advocated for by top levels of government and scientific leadership as the way to address the complex scientific problems shaping the future of our country. Higher education has responded by developing interdisciplinary degree programs and encouraging interdisciplinary research as ways to attract external funding and bolster institutional prestige. Future researchers (in academia, industry, and government) are trained through doctoral education and graduates expect to be well-positioned for a career of choice.

Before embarking on research that will add to a limited body of work around the socialization experiences of doctoral recipients completing interdisciplinary dissertations and the

related career outcomes, it is important to review the available literature. Most of the available literature is descriptive of trends in interdisciplinary dissertations and does not connect this group of students to their career outcomes upon graduation. One seminal study connected interdisciplinary dissertations to career outcomes was published in 2013 and used data from the 2008 Survey of Earned Doctorates (Millar, 2013). The landscape of interdisciplinary opportunities in doctoral education has changed since this was published and is therefore important to reexamine. Importantly, the literature described in this chapter will direct the inclusion of specific variables within the analysis that are identified as having significant influence on career trajectories and academic faculty appointments through socializing experiences in graduate education.

This literature review will explore the current landscape of doctoral education including the career aspirations and outcomes for doctoral recipients. Then, the review will analyze the job market for doctoral recipients upon graduation by exploring trends in tenure-track faculty positions, the overall academic market outlook, and the job market for doctoral students more broadly. It will then go on to examine the characteristics of who is getting faculty jobs and identify the various non-meritocratic advantages certain groups have. It will then review the importance of collaborative science to solve complex problems and the roles of cognitive and disciplinary diversity. Next it will define interdisciplinarity and describe why it is important before looking at current trends in interdisciplinary research and the role of universities and doctoral education to produce researchers ready for this type of work. Then, it will look at the current trends in doctoral recipients completing interdisciplinary dissertations and the career outcomes for students doing this type of research. Finally, it will review the important literature

on graduate student socialization to identify the pertinent variables that lead to different socialization outcomes.

Purpose and Structure of the Literature Review

The purpose of this literature review is to understand the socialization processes that influence doctoral student career trajectories and investigate whether completing an interdisciplinary dissertation has an impact on doctoral recipients obtaining a faculty job in academia upon graduation. It will explore current trends in doctoral degree production and the academic job market for new doctoral recipients, then will move into defining interdisciplinary research and exploring its role in doctoral education. It will review the existing literature that explores the relationship between interdisciplinary dissertations and career outcomes that this study hopes to bring up to date. Finally, socialization theory will be explored as a framework for this study. A variety of questions guided the search process including:

1. What is the current landscape of doctoral degree production in the United States?
2. What are the career outcomes for recent doctoral recipients?
3. What aspects of doctoral student socialization influence career outcomes?
4. What are the characteristics of individuals obtaining faculty positions?
5. What is interdisciplinary research and what has led to its promotion within doctoral education?
6. What are the trends in doctoral students completing interdisciplinary dissertations?
7. What are the career outcomes for doctoral recipients completing an interdisciplinary dissertation?

Search Process

The primary sources included in this review are from peer-reviewed journals published between 2010 and 2022. However, some seminal literature around the definition and purpose of interdisciplinary research and graduate student socialization were included from earlier years due to its importance. Initial searches were done through a broad search of all EBSCOhost's education databases accessed through the Virginia Tech library. For topic areas where those databases produced limited results, I also put the search terms into google scholar with greater results. Due to the specific nature of investigating interdisciplinary doctoral experiences and career outcomes I also used snowballing to review the reference lists of relevant articles to identify additional quality literature. Additionally, I used the feature in google scholar that shows what other articles cite the article you are looking at. This helped identify additional relevant literature and literature that was more recent. The National Science Foundation (NSF), the National Center for Science and Engineering Statistics (NCSES), the U.S. Department of Education, and the Bureau of Labor Statistics (BLS) were also used as authoritative resources for data related to the relevant population of this study.

When looking for literature related to the current landscape of doctoral degree production key search terms included *doctoral*, *doctorate*, *PhD*, *production*, and *trend*. To expand the literature to doctoral recipient career outcomes the key search terms included, *higher education*, *career*, *academia*, and *job market*. This search was then expanded to look specifically at outcomes related to completing an interdisciplinary dissertation by adding *interdisciplinary*, *research and dissertation* as key words. The search for graduate student socialization experiences included *socialization*, *graduate*, and *disciplinary*. Then, more specific terms such as *interdisciplinary*, *race*, and *gender* were added to get a more detailed look at doctoral student

experiences across different groups. When looking for literature related to characteristics of individuals obtaining faculty positions key words included *gender, race, academia, job market, faculty, and tenure*. Key words for literature related to interdisciplinary research included *interdisciplinary, transdisciplinary, multidisciplinary, innovation, research, and trends*. Then, *higher education and doctoral education* were added as search terms to expand the literature to applications of interdisciplinary research in doctoral education and higher education.

Current Landscape of Doctoral Education in the U.S.

Trends in U.S. Doctoral Degree Production

Doctoral degree production from U.S. colleges and universities has been used as a mechanism to spur national research and development efforts and bolster international competitiveness for decades. In 2021, the most recent year of data collected by the Survey of Earned Doctorates (SED), 52,250 doctorate degrees were awarded in the United States. This number has grown nearly 500% since 1958, the first year these data were collected by the National Center for Science and Engineering Statistics (NCSES). There were significant increases in degree production due to the post-World War II G.I. Bill and the competitive environment spurred by the Cold War and doctoral degree production has continued to increase annually ever since. Over the last twenty years, the number of doctorates awarded by U.S. colleges and universities has increased by about 28% (NCSES, 2022). However, for the first time since 2010, there was a decrease in the number of degrees produced in both 2020 and 2021. In 2020, degree production decreased by less than 1% but, in 2021, degree production decreased by 5.4%, the steepest decline measured by the SED (NCSES, 2022). While 40% of respondents indicated COVID-19 impacted the timeline for completing their degree, growth in degree production had already slowed in the years leading up to the pandemic (NCSES, 2022). There

are indicators that this trend may not last as applications for doctorate programs increased by 8.9% from Fall 2020 to Fall 2021 and first-time doctoral enrollment increased by 5.1% during this same time frame (NCSES, 2022).

While there has been growth in doctoral degree production for decades, there is disparity in this trend when comparing fields of study, particularly science and engineering (S&E) fields compared to non-science and engineering (non-S&E) fields. Over the last twenty years almost all S&E and non-S&E fields saw growth, but doctoral degrees in S&E fields are increasing as a share of all doctorates awarded (NCSES, 2022). So, even though most non-S&E fields saw increases the S&E fields grew at a faster rate leading to an increase in the overall share of doctoral degrees awarded. Engineering has consistently produced the most doctoral degrees in any field for the last twenty years. Doctoral degrees awarded in Engineering fields almost doubled between 2001 and 2021, increasing at the highest rate among S&E fields (NCSES, 2022). However, not even Engineering was immune to the decreases seen in 2021. All S&E broad fields had a decline in the number of doctorates awarded. Computer and information science and mathematics and statistics had the smallest decreases in number of doctorates awarded while physical sciences and biological and biomedical sciences saw the largest decreases (NCSES, 2022).

The number of non-S&E doctorate degrees awarded has decreased over the last twenty years but has remained consistent for the last decade with most of the decline occurring between 2009 and 2011 (NCSES, 2022). This is likely an effect of the 2008 recession, however these fields have never recovered. The number of degrees awarded in non-S&E fields between 2001 and 2021 decreased by almost 18% and from 2011 to 2021 only decreased 9% (NCSES, 2022). The differences in both the number of degrees produced and the share of all degrees in S&E

fields compared to non-S&E fields makes this an interesting indicator as potential doctoral students weigh their future.

Demographic Characteristics of Doctoral Degree Recipients

For decades doctoral education was dominated by White male U.S. Citizens due to specific policies and practices limiting who could participate. Coinciding with the continued growth in the number of doctoral degrees awarded annually, there is growth in degrees awarded to groups historically underrepresented in doctoral education such as women and racial and ethnic minorities. Over the last twenty years, women have increased in both the number receiving a doctorate and as an overall share of all doctoral degrees awarded. Between 2001 and 2021, the number of women receiving a doctorate increased by 35% and women increased their share of doctorates awarded from 43.9% to 46.2% (NCSES, 2022). Historically, women have earned a larger share of degrees in non-S&E fields while men have received a larger share of degrees in S&E fields. However, the number of women receiving a doctorate in S&E fields increased by 72% over this twenty-year period (NCSES, 2022).

Significant changes have also occurred when looking at the distribution of doctoral degrees awarded by race. From 2001 to 2021 the share of doctorates awarded to White U.S. Citizens and permanent residents decreased from 77% to 67% (NCSES, 2022). During this time both the number and share of doctoral degrees awarded increased for almost all racial minority groups. From 2001 to 2021 the number doctoral recipients identifying as Hispanic or Latino increased by 126%, Asian recipients increased by 42%, Black or African American by 48%, and more than one race by 261% (NCSES, 2022). Despite this growth among racial minorities, White students still dominate the number and proportion of doctoral degrees received. White

students earned 21,333 doctorates in 2021 which is only a 4% decline from 2001, and still about 67% of all degrees awarded to U.S. citizens or permanent residents (NCSES, 2022).

Larger changes occurred in doctoral degree attainment of temporary visa holders, also commonly referred to as international students, compared to U.S. citizens or permanent residents. From 2001 to 2021, the number of international students receiving a doctorate increased by 80% and they increased their share of all doctoral degrees awarded from 24% to 34% (NCSES, 2022). A large share of this increase came in S&E fields with an 85% increase in degrees awarded to international students in S&E fields from 2001 to 2021 (NCSES, 2022). The changing demographics of individuals receiving doctorate degrees is an important indicator to consider as this research explores the careers of doctoral graduates. These characteristics are especially important when considering which graduates are attaining jobs in academia at both the individual-level as well as in institutional-level characteristics.

Career Outcomes of Doctoral Students

The long-standing philosophy behind doctoral education has been to prepare future generations of college and university faculty. However, recent trends show fewer doctoral graduates are obtaining positions in academia in their first position after receiving their degree. The Survey of Earned Doctorates found a 12 percentage-point decrease from 2001 to 2021 in the percentage of doctorate recipients with definite non-postdoctoral employment plans reporting a position in academia (NCSES, 2022). The percentage of recipients with definite non-postdoc academic employment varies by broad field. Graduates from non-S&E fields tended to have higher percentages of employment in non-postdoc academic positions compared to S&E fields. In 2021, the fields with the highest percentage of graduates reporting non-postdoc academic positions were humanities and arts (65%) and other non-S&E fields (68%) and the lowest rates

were in engineering and physical sciences both reporting 12% (NCSES, 2022). Some graduates intending to enter academia may be more likely to obtain a postdoctoral position instead of a faculty position. Between 2001 and 2021 the proportion of doctoral recipients choosing to accept a postdoctoral position increased in non-S&E fields and all S&E fields except biological and biomedical sciences (NCSES, 2022). Corresponding with the decrease in academic positions, the SED shows an increase in graduates employed in government, industry, and nonprofit positions. The percent of doctoral graduates reporting jobs in government increased from 6.5% in 2001 to 7.7% in 2021, in industry from 29.4% to 43.2%, and in the nonprofit sector from 5.3% to 6.7% (NCSES, 2022).

Career Aspirations of Doctoral Students

Despite the changes in postgraduation employment outcomes, doctoral education is still structured in a way that focuses on preparing graduates for academic appointments (Boothby and Milojevic, 2020; Curtin et al., 2016; Schillebeeckx et al., 2013). Various institutional policies and structures continue to uphold this model. Teaching assistantships and publication requirements reinforce the expected path from doctorate to academic employment (Ganning, 2022). Doctoral advisors also uphold the historical structure of doctoral education by guiding their students toward careers in academia over other career paths (Curtin et al., 2016; Sauermann & Roach, 2012).

Data are lacking related to the career preferences of doctoral students upon entering their program. This makes it difficult to predict whether the trends in postgraduation employment are based on student preference or on the academic job market. Limited research has found doctoral students still find academic research jobs to be the most attractive even if interest is declining (Curtin et al., 2016; Roach & Sauermann, 2017; Sauermann & Roach, 2012). Some research has

been conducted to measure career preferences within specific fields. Ganning (2022) estimates one-third of doctoral graduates in Planning do not wish to pursue an academic career. However, the timing of when students are asked about their career preferences matters as research has found positive attitudes toward faculty research positions decrease at later stages in the doctoral path (Choe & Borrego, 2020; Roach & Sauermann, 2017; Sauermann & Roach, 2012).

Current Landscape of Doctoral Job Market

Some argue that this diversity in career outcomes for doctoral students means programs need to change the focus of their training to accommodate students who intend to pursue a career outside of academia (Larson et al., 2013; Ganning, 2022). However, data are lacking related to the mismatch between entering doctoral student career aspirations and their career after receiving their degree (Etmanski, 2019; Roach & Sauermann, 2017; Sauermann & Roach, 2012).

Additionally, the implications for educational quality cannot be ignored due to the shift from tenured faculty to contingent appointments. There is still demand for instructors in higher education (BLS, 2023b). However, the literature here has shown that universities are making decisions about the types of instructors they choose to hire which could have a detrimental effect on the quality of education they provide (Stein, 2022; Tiede, 2022).

Doctoral Job Market

Employment opportunities for doctoral recipients upon completion are high with around 70% of graduates reporting they already had made a definite employment commitment prior to graduation (NCSES, 2022). While the unemployment rate for individuals with a doctoral degree is extremely low, this does not consider that the purpose of doctoral education is still to obtain a tenure-track faculty position in academia (BLS, 2022c). Even though doctoral students are open to considering industry and government jobs, the doctoral curriculum is still focused on

preparing students for faculty jobs (Boothby and Milojevic, 2020; Curtin et al., 2016; Schillebeeckx et al., 2013). Studies have found doctoral students become more open to jobs outside of academia the longer they are in their program (Choe & Borrego, 2020; Roach & Sauermann, 2017; Sauermann & Roach, 2012), so the trend of career openness may be a practical one after becoming more aware of the competitive faculty job market during their studies.

Universities are set up in a way so that a tenure-track faculty member will produce more doctoral students than will be able to replace them (Larson et al., 2013). Therefore, there will always be an oversupply of doctoral students. This means some doctoral students will voluntarily or involuntarily get pushed into the non-academic labor market (Etmanski, 2019; Roach & Sauermann, 2017; Sauermann & Roach, 2012). It is important for doctoral students seeking academic employment to understand the skills and characteristics that will give them an advantage in the highly competitive faculty job market.

Trends in Tenure-Track Faculty Appointments

While there is an increase in the production of doctoral degrees in the United States, the landscape of tenure or tenure-track faculty appointments is changing. The American Association of University Professors (AAUP) surveyed 926 U.S. colleges and universities and reported that in 2020 the number of full-time faculty decreased at 62% of institutions over the prior year (AAUP, 2021). However, the survey data indicate that the type of institution matters in how much full-time faculty job loss or growth was observed. While an overall decrease of only 0.3% in full-time faculty numbers was observed, the number of positions grew at doctoral institutions, but decreased at all other institution types. (AAUP, 2021). Based on these differences, new

doctoral recipients should consider institution type when entering the job market for academic appointments.

One cause of the highly competitive market for tenure-track faculty positions is that universities are hiring contingent, fixed-term, or adjunct instructors into instructional positions instead of the more expensive tenure-track faculty that have historically held these roles. In 2019, 37% of academic appointments were tenured or tenure-track, 20% were full-time contingent, and 43% were part-time contingent (Tiede, 2022). Looking at just full-time instructional faculty at institutions with a tenure system in the ten years from 2012 to 2021 tenure or tenure-track faculty decreased from 72% to 67% of positions, while non-tenure track positions increased from 27% to 33% (NCES, 2021). Additionally, there are indicators that the shift in job type is not just due to the creation of new instructional positions that are not tenured, but that tenured appointments are being replaced by contingent or adjunct positions. In a 2022 survey of tenure practices, the AAUP found that 53.5% of institutions surveyed indicated that in the last five years they had replaced tenured positions with fixed-term positions (Tiede, 2022).

An additional example of the alarming trends in tenure or tenure-track faculty positions comes from the California State University system, which is the largest four-year public university system in the country. The system reported a decrease in the proportion of full-time equivalent (FTE) faculty from 64.2% in 2009 to 55.3% in 2019 (Stein, 2022). This exemplifies national trends showing a decrease in tenure-track faculty appointments and an increase in contingent instructional positions. Inadequate tenure density may have implications on education quality in areas such as retention, advising, equity, curriculum reform, committee services (Task Force on Tenure Density, 2018).

Academic Labor Market Outlook

Despite the decrease in doctoral graduates obtaining a tenure-track faculty job in academia and institutions hiring fewer tenure-track positions, the Bureau of Labor Statistics (BLS) reported that the field of postsecondary instructors is expected to grow by 12% between 2021 and 2031 (BLS, 2023b). This growth rate is much faster than for other occupations and indicates a strong market for instructors in institutions of higher education. This creates an average of 132,600 job openings for postsecondary instructors each year. Based on data from the Survey of Earned Doctorates 52,250 individuals graduated with a Doctorate in 2021 (NCSES, 2021). While all instructor positions will not go to new graduates, the BLS data do suggest a positive market outlook mostly based on the need to replace existing workers and not any potential new job creation in the field. However, based on the prior literature these may not be the tenure-track, research faculty jobs graduates are looking for.

Individual Characteristics in Labor Market

Decisions about who gets to enter a faculty career trajectory can have a great impact on an individual's career by shaping the opportunity for future research endeavors, scholarly productivity, and career trajectory. Even though women and minorities received increasing numbers of doctoral degrees and show moderate increases in representation in faculty positions, these groups are still underrepresented in faculty positions in academia (Wapman et al., 2022). Restricting these groups' access to faculty position has long-lasting implications on individual's economic outlook and also on who controls the research agenda and who receives funds from federal agencies (Wapman et al., 2022). Additionally, the overemphasis on prestige and family socioeconomic status only further limits who gets these jobs. Therefore, individual social

characteristics constitute important variables to include in models predicting academic faculty employment for doctoral recipients.

Role of Gender in Faculty Appointments

In 2020, full-time faculty in degree-granting postsecondary institutions were 52% male and 48% female (NCES, 2021a). This does not reflect the country's gender distribution across the population and instead shows an underrepresentation of women in faculty positions. This disparity varies when looking within disciplines. In 2020, women held only 18.6% of faculty positions in Engineering (American Association for Engineering Education, 2022). In science, engineering, and health fields women increased their proportion of faculty from 26.4% in 1999 to 38.5% in 2019, but they are still severely underrepresented compared to men (NCSES, 2021).

Additional gender disparities can be seen when looking at faculty positions by rank: among Professors, the highest rank, 65% are male, and 35% are female; Associate Professors are 53% male and 47% female; Assistant Professors are 47% male and 57% female; Instructors are 43% male and 57% female; and Lecturers are 44% male and 56% female (NCES, 2021a). As the ranks go down, so does the proportion of men holding a position in that rank. This has important implications because previous research had noted the tendency for universities to hire part-time or contingent positions which are paid less than tenure/tenure-track faculty (AAUP, 2021; Stein, 2022; Tiede, 2022; U.S. Department of Education, 2021). This data shows women are more likely to be in those positions and therefore will be in positions with lower salaries, prestige, and fewer opportunities for research. Another reason for rank parity is that the increase in women being hired as faculty is due to older men retiring, therefore positions held by a man are being replaced by a woman at a lower rank (Wapman et al., 2022). Despite an increase in new female hires to academic faculty positions, there is still reason to be concerned about future gender

parity. Even though there has been growth, it has remained flat for the last decade and newly hired faculty are still more likely to be men (Wapman et al., 2022). Not even institutional prestige can reduce gender disparities in faculty hiring outcomes. Clauzet et al. (2015) found gender differences in doctoral placement are greatest at the most prestigious institutions with women placing at institutions that rank lower compared to the placement of their male colleagues.

Role of Race, Ethnicity, and Citizenship in Faculty Appointments

According to the National Center for Education Statistics (2022), in 2020 74% of full-time domestic faculty in degree-granting postsecondary institutions were White, 12% were Asian/Pacific Islander, 7% were Black, 6% Hispanic, and American Indian/Alaska Native and Two or more races each made up 1% or less of faculty. The American Association for Engineering Education (2022) found in 2020, 2.6% of Tenure/Tenure-Track faculty in Engineering were Black/African American and 3.9% were Hispanic. In science, engineering, and health fields combined, URM individuals have increased their share of faculty positions from 6.4% in 1999 to 8.9% in 2019, however this population is still severely underrepresented (NCSES, 2021). White doctorate holders employed in universities or 4-year colleges in 2019 had the highest rate of tenure at 49.4% with URM individuals achieving a tenure rate of 42.3% (NCSES, 2021). These trends are exacerbated again when looking at faculty rank by both gender and race and show the dominance of white men in high-ranking academic positions. White men make up 39% of all full-time faculty but make up 51% of all full professors (NCES, 2021a). In contrast, white women make up 35% of all faculty, but only 28% of full professors (NCES, 2021a).

Researchers have investigated why there has been little change in underrepresented minority (URM) doctoral recipients moving into faculty careers (Jaeger et al., 2013; Kamimura-Jienez & Gonzalez, 2018; Layton et al., 2016). One study found advisors had a positive influence for doctoral recipients from well-represented racial and ethnic backgrounds on choosing an academic position but did not have a significant influence for recipients from underrepresented minority groups (Layton et al., 2016). This indicates advisors play an important role in deciding which students move on to academic faculty positions and which self-select to industry jobs. Research has also investigated the pathways underrepresented individuals take to faculty positions (Fleming et al., 2022; Murphrey et al., 2022). Highlighting these successful paths will allow administrators to create effective programming to recruit and retain diverse doctoral students in the future who will become future faculty.

Much of the literature on diversity in faculty appointments focuses on racial and ethnic categories assigned to U.S. Citizens and Permanent residents. However, non-U.S. Citizens, or international doctoral students, are also vying for jobs in the U.S. academic faculty labor market upon graduation. Research has shown this group is more likely than U.S. Citizens to be interested in earning a doctorate for the purpose of pursuing an academic faculty job at the beginning of the PhD (Choe & Borrego, 2020; Roach & Sauermann, 2017). Studies have also found international students do not lose interest in faculty jobs throughout their time in doctoral program in the same way that U.S. Citizen students do (Roach & Sauermann, 2017). Due to these differences, U.S. Citizenship is an important characteristic to consider when predicting the likelihood of a doctoral recipient obtaining a faculty job upon completion.

Interdisciplinary Research

Collaborative Science and Multidisciplinary Research

The idea of collaborative research and interdisciplinary teams is not new, however in recent years there has been a resurgence in literature calling for cross-disciplinary teams to tackle the complex problems our country is facing such as climate change, poverty, water quality, and increased natural disasters. Solutions for approaching these wicked problems will not come from a single discipline. Despite a call in 2005 from the National Academies for researchers to form interdisciplinary teams, researchers continue to encounter many challenges and the gains in interdisciplinary teams did not transpire as the authors of the report hoped (Ledford, 2015; NRC, 2015). Barriers within universities such as disciplinary hierarchies and stigma, faculty aversion to risk, and tenure and promotion practices have slowed excitement over interdisciplinary work (Ledford, 2015). In 2015, the prestigious journal *Nature* dedicated a special issue to interdisciplinarity exploring its history and trends over the last decade signaling this is still a relevant topic to explore. Additionally, the journal published an editorial in 2023 calling for an overhaul of doctoral education and argued PhD training is not preparing future researchers for participating in cross-disciplinary teams signaling their continued interest in pushing interdisciplinary research into the mainstream (“PhD training is no longer fit”, 2023). Before fully diving into the current landscape of interdisciplinary research at colleges and universities it is important to understand what it is and why it is seen as important.

Cognitive Diversity and Disciplinary Diversity

As scientists continue to address the complex problems with which they are tasked with solving it is becoming increasingly common for collaborative teams across disciplines to be tasked to work together across disciplinary boundaries (Hall et al., 2019). Cross-disciplinary

teams have many benefits over single disciplinary teams such as increased capacity for innovation due to the re-combination of disciplinary knowledge (Edmondson & Harvey, 2017). Disciplinary diversity relates to the differences in expertise individuals from varying disciplines will bring to a team (O'Rourke et al., 2019). Teams must identify the right disciplinary experts, along with the right degree of disciplinary diversity, and develop the tools to integrate their disciplinary expertise in ways to produce innovative solutions to complex problems. Cognitive diversity, representing psychological dimensions of an individual, is another important component of developing cross-disciplinary teams. Aggarwal et al. (2019) found that cognitive diversity leads to increased collective intelligence to a point, so moderate levels are ideal.

Interdisciplinarity Defined

Interdisciplinarity is a type of collaborative research defined by the synthesis of ideas, data and information, methods, tools, concepts, and theories from two or more disciplines (Klein, 2013). There are multiple types of cross-disciplinary science, of which interdisciplinarity is one, each distinguished by the level of integration involved. Multidisciplinary science involves sequential work that stays rooted in each disciplinary perspective, interdisciplinarity science combines perspectives, concepts and methods across disciplines, and transdisciplinary science involves the greatest degree of integration involving both synthesis and extension beyond disciplinary approaches and emphasizing the translation of research into solutions (Hall et al., 2019). The focus of this research will be on interdisciplinarity because it is the common phrase used in academia to distinguish collaborative research across disciplines from single disciplinary research. In the Survey of Earned Doctorates, interdisciplinarity is open to interpretation as graduates self-report whether their doctoral dissertation is interdisciplinarity by identifying the two or more fields used in their research.

Various experts in the field have defined the different skills and traits essential to interdisciplinary researchers. One set of skills and traits was established by Allen Repko (2008) and has been used as the basis for other work. Repko (2008) established nine essential traits which are: enterprise, love of learning, reflection, tolerance for ambiguity and paradox in the midst of complexity, receptivity to other disciplines, willingness to achieve adequacy, appreciation of diversity, willingness to work with others, and humility. Additionally, Repko (2008) established six skills which include: ability to communicate, competence, abstract thinking, dialectical thinking, nonlinear thinking, creativity, and holistic thinking. Building on these, Nurius and Kemp (2019) discuss “T-shaped” scientists who bring their interdisciplinary depth to an interdisciplinary team, but also have competency in the skills, tools, and approaches that underlie other disciplines. This is similar to Repko’s definition of willingness to achieve adequacy. An interdisciplinary scientist needs to be able to adequately converse across disciplines to be an effective team member. Other individual competencies identified by Nurius and Kemp (2019) that reiterate much of Repko’s (2008) work include communication across boundaries to understand others and be understood, managing differences, and developing social and relationship skills with diverse partners, collaborative orientation, curiosity and open-mindedness, and non-defensive reflectiveness to name a few. Introducing these skills to doctoral students is important to build capacity for this type of research in the future. Holley (2015) defined the traits doctoral students in interdisciplinary programs develop to create an interdisciplinary identity to be “...a strong disciplinary foundation, an understanding of the integrative process the recognition of interdisciplinary outcomes and the ability to participate in collaborative research” (p. 642).

Importance of Interdisciplinarity

Much of the push toward interdisciplinarity came from a 2005 benchmark report published by the National Academies *Facilitating Interdisciplinary Research*. The four main drivers of the 2005 report are the inherent complexity of nature and society, the desire to explore problems and questions not contained in a single discipline, the need to solve societal problems, and the power of new technologies (National Academy of Sciences, 2005). This report emphasized the necessity of interdisciplinary teams to address complex problems. However, as research advances, fields become more specialized through the creation of narrowly defined subfields which causes researchers to become even more specialized. This contrasts with the notion that today's problems are becoming more complex and therefore require expertise from multiple fields to approach a solution. Teams must take note of this phenomenon and innovate in ways that use specialized knowledge and integrate it across multiple domains of expertise (Edmondson & Harvey, 2017). Integration of knowledge from multiple domains is essential to problem-solving.

Research has found that teams made up of individuals with diverse knowledge and skills lead to more innovation (Fontana et al., 2020; Vestal & Mesmer-Magnus, 2020;). In their study, Vestal & Mesmer-Magnus (2020) use U.S. patent forward citations as a measure of innovation to determine the relationship between team member expertise unsharedness and innovation. They found a positive correlation between team expertise unsharedness and innovation, but only to a point. This confirms other research that found moderate levels of disciplinary diversity led to innovation (Aggarwal et al., 2019; Fontana et al., 2020; Salazar et al., 2012). However, researchers have also found this is only possible when certain team-learning behaviors are present such as integrative capacity (Edmondson & Harvey, 2017; Salazar et al., 2012; Vestal &

Mesmer-Magnus, 2020). This acknowledges that science can make a big impact when grounded in conventional disciplines, however, it's the unique combination of seemingly contrasting disciplines that produces innovative science. Disciplinary diversity alone is not enough, and teams must be intentional in finding common ground.

Measuring Impact of Interdisciplinarity

Another reason interdisciplinary teams are championed is the potential to produce more creative solutions than single-discipline teams. Lee et al. (2014) found teams produce more creative outputs when aggregating members with distinct knowledge bases. Scholarly impact and novelty are factors associated with creativity that measure the impact of interdisciplinary team research. Scholarly Impact, also called scientific impact, measures the number of forward citations, or the number of times a journal article has been cited. Specht & Crowston (2022) found that team disciplinary diversity has a positive impact on scientific output and this impact is mediated through the use of diverse publications in the citations and through publication in journals with diverse disciplinary focuses. This research shows it is the process of how interdisciplinary teams choose to collaborate which results in increased forward citations. Leahey et al. (2017) found increased citations for interdisciplinary research; however, these teams are generally less productive meaning they produce fewer articles. Other researchers have also found an increase in citations when there is variety in the disciplines included, but only within disciplines that are closely related (Fontana et al., 2022).

Wang et al. (2015) found interdisciplinary characteristics of research do have an association with the number of forward citations received. One reason scholarly impact may not be a good measure of impact for interdisciplinary journal articles is because the age of the article matters in its citation accumulation. The interdisciplinary traits of variety and disparity have

negative effects on short-term citations while they have positive effects on long term citations (Wang et al., 2015).

However, Lee et al. (2014) found disciplinary field variety is not a significant predictor of a journal article's impact and argues novelty should be measured instead. Research conducted by interdisciplinary teams has the potential to combine knowledge in ways that produce results never seen before, also known as novel solutions. The novelty of research products such as journal articles has been measured through new combinations of cited works and publication across diverse disciplinary journals (Fontana et al., 2020; Lee et al., 2014). Additionally, Uzzi et al. (2013) found teams are 37.7% more likely than solo authors to contribute novel combinations into already familiar domains. While novelty can be attributed to research that is not interdisciplinary, it is one attempt at measuring the impact of research. Uzzi et al. (2013) defines novelty within a journal article as an atypical combination of knowledge and measure it through the proximity between pairs of backward citations. This means they are looking for combinations of citations that are uncommon in prior research. This research also found through this measure of novelty it does have a positive impact on impact, or forward citations (Uzzi et al., 2013). Wang et al. (2017) defined novelty as the first appearance of a knowledge combination and measured it through new combinations of referenced journals.

Fontana et al. (2020) argues that novelty as an atypical combination of knowledge overlaps with interdisciplinarity but take their analysis further to identify additional interdisciplinary properties of research. This is one of the only analyses of interdisciplinarity and its impact that focuses on the content of the research and not just on backward and forward citations. Their research measures interdisciplinarity through variety of disciplines, balance of

disciplines, disparity between disciplines, and integration of disciplines (Fontana et al., 2020).

Impact of interdisciplinary

Novelty as a measure of innovation goes beyond scientific impact to not just count the number of forward citations, but to look at unprecedented combinations of forward and backward citations and citation combinations that are distinct in their disciplinary focus. Fontana et al. (2020) was able to take the measurement even further to look at specific traits of interdisciplinary work and show the correlation between commonly used measures of novelty and an article's interdisciplinary traits. Wang et al. (2017) also show novel research is risky due to delayed recognition and publication in lower tiered journals. Taken together, these measures show interdisciplinary research teams produce innovative research in a measurable way, but more research needs to be done to measure the influence of interdisciplinary research beyond journal articles as the unit of analysis.

Current Landscape for Interdisciplinary Research

Given the competitive job market for tenure-track faculty and the fact that doctoral programs are still training students with the objective of producing future faculty, students are looking for competitive advantages that will help them obtain those sought-after jobs. In response to some of the most wicked problems our society faces such as poverty, climate change, and public health crises such as global pandemics and water quality, there is a push toward collaborative cross-disciplinary research processes which reach outside of a single discipline to solve a problem. As the primary source for preparing the researchers of the future, doctoral education is the mechanism for which future researchers can be better trained to participate in the co-production of knowledge necessary to solve the greatest problems we are facing. Partial solutions developed from one singular discipline will not be enough to solve these problems.

Trends in Interdisciplinary Research

Due to perceived ambiguity around what constitutes interdisciplinary research there continues to be limited ways to measure trends and impact of interdisciplinary research. Some ways researchers have measured trends in interdisciplinary research are through the evaluation of citations of interdisciplinary journal articles, reviewing reference lists within journal articles, and searching for interdisciplinary rhetoric through journal article titles (Leydesdorff et al., 2019; Okamura, 2019; Specht & Crowston, 2022; Van Noorden, 2015). However, the goals of interdisciplinary research do not necessarily coincide with measuring the impact of journal articles. Measuring the impact of finding solutions for complex problems is much harder to quantify. Despite these limitations, it is important to understand these trends as part of the current landscape of interdisciplinary research. In his summary of the impact of interdisciplinary research for *Nature's* special issue Van Noorden (2015) found an increase in the proportion of references in research papers that reference other disciplines, an increase in the percent of papers with interdisciplinary* in the title, and evidence that in the long-term citations increase as a paper's level of interdisciplinarity increases. This is further substantiated by a 2013 finding that 90% of papers in science and engineering journals were written by teams (NRC, 2015). More recently, Specht & Crowston (2022) found an increased level of interdisciplinary collaboration within a team increased the number of resulting publications and Fontana et al. (2022) found the number of authors on a paper has a positive impact on the number of forward citations.

The Role of Funding Agencies in Interdisciplinary Research

The National Science Foundation (NSF) is one of the biggest funders of academic research at U.S. colleges and universities and therefore has a strong influence on the research being produced. The NSF has used its position as a major funder to influence the occurrence of

interdisciplinary research. One of its most successful interdisciplinary research initiatives influencing doctoral education at U.S. colleges and universities was the Interdisciplinary Graduate Education and Research Traineeship (IGERT). This program was created to meet the challenge of training doctoral students with interdisciplinary backgrounds and establish new models for graduate education and training (NSF, 2011). Research has repeatedly shown improved outcomes from doctoral students who participated in their IGERT program (Borrego et al., 2014; Kniola et al., 2012; Schmidt et al., 2012).

The current version of the IGERT program is the NSF Research Traineeship (NRT). The NRT is “dedicated to effective training of STEM graduate students in high priority interdisciplinary or convergent research areas” (NSF, 2020). The NRT also has a workforce development aspect and encourages proposals that collaborate with the private sector, NGOs, national laboratories and other non-academic partners (NSF, 2020). Through these kinds of funding opportunities, NSF sets the interdisciplinary research agenda by defining the most important interdisciplinary research areas.

In addition to funding academic research, NSF shows the value of interdisciplinary research through supporting almost 60 centers focused on interdisciplinary research. The NSF solicits interdisciplinary research proposals across NSF directorates: BIGDATA, Building Theoretical Foundations for Data Sciences (TRIPODS), Coastlines and People, Dynamics of Integrated Socio-Environmental Systems, Ecology and Evaluation of Infectious Diseases, Growing Convergence Research, Research on Emergence Technologies for Teaching and Learning, and Smart and Connected Communities (NSF, n.d.-b).

The Role of Universities in Interdisciplinary Research

Universities play an important role in the promotion of interdisciplinary research because they are where future researchers are prepared through doctoral education and where research is produced by faculty. Perhaps because universities signal the importance of interdisciplinary research, they also commit to prepare their doctoral graduates for that type of research and encourage faculty to work across disciplines. However, there is still a gap in what universities say is important and the policies and practices in place (Hein et al., 2018). Early and mid-career researchers have expressed uncertainty about the impact that conducting interdisciplinary research will have on their future in terms of tenure and promotion and publishing and has hindered their engagement with it as a result (Daniel et al., 2022; Hein et al., 2018). Additionally, when interdisciplinary collaboration is attempted challenges around disciplinary differences, professional integration, and collaborative practicalities also hinder the process (Daniel et al., 2022). Despite calls for more collaborative cross-disciplinary work, disciplinary socialization continues to shape future scientists within traditional disciplines and departments (Crow & Dabars, 2019; Ng & Litzenberg, 2019).

Extreme reorganization of disciplinary structures in academia may result in increased sponsored research funding. In the case study of one American research institution from FY 2003 to FY 2018, Crow and Dabars (2019) found that after an extreme reconfiguration of academic departments, the number of sponsored projects by collaborative research teams increased 182% while projects involving researchers from a single department increased by only 27%. In terms of the value of these projects, projects involving multiple units increased funding by 367% (Crow & Dabars, 2019). Leahey and Barringer (2020) found that universities with an intentional organizational structure toward facilitating interdisciplinary research increased

interdisciplinary research and NIH grant activity. Other researchers found top-down administrative support for interdisciplinary research and higher levels of interdisciplinary research grants are associated with higher levels of structural commitment to interdisciplinary research (Barringer et al., 2020).

Additionally, tenure and promotion practices do not reward faculty for participation in interdisciplinary teams but is a necessary practice to promote interdisciplinary collaboration (Arnold et al., 2021; Klein & Falk-Krzesinski, 2017). In addition to the National Research Council's (2005) call for new academic structures, various publications have made recommendations and described best practices that universities should follow to institutionalize interdisciplinarity (Arnold et al., 2021; Borrego & DePauw, 2012; Hein et al., 2018; Pryor & Steinberg, 2023). Crow and Dabars (2019) argue the continuation of academic disciplinary silos as the main feature of institutions of higher education will limit future knowledge production stemming from American research universities. This is an important argument because doctoral degree recipients have an important decision to make whether to conduct further research through a faculty position or by entering industry and these rigid structures may lead doctoral students away from the institution that wants to retain them. Maintaining these structures and the individual focus of tenure and promotion policies is also contradictory to the finding that journal articles are increasingly authored by teams and are more interdisciplinary (NRC, 2015; Van Noorden, 2015).

Interdisciplinarity in Doctoral Education

Interdisciplinary learning and research have been promoted as ways to transform graduate education and provide a career advantage through transferable skills and experience solving complex problems (Borrego & Newswander, 2010). Universities are creating new

interdisciplinary degrees and programs and research has focused on best practices for institutionalizing and integrating interdisciplinarity, with little focus on the expected outcomes for the programs. Significant research has found positive effects of NSF's interdisciplinary IGERT program on doctoral student training and outcomes, however this program is no longer in place (Borrego et al., 2014; Kniola et al., 2012; Schmidt et al., 2012). Additionally, Noble et al., (2016) look at the IGPPEB program at Yale to describe the processes and structures that must be put in place for interdisciplinary programs to succeed. The amount of investment necessary to implement new interdisciplinary programs or research opportunities at any institution will need to be backed by clear evidence of successful student outcomes. The Council of Graduate Schools encouraged these trends and published recommendations for graduate schools to follow to successfully champion interdisciplinary graduate education at their institution (Borrego & DePauw, 2012).

A body of literature has been developed detailing the student experience and providing a path for improvement of interdisciplinary programs to meet the needs of students as they learn interdisciplinary skills and develop an interdisciplinary identity (Graybill et al., 2006; Holley, 2015). Marbach-Ad & Marr (2018) investigated the teaching practices that impact graduate student's ability to conduct interdisciplinary research. Holley (2015) described the important characteristics of an interdisciplinary researcher to be: a strong disciplinary identity, an understanding of the integrative process, the recognition of interdisciplinary outcomes and the ability to participate in collaborative research. Additionally, Martin and Umberger (2003) found through their study of an IGERT that interdisciplinary programs provide focused and intensive research experiences, have a clearly articulated interdisciplinary theme, brings together faculty and trainees who probably would not interact otherwise, it exposes students to state-of-the-art

technologies, and provides a funding mechanism to offer highly competitive stipends and additional support for trainees. Time conflicts, scheduling challenges, and the workload of both faculty and trainees are the main challenges of interdisciplinary programs.

Research is outdated on how frequently faculty job listings are seeking individuals with interdisciplinary experience so it is unclear whether this experience will be an advantage or disadvantage (Borrego & Newswander, 2011). One signal that universities do want to break away from traditional disciplinary hiring processes and promote interdisciplinary is through the use of cluster hires. Cluster hires promote both disciplinary diversity as well as demographic diversity and operate outside of typical academic bureaucracy. They bring in groups of faculty from diverse academic backgrounds to work together on interdisciplinary problems (Oldach, 2022). New faculty are typically hired into a home department, but are also affiliated with another academic program, research center, or around a specific institutional priority area (Oldach, 2022; Simmons & Petitt, 2022). One benefit of these types of hires is the job listings are broader and therefore attract more applicants which can lead to greater diversity among applicants. These practices are transformative and require shifting practices throughout the university and the macrostructure and microstructure levels (Simmons & Petitt, 2022). One study even found statistically significant gains in research output, collaborations, and research impact among faculty members that were part of cluster-hires (Curran et al., 2020).

This body of research has established the structural components necessary for interdisciplinary education and research while developing models of best practices both from the student and teacher perspective. These plans for implementation leave a gap in the literature relating these programs to students' career outcomes. The emergence of these interdisciplinary programs brings forward the need to evaluate whether they influence career outcomes for their

students. If universities are going to continue to promote interdisciplinary learning and degree programs, it is important to know the ways in which they are beneficial.

Trends in Interdisciplinary Dissertations

This research will build upon prior studies that have used the Survey of Earned Doctorates to evaluate the prevalence of interdisciplinary dissertations. Falkenheim (2010), Golembiewski et al. (2018), Millar and Dillman (2012) and the Humanities Indicator Project (2015) examined trends in interdisciplinary dissertations and whether those fields are closely related or divergent. Each of these studies found that interdisciplinary dissertation research has increased over time and that most research is still done between two closely related fields. Falkenheim (2010) and Millar and Dillman (2012) examined data across all broad fields while Golembiewski, et al. (2018) and the Humanities Indicator Project (2015) looked at dissertations within public health and the humanities, respectively. These trends need to be re-evaluated because additional years of data have become available since these studies were published.

Career Outcomes of Doctoral Students Conducting Interdisciplinary Research

There is limited literature investigating the career outcomes for students completing interdisciplinary dissertations. Millar (2013) found those who reported conducting interdisciplinary research were more likely to obtain a position in academia than those who did not. However, some research has shown reluctance by doctoral students to conduct interdisciplinary research because of the unknown effects it will have on their job search. Holley (2018) found that while students in interdisciplinary programs felt prepared for their postgraduation work, their concerns over a weak job market and the instability of postdoctoral positions overshadowed their desire to complete interdisciplinary work. A survey of individuals who left an interdisciplinary doctoral program expressed the importance of preparing students for

careers beyond academia and more importantly making this path valued and culturally accepted (Reisman et al., 2022). These trends make it even more important to use empirical evidence to better understand the career outcomes for doctoral students with interdisciplinary research experiences.

Theoretical Framework

This study is conducted through the lens of socialization with a specific focus on graduate student socialization theory. In their widely used work on graduate and professional student socialization, Weidman, Twale, and Stein (2001) described socialization as "...the process through which individuals gain the knowledge, skills, and values necessary for successful entry into a professional career requiring an advanced level of specialized knowledge and skills" (p. 5). Expanding upon this definition to include the role of research, socialization in this context is defined as the process through which students develop the knowledge, skills, and values that will equip them to be producers as well as consumers of research (Weidman, 2010).

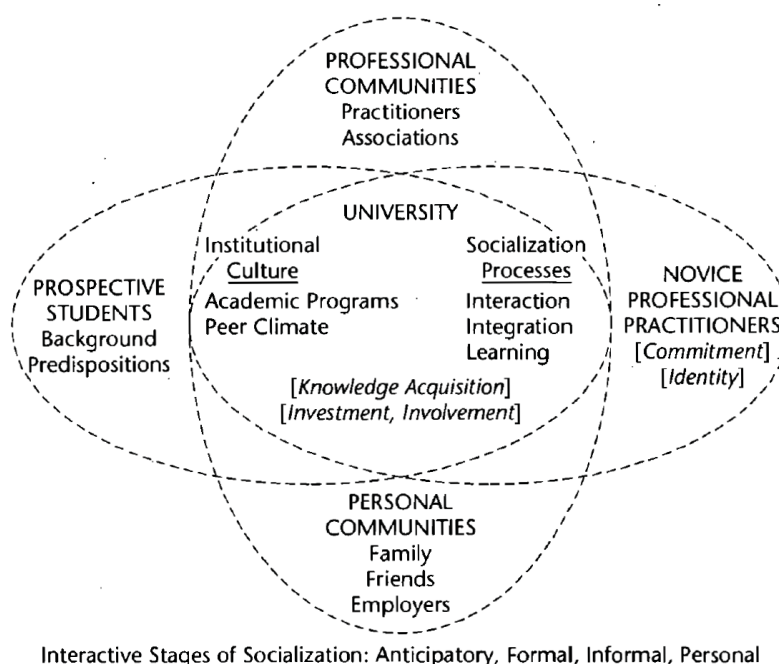
This process provides a clear link between the ways doctoral students experience their education and their career outcomes upon completion. There are both individual and institutional factors that influence doctoral student identity formation through socialization and impact the outcomes related to the process. Given the aim of my study to better understand the influence of interdisciplinary research experiences on doctoral students' career outcomes, approaching this study through the lens of socialization processes is warranted.

Graduate Student Socialization

Graduate student socialization is not a linear process where a student enters their academic department, the department socializes them to a specific career, and then they graduate ready to enter that career. The Weidman, Twale, and Stein (2001) model of graduate and

professional student socialization (Figure 1) shows the various elements that impact student socialization, both internal and external, and that these elements are nonlinear, seamless, and interactive. The contextual factors brought in by the outer part of the model interact with the processes and environments represented in the interior of the model to form the graduate student socialization environment in which identity development occurs.

Figure 1. Conceptualizing Graduate and Professional Student Socialization



The central part of the model in Figure 1 shows the core elements of socialization that occur within the university setting which are institutional culture, the socialization processes, and the core elements of socialization. The core elements of graduate student socialization are knowledge acquisition, investment, and involvement (Weidman et al., 2001). Knowledge acquisition allows doctoral students to move from being a novice in their field to becoming a professional. During socialization, knowledge acquisition moves from general to more specialized and complex (Weidman et al., 2001). This is part of the student's identity formation whereas they gain more specialized knowledge they begin to act and feel more like the

professional they are hoping to become. Investment also shapes the student's identity formation as the student must make a commitment to a certain discipline and professional role to the exclusion of other opportunities. This means as the student is preparing for a certain professional role they will make decisions that require sacrificing other options such as other education institutions and other professions (Weidman et al., 2001). The further into the socialization process the student becomes, the harder it is to change that path. The third core element of socialization is involvement which includes how the student decides to immerse themselves in the academic environment. This means the doctoral student must participate in some part of the professional role they seek or in preparation for it (Weidman et al., 2001). Investment through increased interactions with older faculty and older students will provide critical guidance on professional expectations and pathways. Another important element placed within the central part of the model are the three processes for graduate student socialization. Weidman, Twale, and Stein (2001) identify these mechanisms as interaction with others, integration into or sense of fit with the expectations of faculty and peers, and learning of knowledge and skills necessary for effective professional practice.

Four components external to the institution and academic department which influence the socialization process are the prospective students and their predispositions, professional communities, personal communities, and novice professional practitioners (Weidman et al., 2001). Each of these components interact with the internal processes of socialization and have varying levels of influence on the socialization outcomes for doctoral students. The student brings with them characteristics such as their race, ethnicity, gender, and sexual orientation along with a set of predispositions such as their values, beliefs and professional aspirations (Weidman et al., 2001). The student also has many personal communities that play an important role in their

socialization. These communities may include family, relatives, peers, and employer (Weidman et al., 2001). These communities may participate in varying degrees but hold importance to aspiring students through their own displays of support and expectations. Professional communities also play an important role in the process because individuals in the community serve as a role model for the students and the community likely has a professional associate which sets the standard for entering that role (Weidman et al., 2001). Finally, the novice professional practitioner is included in the model because this is the ultimate outcome of the socialization process (Weidman et al., 2001).

Stages of Graduate Student Socialization

Along the bottom of the model shown in Figure 1 are the four interactive stages of socialization. Weidman, Twale, and Stein (2001) include the various stages of graduate student socialization in their model to show their importance as students move from being a novice to developing a professional identity. These stages are: anticipatory, formal, informal, and personal. These stages are important to consider in the model because doctoral students experience each of the elements in Figure 1 in different ways during each of the stages. In the anticipatory stage, the student is getting ready to begin their graduate program and has a set of preconceived expectations regarding what they will need to do to be successful in their program (Weidman et al., 2001). This phase is characterized by learning, uncertainty, one-way downward communication, and information seeking (Weidman et al., 2001).

During the formal stage of socialization graduate students are inducted into the program and determine how well they fit with program norms and expectations. During this stage the student is still a novice but becomes an apprentice and receives formal instruction related to the knowledge that will be required for their future professional role and observes older students to

learn about normative expectations (Weidman et al., 2001). This formalized process is important because it is how the novice moves toward become a more experienced student and is prepared to meet program milestones such as examinations and progress to program completion.

The third stage of graduate student socialization is the informal stage. This is where the novice student learns the informal expectations of the program from more experienced members. This involves observing acceptable behavior and learning to react and respond appropriately which can only be learned once immersed within the program (Weidman et al., 2001). While faculty play a large role in the formal stage amid the transmission of knowledge, peer social groups play a larger role in the informal phase of socialization. Close knit peer support groups can help ease the anxiety associated with fitting in as students see older peers move to the next level (Weidman et al., 2001). These interactions are important because knowledge alone will not prepare a student for their profession. Finally, during this stage the novice student also begins to see the flexibility of their role and begin to feel less like a student and more like a professional (Weidman et al., 2001).

In the personal stage students form a professional identity which requires reconciling their previous self-image with their new professional one through an internalized process (Weidman et al., 2001). This internalization of their new role allows them to move from novice to professional. The student has been immersed in their program where they have complied with the expected attitudes, values and higher expectations which has allowed them to evolve into the role of a scholar (Weidman et al., 2001). At this point, the student is aware of their research interests and specialties and has likely become involved in professional activities such as publication and presenting. The student has also realized their program is preparatory for the real

thing and the student is ready to assess their career marketability and competitiveness and focus on how to succeed in the professional world (Weidman et al., 2001).

Individual Level Influences of Socialization

In Weidman, Twale, and Stein's (2001) model for graduate and professional student socialization, one of the external factors influencing the student's experience and outcomes are the identities and background they bring with them upon entering the program. Personal background is important to the socialization process including experiences, identity, and other relationships (Gardner & Doore, 2020). It is important to address potential differences in socialization outcomes based on social identities because it cannot be assumed that all doctoral students are socialized to potential career pathways in the same way. Social identities have been shown to play an important role in the doctoral education experience and socialization to certain professions (Phelps-Ward, 2020; Winkle-Wagner, 2010; Wofford & Blaney, 2021).

Additionally, many scholars have argued that socialization is not an identity neutral process (Garcia et al., 2020; Perez et al., 2023; Robbins et al., 2023; Winkle-Wagner et al., 2020).

Additional models of graduate student socialization have been established that account for the ways power, privilege and oppression in graduate environments interact with various student social identities such as race and gender (Felder et al., 2014; Garcia et al., 2020; Perez et al., 2023; Twale et al., 2016; Winkle-Wagner et al., 2020). In revisiting the Weidman-Twale-Stein (2001) graduate student socialization framework, Twale et al. (2016) make additions to the framework which account for the experiences of diverse groups of students. These additions include differences in academic resources, environment, faculty climate, and engagement. When students are socialized differently, they leave with unequal skills, abilities, and resources based on differences in access to certain competitive advantages during their doctoral training (Twale

et al., 2016). This revised model of graduate student socialization recognizes graduate students need social, cultural, and academic access to people, resources, and activities. Inequality in these areas directly influences career opportunities available upon graduation and future progress throughout a chosen career path. Individuals who do not fit into the traditional system of doctoral education, whether based on demographic characteristics or not fitting into a disciplinary silo, still need to be socialized to their future profession.

The Weidman, Twale, and Stein (2001) model is defined by the graduate student socializing within a disciplinary structure with explicit norms and values. However, these norms and values make up the institutional culture and climate which has the potential to isolate students from underrepresented or minoritized populations. Department climate influences the socialization process primarily through how they choose to address students' social identities, if they address them at all (Robbins et al., 2023). A lack of a sense of belonging and feelings of isolation can prevent doctoral students from minoritized groups from achieving their desired academic and career outcomes (Garcia et al., 2020). These groups of students encounter social obstacles such as a lack of perceived fit in research labs (Wofford & Blaney, 2021) and lack access to faculty (Phelps-Ward, 2020; Winkle-Wagner, 2010) in addition to the systematic obstacles encountered by their presence in a system of oppression (Garcia et al., 2020; Perez et al., 2023; Robbins et al., 2023).

Race/Ethnicity

Weidman, Twale, and Stein (2001) mark the importance of the individual characteristics a graduate student brings with them to their academic program and how these characteristics influence their socialization to certain professional outcomes. Although Weidman, Twale, and Stein (2001) address individual differences in socialization and the need for diversity, many

authors have critiqued the Weidman model as ignoring the many ways socialization leads to different outcomes for minoritized students (Felder et al., 2014; Garcia et al., 2020; Perez et al., 2023; Twale et al., 2016; Winkle-Wagner et al., 2020). Negative outcomes related to the current socialization experiences of graduate students include feelings of isolation and a lack of a sense of belonging which can lead to students questioning whether they even belong in their doctoral program, in academia, or in their desired future career field (Garcia et al., 2020; Weidman et al., 2001).

Racially minoritized students are isolated through the presence of predominantly white faculty, a white curriculum and white peers which lead to a white normative socialization experience (Garcia et al., 2020). As described in the sections above, faculty play a large role in socializing doctoral students and in preparing them for their future professional roles. However, many studies have shown minoritized students do not experience their faculty-advisor relationship as positively, or receive the same levels of support, as their white counterparts (Garcia et al., 2020; Winkle-Wagner, 2010). Doctoral students frequently encounter departments that ignore the role of students' social identities in their socialization or experience conditional acceptance of their identities (Robbins et al., 2023). Students also report a lack of access to faculty due to racial differences (Phelps-Ward, 2020; Winkle-Wagner, 2010). By diminishing the role race plays in socialization, and particularly on relationships between doctoral students and faculty advisors, there is a missed opportunity to recognize the two-way socialization where the student's presence also changes the academic department and those operating within it.

Gender

A student's gender cannot be ignored when considering how doctoral students are socialized through their experiences in graduate education. The Weidman, Twale, and Stein

(2001) model of socialization notes the importance of the individual characteristics a student brings with them to their academic program. Gendered socialization occurs through students' experiences with their advisor. Male and female students have reported differences in how positively they view their advising relationship due to differences in the type of advising support they receive and in the level of social interaction with their advisor (Sallee, 2010). Female doctoral students' socialization experiences are frequently engrained with inequality which leads to differences in career outcomes for men and women. These differences in outcomes are seen in women not pursuing faculty roles and women being more likely to pursue teaching careers while men pursue research-related careers (Hughes et al., 2017; Mathur et al., 2018).

Additionally, men and women in science fields report differences in how they select a research lab. Women feel like they must choose between a lab that aligns with their research interests and one that will be inclusive (Wofford & Blaney, 2021). By not choosing the most prestigious lab or the one that matches their research interests, women are at a disadvantage when entering the job market upon graduation. Another way these gendered experiences manifest in ways that are detrimental to career outcomes is in publication rates. Women in doctoral programs have been found to have lower publication rates than men in the same discipline and this difference increases the further along they get in their program (Feldon et al., 2017; Pezzoni et al., 2016; Roksa et al., 2022). This is important because having publications as an early career researcher increases the likelihood of obtaining a faculty job.

Socialization and the Role of Disciplines

Academic discipline is one of the factors that make up institutional culture in the Weidman, Twale, and Stein (2001) model of graduate student socialization. Disciplinary departments, and the faculty within, create both formal and informal structures to integrate

students into the professional roles they see as representative of success in their discipline. Differences in socialization between disciplines are also largely driven by the faculty who, “establish the norms for teaching, research, and services within the constraints of the larger university community” (Weidman et al., 2001, p. 50). Faculty shape the curriculum, organization, and social relationships within the program.

Faculty Role in Socialization

The main goal of the socialization of graduate students is to prepare them for their future career. Faculty establish the norms for teaching, research and service within the larger university community (Weidman et al., 2001). This has typically meant faculty train doctoral students to follow their path and become the next generation of faculty in higher education institutions. However, more attention is being drawn to the changing career aspirations of doctoral students along with an unfavorable job market for those seeking tenure-track faculty positions. As part of their socialization framework Weidman et al. (2001) argue graduate students should be prepared for a variety of potential professional pathways. However, more than twenty years later, many scholars argue there is a lack of socialization of graduate students to the breadth of potential professional pathways (Gardner & Doore, 2020; St. Clair et al., 2017).

Faculty play an outsized role in socializing doctoral students to potential career pathways and faculty are likely to train what they know, which is how to become faculty in higher education institutions (Gardner and Doore, 2020; St. Clair et al., 2017; Thiry et al., 2015). This creates conflict in the socialization process if a doctoral student does not feel they are in a supportive environment or feels a lack of fit with their advisor. Research has found doctoral trainees who are pursuing non-academic careers receive different levels of career search support from their advisors (Thiry et al., 2015; St. Clair et al., 2017).

Some view the purpose of doctoral education more broadly as socialization to become a scholar, which does not necessarily have to be within academia, so socialization should focus on developing scholars, not just disciplinarians (Weidman & Stein, 2003). Faculty are seen as gatekeepers of information on potential career pathways and can choose what information or resources to share with students. This leaves doctoral students unaware of the multiple career pathways available to them (Thiry et al., 2015). If a doctorate degree is required to enter a particular profession, then it is the duty of the programs training these future PhD holders to introduce the knowledge, values, and standards of the given profession (Gardner & Doore, 2020).

Socialization in Disciplines

Academic disciplines play a very important role in the socialization of doctoral students. Institutions of higher education are structured in a way that doctoral students are typically socialized within a single disciplinary department. Weidman and Stein (2003) emphasized the importance of social interaction among students and faculty, collegiality among faculty, and a supportive environment as important for providing the foundation to doctoral students for future research and scholarly activities. In addition, each discipline has its own set of knowledge, skills, and values that it deems necessary for doctoral students to learn. This leads to disciplinary differences in the development of doctoral student research skills which are learned through socialization processes. This includes interpersonal interaction with faculty and peers, participation in professional activities, hands-on research experience, and practice writing for academic publication (Weidman, 2010).

As discussed above socialization is a gendered process, and it is further compounded by gender differences in disciplines. Gendered disciplines lead to an environment favoring

masculine norms and male students, particularly in science and engineering (Sallee, 2010). Even though women have increased parity in STEM doctoral programs, women remain underrepresented in senior academic positions. These differences are often due to the experiences and inequality female students encounter in doctoral education (Hughes et al., 2017). Gender also contributes to the role a particular discipline has on the likelihood of a doctoral student obtaining a faculty job (Sallee, 2010).

Socialization of Interdisciplinary Scholars

Socialization to values, attitudes, norms, knowledge, and skills are different for students conducting interdisciplinary research compared to those who have stayed within disciplinary bounds. The main mechanisms of socialization described by Weidman, Twale, and Stein (2010) include interaction with others, integration into or sense of fit with the expectations of faculty and peers and learning of knowledge and skills necessary for effective professional practice are directly at odds with students conducting interdisciplinary research. Students who conduct interdisciplinary research are still typically embedded in a disciplinary structure due to lack of support for true interdisciplinary departments. Therefore, students conducting interdisciplinary research have less interaction with others (both faculty and students) due to differences in physical location and spending time in other departments, less fit with faculty and peers who are doing disciplinary research because they may not understand their research goals and will be in different labs, and have a feeling of inadequate skills and knowledge in a single discipline due to pressure from faculty that still deem this specialization necessary for socialization (Holley, 2010).

Academic disciplines expect a commitment of the student to the norms of the anticipated professional role (Weidman & Stein, 2003). Interdisciplinary students may not adhere to these

norms associated with the expected professional path, types of scholarly activity, and student involvement in certain disciplinary professional organizations which can put them in conflict with the faculty of a discipline. Other disciplinary landmarks such as following the career path of a faculty advisor and set disciplinary journals and professional conferences provide barriers to the socialization of students conducting interdisciplinary research (Holley, 2010). With much of the socialization process taking place within a discipline, under the assumption that doctoral students will spend most of their time in this silo, students conducting interdisciplinary work may not experience the less formal structures of socialization that come through informal interactions with faculty and more advanced students (Holley, 2010).

It is clear that interactions with faculty are influential in the socialization process so it is important that students conducting interdisciplinary research have access to faculty who understand the importance of their work and validate their legitimacy as a scholar (Holley, 2010). Scholars, including those that become faculty members in higher education, are important to society as the ones exploring solutions to the complex problems that trouble the world (Kawa et al., 2021). The ways students are prepared for that role and particularly whether those who do not follow a disciplinary path are prepared for the same potential career pathways as those who are socialized within a single discipline remains an area of focused research (Curtin et al., 2016; Holley, 2010).

Barriers to Interdisciplinary Socialization

The hierarchical nature of higher education institutions and the creation of disciplinary silos creates a disciplinary culture that cannot be avoided by doctoral students throughout their socialization. This culture of disciplinarity is a barrier to students wishing to conduct interdisciplinary research. Doctoral students are socialized within this disciplinary system and

are therefore naturally resistant to interdisciplinary training which leads to continued organizational barriers for promoting interdisciplinarity (Boden et al., 2011). Just like students in traditional disciplines, Boden et al. (2011) found that the student-supervisor relationship is important to students completing interdisciplinary work and is of particular importance to integrating with scholars outside of their department. Boden et al. (2011) recommend removing institutional barriers that disincentivize the formation of interdisciplinary communities. Building a sense of community, socialization to professional communities, and administrative support are all ways these barriers can be broken down.

While many of the processes of socialization are similar in interdisciplinary settings, special attention should be paid to overcoming organizational barriers to interdisciplinary related policies, spaces, engagement with future employers, and open discussion of the politics of interdisciplinarity (Borrego & Newswander, 2011). It is a serious challenge of doctoral training to foster interdisciplinary socialization when the student is embedded in a disciplinary structure. There is evidence that students that participate in structured interdisciplinary opportunities have more positive socialization experiences (Culpepper et al., 2020; Gardner et al., 2012). These programs can replicate the socialization process that typically takes place within a discipline but apply it to the unique setting of interdisciplinary research and provide the necessary resources to help this group of students become professionals.

Institutional Level Influences of Socialization

While every doctoral student brings certain characteristics and qualities with them that influence their doctoral experience and their socialization to certain career pathways, there are also characteristics of the environment in which they are entering that influence this process and the related outcomes. This is identified as institutional culture and is made up of both the

academic program and peer climates (Weidman et al., 2001). Demographic characteristics of both peers and faculty as important influencers of socialization outcomes. The Weidman, Twale, and Stein (2001) model is defined by the graduate student socializing within a disciplinary structure with explicit norms and values. However, these norms and values make up the institutional culture and climate which has the potential to isolate students from underrepresented or minoritized populations. Institutional climate influences the socialization process primarily through how they choose to address students' social identities, if they address them at all (Robbins et al., 2023). Doctoral students' experiences are improved when there are other students and faculty that represent their identities. Moving beyond the influences of socialization, another institutional characteristic that influences a doctoral student's ability to obtain a career in academia is institutional prestige.

Peer and Faculty Gender

The gender of a doctoral student's peers and the gender of faculty both play an important role in socialization outcomes through the way these individual's construct and influence the institutional culture experienced by the doctoral student. Weidman, Twale, and Stein (2001) acknowledge in their socialization model that there is a mismatch between the increasing enrollment of women into graduate programs and their representation as faculty. As this trend has remained consistent in recent years, it is influential on the socialization experiences of female doctoral students. The gender makeup of a doctoral students' peers and faculty mentors can have a significant impact on their experience socializing in doctoral education and related outcomes (Wofford & Blaney, 2021).

Faculty members play a critical role in the socialization outcomes of doctoral students and gender plays a notable role in this relationship (Twale et al., 2016). When women do not feel

they are getting the guidance they need from faculty they turn to their peers. Peers play an important role as lab mates, study partners, and as another person who is sharing many of the same experiences of doctoral education. Women in doctoral cohorts with no other women peers are less likely to graduate within 6 years which is indicative of the role institutional climate has on socialization outcomes (Bostwick & Weinber, 2018). It is important for women to have same-gender peers because there is also likely to be a limited number of women faculty mentors. One coping mechanism researchers found for women lacking same-gender faculty mentors is to form same-gender mentoring relationships with advanced doctoral students (Hirshfield, 2014). These older peers are an important component of Weidman, Twale, and Stein 's (2001) socialization model. Finally, women have enhanced socialization outcomes, such as increased publishing rates and moving into academic careers, when they have a faculty mentor of the same gender (Gaule & Piantentini, 2019).

Peer and Faculty Race

As previously discussed, a doctoral student's race plays in their socialization and the related outcomes. However, the race of their peers and faculty play an important role as well as they form the institutional culture and climate within which students are socialized. Weidman, Twale, and Stein (2001) mark the importance of institutional culture in graduate student socialization, including the roles of academic programs and peer culture, and many studies since have investigated the ways these facets of socialization do harm to minoritized students. These studies have critiqued the Weidman model as ignoring the many ways minoritized students experience institutional climate differently than their peers in normative groups (Felder et al., 2014; Garcia et al., 2020; Perez et al., 2023; Twale et al., 2016; Winkle-Wagner et al., 2020). Despite increases in doctoral student racial diversity, faculty background does not match the

students. The presence of predominantly white faculty leads to feelings of isolation by doctoral Students of Color (Garcia et al., 2020). To make the socialization process and related outcomes more positive for students of color more faculty must be hired from underrepresented racial groups in proportions similar to the student population (Twale et al., 2016). To see real change in faculty representation, existing structures within doctoral training must change to provide an environment where students of color feel they belong (Phelps-Ward, 2020; Winkle-Wagner et al., 2020).

Peer racial makeup also plays an important role in socialization. Garcia et al. (2020) found that when peers uphold the normative structures of doctoral socialization it can have a negative impact on Latinx students by making them feel isolated. Latinx students feel like their white peers exclude them from study groups, avoid them in the classroom, used racial slurs, and committed other microaggressions (Garcia et al., 2020). Same race peers play an important role in helping minoritized students navigate doctoral education and influence their socialization. Peer support often supplants perceived lack of support from advisors, particularly for students of color, so they form support groups and socialize one another, however this is not necessarily beneficial in relation to preparation for their academic careers (Garcia et al., 2020; Winkle-Wagner et al., 2010).

Prestige of Doctoral Institution

Another influential factor related to institutional culture on doctoral socialization is the rank of an institution, a department, and its faculty (Weidman et al., 2001). Reports on faculty hiring trends is missing the impact of doctoral institution reputation on academic employment outcomes (Ganning, 2022). Some research has considered school reputation and found that most new hires come from a small group of universities (Clauzet et al., 2015; Fleming et al., 2023;

Pinheiro et al., 2017; Wapman et al., 2022). This bottleneck exacerbates the competitive academic labor market for students that are not at one of the top ranked universities. Clauset et al. (2015) found 25% of institutions produce 71-86% of all tenure-track faculty depending on discipline. Wapman et al. (2022) substantiated this finding more recently and found 80% of U.S.-trained faculty were trained at 20.4% of universities and the top five most common doctorate producing institutions accounted for just over one in eight faculty that were trained in the U.S.

Doctoral institutional prestige is the most influential factor in predicting successful applications for faculty positions (Way et al., 2019; Wright & Vanderford, 2017). Most institutions hire faculty who received their doctorate from a more prestigious institution further restricting who can obtain a job in academia. Wapman et al. (2022) found that between 5% and 23% of faculty are employed at universities more prestigious than their doctoral university depending on the field. Even when looking across very different disciplines Wapman et al. (2022) found severe magnitudes of difference in doctoral placements which make it hard to imagine a system that is meritocratic. This is another way the obsession with institution prestige limits career outcomes in academia for doctoral graduates.

Prestige becomes an important indicator of career outcomes even earlier than a student's doctoral career. Few undergraduate students attending institutions outside of the top 10 move on to the highest ranked institutions for graduate education. Fleming et al. (2023) argued such a narrow definition of which colleges and universities produce students able to continue to doctoral education and then to be qualified enough for faculty positions, limits the pool of potential faculty as well as limits the diversity of future faculty. Valuing prestige of bachelor institution in graduate admissions decisions is yet another factor detrimental to doctoral applicants who identify as Black/African American or Hispanic because smaller proportions of

these earned their bachelor's degree from a top-ranked institution (Fleming et al., 2023). The hierarchical nature of faculty hiring networks making these decisions reflect extreme social inequality (Clauset et al., 2015). The literature remains unclear on what characteristics may distinguish a doctoral graduate who achieves a faculty placement from those that do not within the same institution when measures of institutional prestige have been found to play an outsized role compared to meritocratic factors.

Research has also found parent education and socioeconomic status influence the likelihood of getting a faculty job. Morgan et al. (2022) found that in the United States, faculty members were 25 times more likely to have a parent with a PhD than the general population. This shows how educational privilege and socioeconomic status plays a role in who has faculty jobs. The combination of these recent studies on prestige and socioeconomic background paints a grim picture about who is getting hired into faculty positions. This research will expand on this prior research and combine interdisciplinarity, faculty hiring behavior, and demographic characteristics into a model that can control for both the individual and institutional effects.

Gaps in Literature

Multiple facets of doctoral student socialization such as individual background, disciplinary characteristics, and institutional culture influence the career paths of doctoral students. Including each of these attributes into a model predicting the likelihood of obtaining a faculty job in academia upon graduation will provide a unique look at how various measures of socialization influence this outcome. Much of the research on socialization outcomes is theoretical in nature, qualitative, or uses small sample sizes. This study will be the first to implement multi-level modeling to study the influences of socialization on career outcomes. It

will provide a unique attempt to measure the role of interdisciplinary research experiences, which go against much of the normal socialization framework, on career outcomes.

Existing research related to the impact of completing an interdisciplinary dissertation on academic career outcomes is outdated. Additionally, institution-level factors such as prestige and demographic makeup of faculty and students have rarely been considered. This literature shows there is still a gap in understanding how interdisciplinary research influences doctoral graduates' career outcomes. Most of the available literature provides descriptive analysis of trends in interdisciplinary dissertations and does not connect this group of students to their career outcomes upon graduation. The literature that does connect interdisciplinary dissertations and career outcomes is outdated and is limited to analyzing only the influence of certain individual characteristics (Golembiewski et al., 2018; Holley, 2018; Millar, 2013; Miller & Dillman, 2012).

The literature does provide some examples of researchers using more advanced statistical models to predict the likelihood of an individual career preference of a job in academia but does not use actual outcomes or consider the role of interdisciplinary dissertations (Choe & Borrego, 2020). Ganning (2022), in one of the most recent studies on the topic, explicitly lists a limitation as not considering individual characteristics or school characteristics such as reputation on academic employment outcomes. Borrego and Newswander (2011) investigated the interdisciplinary nature of the academic job market by analyzing job postings. Using data from 2007, they found 6% of postings described interdisciplinarity in some way. The landscape of doctoral education and interdisciplinary research has changed significantly since that data was collected, so it is imperative to update our understanding of how interdisciplinarity is valued in the academic job market.

Chapter Summary

This research will build on the existing literature to create a model that uses both individual doctoral recipient characteristics and doctoral institution characteristics where they received their degree to predict the likelihood of obtaining a faculty job upon graduation. Including important individual characters such as those discussed in the literature above along with institutional characteristics will provide a unique look into how likely a doctoral student is to obtain a faculty job upon completion of their degree. This literature review showed individual characteristics such as discipline, gender, citizenship, and status as an underrepresented minority, along with institutional characteristics such as prestige and institutional culture that are influencing factors in faculty job attainment and will be considered in the study.

Chapter Three: Methodology

The purpose of this study was to examine the impact of interdisciplinary research experiences during doctoral education on career outcomes. Specifically, this study examined the likelihood of obtaining a faculty job upon degree completion for doctoral recipients who reported they completed an interdisciplinary dissertation. Additionally, this study examined the important individual and institutional components of socialization that contribute to differences in career outcomes among doctoral graduates that complete interdisciplinary dissertations. This research addressed the following questions:

1. What are the characteristics of doctoral graduates that are most likely to complete an interdisciplinary dissertation?
2. Does completing an interdisciplinary dissertation influence the likelihood of obtaining a faculty job in academia upon graduation compared to completing a single discipline dissertation?
3. What individual characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?
4. What institution characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?

In this chapter I describe the methodology that was used to achieve these purposes and answer the research questions outlined above. It includes the research design, data collection, data sources, and analytic strategies employed to answer each of the four research questions.

Research Design

As the literature has shown, both individual and institutional characteristics influence a doctoral recipient's likelihood of obtaining a faculty job upon graduation (Clauset et al., 2015;

Fleming et al., 2022; Jaeger et al., 2013; Kamimura-Jienez & Gonzalez, 2018; Layton et al., 2016; Pinheiro et al., 2017; Wapman et al., 2022). Due to the nature of the subjects in this study being nested within institutions, this analysis focused on two levels of independent variables to examine the outcome variable and how it varies among doctoral graduates. Hierarchical Linear Modeling (HLM) was used to investigate the relationship of variables across these levels. The outcome variable used in this study is obtainment of a faculty job. The individual-level independent variables included demographic indicators related to sex, citizenship, and race as well as academic indicators such as doctoral field of study and completing an interdisciplinary dissertation. The individual variables that were aggregated to create a proportion at the institution level were completing an interdisciplinary dissertation and doctoral field of study. The institution-level independent variables obtained from external data sources included a measure of institutional prestige, faculty sex and race indicators, as well as student demographics such as sex, citizenship, and race.

The Survey of Earned Doctorates (SED) data are ideal for this modeling structure because the graduates that completed the survey are nested within a single college or university. The graduates and the institutions have unique characteristics that were necessary to consider in the model. This allowed for the differentiation between individual effects and institution effects. Further, the size of this dataset made it ideal to use in this type of modeling. In the 2021 SED, after removing records with missing variables of interest and removing level 2 institutions with less than 30 cases, 196 institutions were included, and the average cluster size was around 172, which is quite large.

Data Sources

This study combined data from multiple national datasets to provide a broad look at doctoral students across the entire United States. It was important to collect data from multiple sources to obtain data about individual doctoral recipients as well as characteristics about the institutions where they were awarded their degree. Individual-level student data were collected from the 2021 Survey of Earned Doctorates, the most recent year of available data at the time of writing. Institutional-level data were collected from the National Center for Education Statistics (NCES) operated by the U.S. Department of Education and from the SpringRank produced by Wapman et al. (2022). Each of these data sources are addressed below.

Survey of Earned Doctorates

The Survey of Earned Doctorates (SED) is used to collect data from individuals receiving a research doctoral degree from U.S. academic institutions. The SED is an annual census that has been conducted since 1957 and is sponsored by the National Center for Science and Engineering Statistics (NCSES), which is a division of the National Science Foundation, along with the National Institutes of Health, Department of Education, and National Endowment for the Humanities. The SED collects data on each doctoral recipient's institution, education history, various demographic characteristics, financial support, and post-graduation plans.

An NSF Restricted-use license was obtained to gain access to the historical Survey of Earned Doctorates microdata files. These files contain more data than are publicly available and allow for access to individual-level data for doctoral recipients across all colleges and universities in the United States that participate in the survey. This file is essential to this research because the variables needed to identify a dissertation as interdisciplinary are only in this datafile. The process for license approval included working with the NCSES Licensing

Coordinator, completing an application which included a description of the research and a security plan, approval from Virginia Tech's representative from the Office of Sponsored Programs, and signed affidavits of nondisclosure from all individuals who may need to access the raw data files. This data is stored in a secure data enclave that is accessed remotely using a multi-level password and security token procedure. This license was officially executed on September 2021 and has been renewed and will now expire on June 1, 2024.

This research is based on data from the 2021 survey cycle which is for degrees completed from July 1, 2020 to June 30, 2021. The survey collected responses from 52,250 individuals across 448 institutions. One of the defining characteristics of the SED that makes it highly reliable and widely used is the high response rate. For this cycle, the response rate was 91.5%. There is no sampling error to consider because this survey is a census. Additionally, 33,170 respondents reported having definite postgraduation commitments for employment or postdoctoral study which is the target population for this research. The SED is the most comprehensive survey of doctoral graduates that asks about both interdisciplinary dissertation completion and career outcomes, so it is the ideal data source for this analysis. The SED contains a unique identifier for each institution which allows for merging with other public data sets to collect additional institutional data.

Instrumentation

The SED is authorized under the National Science Foundation Act of 1950 and the America COMPETES Reauthorization Act of 2010 (NCSES, 2022). NCSES contracts with RTI International to oversee the survey implementation and data collection (NCSES, 2022). The SED collects data using self-administered Web surveys and computer-assisted telephone interviewing (CATI), with the Web survey being the primary mode of completion at 97.6% of surveys in 2021

(NCSES, 2022). Doctoral recipients are provided the link to the survey registration website by their institutional coordinator at the time they apply for graduation (NCSES, 2022). Part of the reason for the high response rate is the coordination at the university level along with extensive follow up procedures in place by the survey administrators. Non-respondents are contacted by the survey administrators by e-mail and mail, and if the series of follow-up messages are unsuccessful, they will attempt to reach the individual to complete a shortened version of the survey using CATI (NCSES, 2022).

The survey consists of three main sections with subsections within each. Part A gathers information on the recipient's current degree and all prior education. Part A1 collects information related to the research doctoral degree the respondent just obtained. It asks respondents to report information such as the month and year when they started and completed their doctoral degree, department name, primary field of study, primary field of dissertation, whether the dissertation was interdisciplinary and the fields included, and whether they received any tuition remission (NCSES, 2021). Part A2 collects information on the respondent's educational history prior to entering the current research doctoral degree. This includes reporting all prior degrees and the institution name, location, and field, as well as the date started and completed, whether the student has received a professional doctorate or is currently enrolled in a professional doctoral program (NCSES, 2021). This section also asks students to report on any sources of financial support during all graduate-level degree programs and how debt was accrued during undergraduate and graduate education.

Part B moves away from education history and focuses on postgraduation plans. Part B1 focuses on gathering detailed information about a variety of potential postgraduation plans. This includes data on location of employment inside or outside of the United States, progress on job

search or further education plans, intention to pursue a postdoctoral training position, employment sector, employer name and geographic location, expected salary and primary and secondary work activities (NCSES, 2021). New to the 2021 survey instrument is section B2 which asks about the impact of the COVID-19 pandemic on graduate experiences and career plans. Finally, Part C collects background information on the survey respondent. Some demographic data that are collected include sex, marital status, dependents, citizenship, race, ethnicity, parental education attainment, high school geographic location, place of birth, birthday, disability statuses and functional limitations, and contact information.

Survey Quality Measures

The quality of the SED is assessed by reviewing the coverage error, nonresponse error and measurement error. Sampling error is a standard measure of data quality but does not apply in this case because the SED is a census. Coverage error is also minimized due to the availability of comprehensive lists of doctoral-granting institutions and high participation rates. Data on institutions and the number of research doctorate recipients covered by the SED are compared to the data institutions report to NCES as another way of confirming minimal coverage error (NCSES, 2022). Nonresponse error is broken down by unit nonresponse and item nonresponse. In 2021, 52,250 individuals received a research doctorate and 91.5% completed the survey while skeletal records for the remaining non-respondents were constructed from administrative records at the university (NCSES, 2022). In 2021, item nonresponse ranged from 0%-7.9% for the five key demographic variables and overall, the majority of items had a response rate over 90% with many questions receiving 99% or 100% response (NCSES, 2022). Finally, measurement error is most likely to be attributed to incomplete or vague information for degree or dissertation field of study and educational history (NCSES, 2022). This data is collected by degree code and in some

cases, respondents provide a string text that must be manually coded by the survey contractor (NCSES, 2022). However, the occurrence of this kind of re-coding is low with less than 2% of responses recoded in any of those categories (NCSES, 2022).

Integrated Postsecondary Education Data System

Under the Higher Education Act of 1965 all institutions in the United States that participate in the federal student financial aid programs are required to submit data annually to the Integrated Postsecondary Education Data System (IPEDS) (NCES, n.d.). Institutions submit data on enrollments, program completions, graduation rates, faculty and staff, finances, institutional prices, and student financial aid. This data creates a system of interrelated surveys that are publicly available to be used by prospective students and researchers. It is also used by government officials to make decisions about postsecondary education. This study used data from the publicly available Human Resources and Fall Enrollment surveys to obtain institution-level race/ethnicity and gender characteristics for faculty-members and graduate students.

The IPEDS data was used to create a variable for faculty percent-female and faculty percent-underrepresented minority (URM) for each institution. It was also used to create variables at the student-level for each institution's proportion female, URM, and international students. Multiple years of data were used to create an overview of the institutional environment during the time the doctoral students were completing the coursework and research prior to obtaining their degree. To obtain this data at the institutional level a custom table was generated using the IPEDS Data Center Statistical Tables platform. This platform allows for the selection of specific institutions for comparison, by-group comparisons, and custom variable selection (NCES, 2021b). The data includes a unit id which is the unique identification number of the

institution which was used to merge the derived institutional data to the appropriate student records in the Survey of Earned Doctorates data file.

For faculty, the population, or denominator, was full-time instructional staff with faculty status, all ranks. To calculate a percent-female for each institution the population was divided by the value in the variable HRTOTLW which is the grand total women (NCES, 2021b). The calculation for percent-URM combines multiple variables including: HRAIANT (American Indian or Alaska Native Total), HRBKAAT (Black or African American Total), HRHISPT (Hispanic or Latino total), and HRNHPIT (Native Hawaiian or Pacific Islander) (NCES, 2021b). The population used in the denominator is the same as above, except the number of nonresident aliens (HRNRALT) is subtracted because URM is a designation only for U.S. citizens. For students, the IPEDS data does not split out graduate students by doctoral and master's degree-seeking so the makeup of all graduate students was used to determine the student environment. The variable EFALEVEL was filtered to only include graduate students and this became the denominator in the calculations for each institution. The variable EFTOTLW was the grand total count of women and EFNRAAL is the grand total of nonresident alien students, also referred to as international students. To calculate the percent URM, EFAIANT (American Indian or Alaska Native Total), EFBKAAT (Black or African American Total), EFHISPT (Hispanic or Latino total), EFNHPIT (Native Hawaiian or Pacific Islander) were totaled and divided by the grand total (EFTOTLT) and subtracting EFNRAAL (nonresident alien total) from the denominator.

Institutional Prestige

There are many ways that institutional prestige can be measured including national and international rankings and faculty hiring networks. U.S. News and World Report university rankings are a common indicator of prestige because of their publicity and availability (Fleming

et al., 2023; Headworth & Freese, 2016). However, multiple researchers have defined prestige in relation to faculty hiring networks (Clauset et al., 2015; Wapman et al., 2022; Way et al., 2019; Zhang et al., 2022). Faculty hiring networks create a measure of prestige because they can determine whether an institution's graduates are hired by other universities. Faculty hiring networks make a better measure of prestige than rankings based off aggregated measures because they focus solely on faculty hiring patterns which is the topic of study here.

The SpringRank algorithm is one method for testing hierarchical networks. The SpringRank is a good fit of prestige for this analysis because it accounts for the relative ranks of the connecting nodes which formalizes the assumption that individuals tend to interact with others of a similar rank (De Bacco et al., 2018). The authors tested SpringRank against multiple other methods, including ordinal rankings, and found for faculty hiring networks the most prestigious universities are even more separated from those below them than an ordinal rank would be able to show (De Bacco et al., 2018). Wapman et al. (2022) applied the SpringRank algorithm to faculty hiring networks created by connecting tenured or tenure-track faculty at PhD-granting institutions between 2011-2020 with their doctoral university. This population produced nearly 300,000 faculty for analysis. This ranking system is more in line with the purpose of this study than USNWR because it only includes variables that align with this study's population and does not have extraneous variables that are irrelevant to the population. After applying the SpringRank algorithm to faculty hiring patterns to create hierarchies, the ranking method employed by Wapman et al. (2022) looks at graduate placed downward, graduates placed upward, faculty hired from lower ranks, and faculty hired from higher ranks.

As part of their analysis, they found the top-5 ranked doctoral training universities accounted for just over 1 in 8 domestically trained faculty (Wapman et al., 2022). Therefore, the

top-5 rank was used as a dummy indicator for prestige to account for hiring differences for those graduating from the top-5 most universities and those who did not. This data is provided by Wapman et al. (2022) in Data Table 4 and will be added to the dataset manually since it is only five institutions.

Data Cleaning

There are multiple criteria that had to be included in the population for analysis. The dataset used in this study has multiple years' worth of data included so the first delimiter was to select only the year of interest which is PHDFY = 2021. The next delimiter was the respondent must have definite career plans. The variable PDOCSTAT is postgraduation status and is derived from the response to question B2 "What best describes the status of your postgraduate plans?". To be included in the population the respondent must have chosen "Returning to, or continuing in, predoctoral employment" or "Accepted or began a postdoc or other employment". Next, the variable PDFACULTY, employment in faculty position, must not be blank because this is the dependent variable of interest in this study. This is derived from question B12 in the survey instrument "Will you be holding a faculty position?". The final delimitation made was based on the doctoral institution type. Doctoral institution Carnegie Classification, 2018 (PHDCARN) must be Doctoral Universities: Very High Research Activity or Doctoral Universities: High Research Activity. These institutions were included because they show a dedication to research and doctoral education by awarding at least 20 research/scholarship doctoral degrees per year and have at least \$5 million in total research expenditures (Indiana University Center for Postsecondary Research, (n.d.). Finally, the record could not be missing any of the student characteristics used in the model at the individual or institutional level.

Variable Selection

Variable selection for the outcome variable and the individual-level (level 1) components of this model were driven by available items from the Survey of Earned Doctorates (SED). The outcome variable used in this study was obtainment of a faculty position. On the Survey of Earned Doctorates, question B12c asks whether the respondent's employment will be at a college or university. If they choose "Yes" they are directed to question B13 which asks whether the position is a faculty position and whether it is tenure-track or not. The key independent variable in this study was whether the student completed an interdisciplinary dissertation. This is a question on the Survey of Earned Doctorates. Question A4 asks "Was your dissertation research (or performance, project report, or music or literary composition) interdisciplinary?" (NCSES, 2021). If a respondent selects "Yes" then they are shown question A5 which asks the respondent to list the fields of study for their dissertation research. This question was changed beginning with the 2017 survey cycle to not just ask students to list the fields of their dissertation, but to explicitly ask the student whether their dissertation research was interdisciplinary. Then, if they answered yes, they were directed to enter additional fields.

Operationalizing interdisciplinarity in this way is consistent with common definitions of interdisciplinary research emphasizing the combination of two or more disciplines and that it can be done by individuals or teams (Klein, 2013; NSF, n.d.-b). Additionally, this approach follows the path of other studies utilizing interdisciplinarity as a variable in their research (Barringer et al., 2020; Falkenheim, 2011; Golembiewski et al., 2018; Humanities Indicator Project, 2015; Kniffin, 2017; Millar, 2013; Millar & Dillman, 2012). As confirmed by other studies, the SED is the only accessible national census instrument that collects information on interdisciplinary dissertation experiences (Millar, 2013). Additionally, in reviewing the literature I did not find

any study measuring interdisciplinary dissertations that used a data source other than the Survey of Earned Doctorates. One limitation to using this variable as a measure of interdisciplinary experience is that it is self-reported data and therefore an indirect measure of interdisciplinarity that does not account for the degree to which it used various interdisciplinary research approaches reviewed previously in the literature. The range of fields involved in dissertation research provides the context for their socialization experience and the norms in their field, department, and institution. Additionally, this strategy likely undercounts interdisciplinary experiences because some doctoral students receive their degree in a field that is inherently interdisciplinary (Barringer et al., 2020).

I created all the Level-1 variables from one or more survey questions on the SED. The dependent variable was created through a combination of survey questions which ask if the student will be employed at a college or university and if that position is in a tenure-track faculty position or non-tenure-track faculty position. Either of those responses indicate a faculty position in this analysis. The additional level-1 variables in the model are coded as dummy variables meaning they are assigned a value of 1 or 0 based on whether the condition is met. For example, the variable FEMALE is coded as 1 if the student responds Female to question C1. The other variables are coded in a similar manner. Table 1 summarizes these variables, coding, and identifies the survey questions used (See Appendix A) and the logic applied to each to create the binary codes. The level- 2 model includes institutional means for some variables that were included in level-1. Additional faculty and student demographic variables were added from external sources. This allows for consideration of the institutional environment in which the individual was situated. Table 2 summarizes the level-2 variables including the variable name, codes, description of coding logic, and data source.

Table 1*Description of Student-Level Variables*

Variable	Description	Dummy Variable Logic
Outcome variable		
Fac_YN	0 = no faculty job 1 = obtained faculty job	Employment at college or university (B12c) = Yes and B13 = Yes, tenure-track faculty position (1) or Yes, a non-tenure-track faculty position (2).
Level-1		
FEMALE	0 = Male 1 = Female	Sex of doctorate recipient (C1) = Female (2)
INTD	0 = Single discipline dissertation 1 = Interdisciplinary dissertation	Interdisciplinary dissertation research (A4) = Yes.
INTL	0 = Domestic student 1 = International student	Type of Citizenship (C7): Non-U.S. Immigrant (temporary resident) (3) or non-U.S., VISA status unknown (4)
URM	0 = Non-URM 1 = URM	Race (C10 & C11): any graduate who self-identifies as American Indian or Alaskan Native, Native Hawaiian or other Pacific Islander, Black or African American, Hispanic of any race, or any combination of races other than White and Asian.
BF1	0 = No 1 = Yes	Doctoral field (A3): Life Sciences
BF2	0 = No 1 = Yes	Doctoral field (A3): Physical Sciences & Earth Science
BF3	0 = No 1 = Yes	Doctoral field (A3): Math and Computer Science
BF4	0 = No 1 = Yes	Doctoral field (A3): Psychology and Social Sciences
BF5	0 = No 1 = Yes	Doctoral field (A3): Engineering
BF6	0 = No 1 = Yes	Doctoral field (A3): Education
BF7	0 = No 1 = Yes	Doctoral field (A3): Humanities and Arts
BF8	0 = No 1 = Yes	Doctoral field (A3): Other Non-Science & Engineering

Table 2*Description of Institution-Level Variables*

Variable	Description	Dummy Variable Logic (1)	Data Source
MEAN_INTD	1=INTD 0=Non-INTD	Proportion of the institution's student population completing an interdisciplinary dissertation.	Survey of Earned Doctorates (2021)
BF1_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Life Sciences fields.	Survey of Earned Doctorates (2021)
BF2_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Physical & Earth Science field.	Survey of Earned Doctorates (2021)
BF3_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Math and Computer Science fields.	Survey of Earned Doctorates (2021)
BF4_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Psychology and Social Sciences fields.	Survey of Earned Doctorates (2021)
BF5_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Engineering fields.	Survey of Earned Doctorates (2021)
BF6_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Education fields.	Survey of Earned Doctorates (2021)
BF7_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in Humanities and Arts fields.	Survey of Earned Doctorates (2021)
BF8_MEAN	1=Yes 0=No	Proportion of the institution's student population completing a Doctorate in other non-Science & Engineering fields.	Survey of Earned Doctorates (2021)
Top_5	1=Yes 0=No	Yes, if ranked 1-5 in SpringRank analysis	Wapman et al. (2022)
FEM_F	1=Female 0=Male	Proportion of the institution's faculty population identifying as a female.	IPEDS Human Resources Survey (2017-2021)

URM_F	1=URM 0=Non-URM	Proportion of the institution's U.S. faculty population identifying as an underrepresented minority.	IPEDS Human Resources Survey (2017-2021)
FEM_S	1=Female 0=Male	Proportion of the institution's student population identifying as a female.	IPEDS Fall Enrollment Survey (2017-2021)
URM_S	1=URM 0=Non-URM	Proportion of the institution's U.S. student population identifying as an underrepresented minority.	IPEDS Fall Enrollment Survey (2017-2021)
INTL_S	1=INTL 0=Non-INTL	Proportion of the institution's student population identifying as a non-U.S. Citizen.	IPEDS Fall Enrollment Survey (2017-2021)

Hierarchical Linear Modeling

The main analytic strategy employed in this study was Hierarchical Linear Modeling (HLM) as most applications of HLM involve data with a hierarchical structure such as people nested within organizations (Raudenbush & Bryk, 2002). HLM is also known as multilevel regression as it considers individual subject characteristics which are known as level-1 variables (N) and group level characteristics which are known as level-2 variables (J). In HLM, each of the levels is represented by its own sub-model which expresses relationships among variables within a given level and specifies how variables influence relationships at a different level (Raudenbush & Bryk, 2002). In other words, the predictor variables in the level-1 model become the outcome variables in the level-2 models. It was important for researchers to expand beyond single level linear modeling to multilevel modeling because nested data violates two of the main assumptions of linear regression: independence of errors and homoscedasticity (Raudenbush & Bryk, 2002).

HLM models carry their own assumptions around the error structure and predictor variables. There are three assumptions related to the error. The first is independent and normally distributed level-1 residuals, with a mean of 0 and common variance σ^2 , the second is

independent random effects at higher levels, multivariate normally distributed with a mean of 0 and common variance of τ^2 , and the third is residuals between levels are independent (Anderson, 2012). There are also three assumptions related to the predictor variables. The first is level-1 predictors are independent of level-1 residuals, the second is higher level predictors are independent of residuals at the same level, and finally predictors at each level are independent of the random effects at other levels (Anderson, 2012).

In this study HLM was used to model the effects of individual and institutional characteristics on the likelihood of obtaining a faculty position at the time of graduation. Doctoral recipients (N) are nested into larger groups based on their institution (J) and therefore fit well with this model. More specifically, Hierarchical Generalized Linear Model (HGLM) was used for this analysis as it is better suited for models with a binary categorical outcome variable such as faculty job attainment. HGLM with a binary outcome variable violates the assumptions of linearity and normality mentioned above for HLM (Raudenbush & Bryk, 2002). HGLM includes a transformation of the dependent variables and appropriate error distribution to mitigate these violations (Luke, 2004). This transformation is necessary to be able to interpret the estimates created in the HGLM model as the probability of an event occurring. The HGLM framework consists of a sampling model, link function, and structural model. The sampling model for HGLM is a Bernoulli distribution is given by:

$$E(Y_{ij} \mid \mu_{ij}) = \mu_{ij}, \text{Var}(Y_{ij} \mid \mu_{ij}) = \mu_{ij}(1 - \mu_{ij}) \quad (1)$$

Where the level-1 outcome Y_{ij} , given the expected value μ_{ij} , is distributed with a mean of μ_{ij} and variance of $\mu_{ij}(1 - \mu_{ij})$. The binary outcome Y_{ij} is the probability of success given as $\Pr(Y=1) = \pi_{ij}$ (or p_{ij}). The level-1 link function performs a transformation of the expected outcomes and is defined as the logic link:

$$\eta_{ij} = \log_e\left(\frac{\mu_{ij}}{1-\mu_{ij}}\right) \quad (2)$$

Where η_{ij} is the log odds for person i in group j and $\frac{\mu_{ij}}{1-\mu_{ij}}$ is the odds of success for person i in group j . The structural model is the same as the normal case of HLM where:

$$\eta_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \dots + \beta_{pj}X_{pij} \quad (3)$$

Finally, there is no level-1 error component in HGLM. When the outcome variable is binary the variance is determined by the mean and therefore not a separate term (Luke, 2004).

Analytic Strategy

Descriptive statistics were produced to provide important context to this study on the characteristics of doctoral recipients who obtain a faculty job upon graduation and the characteristics of those students who complete an interdisciplinary dissertation. A chi-square test of independence was conducted on multiple variables to determine any significant relationships between key variables included in the model. A logistic regression was conducted to address the first research question providing valuable information about the characteristics of doctoral students that were most likely to have completed an interdisciplinary dissertation. Next, Hierarchical Generalized Linear Modeling (HGLM) was used to address the second research question to investigate the individual-level and institutional-level characteristics that influence the likelihood of a doctoral recipient obtaining a faculty position upon graduation. Finally, to answer research questions 3 and 4 the population was subset to only those individuals who completed an interdisciplinary dissertation and the models were formed again to investigate the individual-level and institutional-level characteristics that influence the likelihood of this population obtaining a faculty position upon graduation.

Research Question 1

Research Question 1 (RQ1) investigates the characteristics of doctoral students that were most likely to have completed an interdisciplinary dissertation. Logistic regression was used to answer this question because it allows for a dichotomous outcome variable. This goes beyond the chi-square tests of independence discussed earlier to consider the effects of the key independent variables together in one model. A logistic regression model begins with a linear combination comprised of predictor variables and their corresponding coefficients where the conditional probability of the outcome being present is denoted by $\Pr(Y=1 \mid x) = \pi$. This model is expressed by the equation:

$$g(\pi) = \text{Ln}\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1x_1 + \beta_2x_2 + \dots + \beta_px_p \quad (4)$$

Where π is the probability of success which is defined in this model as completing an interdisciplinary dissertation. An important component when conducting analysis of binary variables is the link function. The logit link function, represented as $g(\pi)$, is used for binomial outcome variables and allows for the interpretation of differences on the logistic scale. When the linear combination is passed through the link function there is a transformation that occurs which is shown in Equation 5. This allows for the interpretation of the results into a predicted probability where:

$$\pi(x) = \frac{e^{g(x)}}{1+e^{g(x)}} \quad (5)$$

One final transformation will allow for the interpretation of each coefficient as an odds ratio where:

$$\text{OR} = e^{\beta x} \quad (6)$$

This analysis was conducted using the LOGISTIC procedure in SAS. The SAS output automatically compares the model with predictor variables to a null model so a separate null

model was not created. Two logistic regression models were conducted to allow for the comparison of models to determine the best fit. First, a logistic regression was conducted on completion of interdisciplinary dissertation regressed on dummy variables for identifying as female, international student, and URM. Students identifying as male and a non-URM U.S. citizen are the reference group in this model. The second logistic regression model added dummy variables for each of the broad fields of study with Engineering serving as the reference group. The results of each model will be compared using the AIC statistic where a smaller value is better model fit. Each model will be compared against a null model, whose results are produced in the SAS output, as well as against each other to determine the best model fit.

Research Question 2

Research Question 2 (RQ2) looks at the influence of completing an interdisciplinary dissertation on obtaining a faculty job in academia. Hierarchical Linear Model was used to control for variance within a school and between schools. To begin to answer this question a model building process took place. Model building is an essential component of HLM to allow for the incremental addition of predictor variables to the model and to compare the overall model fit throughout each. This allows the researcher to make decisions about which variables to include in the final model. Model fit is measured by the deviance statistic which is the -2 log likelihood ratio and used as an incremental fit indicator to compare deviance between models (Anderson, 2012). The deviance measure represents a lack of fit and a higher value indicates a poorer fit. This value was computed with the HLM software for each model and compared to the previous model. An additional measure accounting for the amount of level-2 variance explained through the addition of variables in subsequent models was used to compare model fit. The intraclass correlation coefficient (ICC) is a standard measurement in HLM that captures the

degree to which variance at level-1 depends on group membership in level-2, but there is no level-1 variance in a binomial model (Luke, 2022). Similarly, Pseudo R^2 is also an inappropriate measure of model fit for a model with a dichotomous outcome variable.

Model Building

HGLM was used to model the probability of doctoral graduates obtaining a faculty job in academia at the time of graduation. In the following models Y_{ij} is the success ($Y_{ij}=1$) of obtaining a faculty job, μ_{ij} is the probability of success for doctoral recipient i in institution j , and η_{ij} is the log-odds that a doctoral recipient i in university j will obtain a faculty appointment at graduation. Transformation of η_{ij} must occur to make the results of the model more meaningful. Equation 7 was used to interpret the estimates in chapter 4:

$$\mu = \frac{1}{1+e^{-\eta}} \quad (7)$$

Model building is an essential part of any regression analysis to determine which variables explain more variance in the model. The model building process begins with the unconditional model which contains no predictors, then multiple iterations of a conditional model will be tested before settling on the final model for analysis. The strategy will focus on adding the key variables in stages to isolate the variance explained by completing an interdisciplinary dissertation.

Unconditional Model

The first step was to develop an unconditional model with no predictor variables. This established the baseline variance and how it is distributed within schools and between schools, as well as the deviance which will be used for comparison against other models. In the unconditional model shown in Equation 4, the intercept β_{0j} estimates:

Student-level (Level-1) model

$$\eta_{ij} = \beta_{0j} \quad (8)$$

where

η_{ij} is the log-odds that a doctoral recipient i in university j will obtain a faculty appointment at graduation.

β_{0j} is the overall grand mean or proportion of all doctoral recipients that will obtain a faculty job in academia upon graduation.

School-level (Level-2) model

In the level-2 model the overall grand mean becomes the outcome variable varying randomly around school-level means. This is shown in Equation 9:

$$\beta_{0j} = \gamma_{00} + u_{0j}, \quad u_{0j} \sim N(0, \tau_{00}) \quad (9)$$

where

β_{0j} is the mean proportion of individuals in school j obtaining a faculty job.

γ_{00} is the overall intercept for the model.

u_{0j} is the random effect related to the institution the student attended and is normally distributed with a mean of 0 and variance τ_{00} .

Conditional Model Building

After determining the unconditional model, the next step was to incrementally add predictor variables. Before adding predictors to the model, an important issue in multilevel models must be addressed which is the centering of predictor variables. Centering is important because it makes the interpretation of the intercept easier to understand. At level-1, the independent variables are centered around the institutional mean for that variable which allows the intercept to be interpreted as the unadjusted mean for that institution and all coefficients are then interpreted in relation to the institution mean (Raudenbush & Bryk, 2002). To create a

group mean centered Level-1 predictor a proportion is created for every institution (j) and is subtracted from the dummy indicator (0 or 1) to create a level-1 variable that relates directly to the average for the institution. This separates within institution effects. This is considered an appropriate approach even when using dummy variables (Raudenbush & Bryk, 2002). At level-2, the adjustment was made through grand-mean centering. The Level-2 aggregated means were adjusted in relation to the overall population means. Similar to the way individual predictors were interpreted in relation to the institution, the institution predictors are now interpreted in relation to the overall population mean. This separates out the between institution effects. Additionally, to make the continuous Level-2 predictors easier to interpret the resulting coefficients will be multiplied by 0.1 to transform the meaning of a one-unit change from comparing an institution with 0% to one with 100% of the variable proportion to a 10% change.

Research Questions 3 and 4

Research question 3 and 4 were addressed in a similar manner by considering only those individuals who completed an interdisciplinary dissertation. Some institutions that were included in the analysis for RQ2 may not be included in the analysis for RQ3 and RQ4 because they still must meet the threshold of having at least 30 students. An unconditional model will be defined, and then conditional models will be established and compared through the incremental addition of predictor variables. This will explain certain factors that impact whether students completing an interdisciplinary dissertation obtain a faculty job upon graduation. This will also allow for a comparison of significant predictors between the entire population of doctoral recipients and those who completed an interdisciplinary dissertation.

Chapter Summary

In summary, the purpose of this analysis was to examine the impact of interdisciplinary research experiences during doctoral education on career outcomes. It was done using HGLM to predict the likelihood of a doctoral student completing an interdisciplinary dissertation obtaining a faculty job upon degree completion. This model examined the important individual and institutional components of socialization that contribute to differences in career outcomes among doctoral graduates. The results and implications of this analysis will be discussed further in chapters 4 and 5.

Chapter Four: Findings of Study

The purpose of this study was to examine the impact of interdisciplinary research experiences during doctoral education on career outcomes. Specifically, this study examined the likelihood of obtaining a faculty job upon degree completion for doctoral recipients who reported completing an interdisciplinary dissertation. Additionally, this study examined the important individual and institutional characteristics that contribute to differences in career outcomes among doctoral graduates. The Survey of Earned Doctorates was used because it is one of the only data collection mechanisms that asks doctoral students about interdisciplinary experiences. This survey operationalizes interdisciplinary research experiences through a question asking whether the student conducted an interdisciplinary dissertation.

This study examined the following research questions:

1. What are the characteristics of doctoral graduates that are most likely to complete an interdisciplinary dissertation?
2. Does completing an interdisciplinary dissertation influence the likelihood of obtaining a faculty job in academia upon graduation compared to completing a single discipline dissertation?
3. What individual characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?
4. What institution characteristics increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia?

In this chapter I report the results from this study. First, I will describe the population of survey respondents. Next, I present descriptive statistics related to the variables of interest in the survey and any significant relationships between these variables. Then, I report the results of the

various statistical analyses that were conducted, along with a summary of findings for each research question.

Description of Survey Respondents

The 2021 Survey of Earned Doctorates had 52,250 respondents. After cleaning the data for the population of interest based on the steps outlined in Chapter Three, 28,928 survey participants across 186 institutions of higher education were used to complete data analysis. Through the cleaning process 4,159 responses were removed due to the Carnegie classification of their institution, another 17,287 responses were removed because the respondent did not yet have definite career plans, another 400 were removed for indicating a post-graduation job in higher education and did not provide a response to the question about whether their job was as a faculty member, 293 were removed for missing a key demographic characteristic in the model, and 1,183 records were removed because their institution did not meet the thirty respondent threshold for inclusion in hierarchical models.

Table 3 describes the characteristics of this population. Respondents in the population identified as male (55.6%) or female (44.4%). There were no other options available to determine sex or gender identity in the instrument. The population included 52.3% U.S. citizens who are not from an underrepresented minority (URM) race, 10.4% U.S. citizens from an underrepresented minority (URM) race, and 37.3% international students. Additionally, the most prevalent doctoral fields of study were Life Sciences (21.8%) or Engineering (20.6%). Regarding the variables of interest, just under half of respondents completed an interdisciplinary dissertation (45.7%) and 17.4% of respondents reported being hired into a faculty position upon graduation.

Table 3
Description of Participants in Sample

Characteristic	<i>n</i>	%
Sex		
Female	12,856	44.4
Male	16,072	55.6
Race/Citizenship		
U.S. Citizen, Non-URM	15,135	52.3
U.S. Citizen, URM	2,995	10.4
International	10,798	37.3
PhD Broad Field of Study		
Life Sciences	6,298	21.8
Physical Sciences and Earth Sciences	3,590	12.4
Mathematics and Computer Sciences	2,820	9.8
Psychology and Social Sciences	4,778	16.6
Engineering	5,944	20.6
Education	2,122	7.3
Humanities and Arts	1,850	6.4
Other Non-Science & Engineering	1,526	5.3
Dissertation Type		
Single-Discipline	15,715	54.3
Interdisciplinary	13,213	45.7
Position Upon Graduation		
Faculty Job	5,020	17.4
Not-Faculty Job	23,908	82.6

Descriptive Statistics

Descriptive statistics for all student-level (Level-1) and institution-level (Level-2) variables are shown in Table 4. All variables included at Level-1 are dummy variables meaning they hold a value of either 0 if they do not meet the criteria and a 1 if they do meet the criteria. The Level-2 statistics represent institutional-level statistics. Some of these variables are created by aggregating student-level data which represent a compositional effect in hierarchical modeling. The other Level-2 variables were brought in from external data sources as described in Chapter Three.

Table 4
Descriptive Statistics

Variable	<i>n</i>	Mean	Minimum	Maximum	Std. Dev
<i>Level-1</i>					
Faculty Job (FAC_YN)	28,928	0.174	0	1	0.379
Interdisciplinary Dissertation (INTD)	28,928	0.457	0	1	0.498
International Student (INTL)	28,928	0.373	0	1	0.484
Underrepresented Minority (URM)	28,928	0.104	0	1	0.305
Female (FEMALE)	28,928	0.444	0	1	0.497
Life Sciences (BF1)	28,928	0.218	0	1	0.413
Physical Sciences and Earth Sciences (BF2)	28,928	0.124	0	1	0.330
Mathematics and Computer Sciences (BF3)	28,928	0.098	0	1	0.297
Psychology and Social Sciences (BF4)	28,928	0.166	0	1	0.371
Engineering (BF5)	28,928	0.206	0	1	0.404
Education (BF6)	28,928	0.073	0	1	0.261
Humanities and Arts (BF7)	28,928	0.064	0	1	0.245
Other Non-Science & Engineering (BF8)	28,928	0.053	0	1	0.224
<i>Level-2</i>					
% Interdisciplinary (INTDMEAN)	186	0.444	0.231	0.686	0.082
% International Students (INTL_S)	186	0.210	0.043	0.603	0.114
% URM Students (URM_S)	186	0.191	0.051	0.838	0.113
% Female Students (FEM_S)	186	0.539	0.228	0.790	0.088
Prestige (Top_5)	186	0.027	0	1	0.162
% Female Faculty (FEM_F)	186	0.419	0.211	0.644	0.061
% URM Faculty (URM_F)	186	0.098	0.017	0.644	0.059
% Life Sciences (BF1_MEAN)	186	0.214	0	0.738	0.123
% Physical Sciences and Earth Sciences (BF2_MEAN)	186	0.115	0	0.374	0.061
% Mathematics and Computer Sciences (BF3_MEAN)	186	0.090	0	0.395	0.065
% Psychology and Social Sciences (BF4_MEAN)	186	0.181	0	0.900	0.101
% Engineering (BF5_MEAN)	186	0.186	0	0.819	0.136
% Education (BF6_MEAN)	186	0.098	0	0.714	0.100
% Humanities and Arts (BF7_MEAN)	186	0.061	0	0.364	0.056
% Other Non-Science & Engineering (BF8_MEAN)	186	0.055	0	0.435	0.049

Chi-Square Test of Independence

A chi-square test of independence was conducted to look for relationships between the dependent variable, faculty job, and multiple doctoral student characteristics. This analysis tests the null hypothesis that there is no relationship between two categorical variables. These cross-tabulations and chi-square results are shown in Table 5 which depicts the number and proportion of students in each variable level that reported having obtained a faculty job upon graduation. For example, 19.9% of female students obtained a faculty job. The most important question I was interested in exploring was whether there was a relationship between completing an interdisciplinary dissertation and obtaining a faculty job upon graduation. This analysis found no significant difference in faculty job obtainment for students who completed an interdisciplinary dissertation compared to those who did not. However, other student characteristics were found to have a statistically significant relationship with obtaining a faculty job. The relationship between obtaining a faculty position and sex was statistically significant, $\chi^2(1, n = 28,928) = 105.7, p < .001, \Phi = .06$. Female students are more likely than male students to report having a faculty position upon graduation. The relationship between obtaining a faculty position and race/citizenship was also found to be statistically significant, $\chi^2(1, n = 28,928) = 23.12, p < .001, \Phi = .03$. Students who identified as a URM were more likely to obtain a faculty position than non-URM students or international students. Finally, broad field of study was found to have a significant relationship with faculty career outcomes, $\chi^2(1, n = 28,928) = 4340.26, p < .001, \Phi = .39$. Students completing their doctoral studies in Humanities and Arts fields, or Other Non-Science and Engineering (Other Non-S&E) fields were mostly likely to obtain a faculty job. Sex and race/citizenship had small effect sizes as they were both under 0.1 and broad field of study had a larger effect size of 0.39 which is considered a medium effect size.

Table 5*Number and Proportion of PhD Graduates Obtaining a Faculty Position by Student**Characteristics.*

Variable	<i>n</i>	%
Sex***		
Female	2,560	19.9%
Male	2,460	15.3%
Race/Citizenship***		
U.S. Citizen, Non-URM	2,594	17.1%
U.S. Citizen, URM	613	20.5%
International	1,813	16.8%
PhD Broad Field of Study***		
Life Sciences	591	9.4%
Physical Sciences and Earth Sciences	130	3.6%
Mathematics and Computer Sciences	471	16.7%
Psychology and Social Sciences	1,118	23.4%
Engineering	397	6.7%
Education	607	28.6%
Humanities and Arts	774	41.8%
Other Non-Science & Engineering	932	61.0%
Dissertation Type		
Single-Discipline	2,780	17.7%
Interdisciplinary	2,240	17.0%

* $p < .05$. ** $p < 0.01$. *** $p < .001$

A chi-square test of independence was also conducted to look for relationships between the key independent variable of completing an interdisciplinary dissertation and other independent variables related to student characteristics. These cross-tabulations and chi-square results are shown in Table 6 which depicts the number and proportion of students in each variable level that reported completing an interdisciplinary dissertation. The chi-square analyses found a significant relationship between completing an interdisciplinary dissertation and the key student characteristics. The relationship between completing an interdisciplinary dissertation and sex was statistically significant, $\chi^2(1, n = 28,928) = 11.69, p < 0.001, \Phi = .02$.

Table 6*Number and Proportion of PhD Graduates Completing an Interdisciplinary Dissertation**Obtaining a Faculty Position by Student Characteristics.*

Variable	<i>n</i>	%
Sex***		
Female	6,016	46.8%
Male	7,197	44.8%
Race/Citizenship***		
U.S. Citizen, Non-URM	6,882	45.5%
U.S. Citizen, URM	1,529	51.0%
International	4,802	44.5%
PhD Broad Field of Study***		
Life Sciences	3,178	50.5%
Physical Sciences and Earth Sciences	1,475	41.1%
Mathematics and Computer Sciences	963	34.2%
Psychology and Social Sciences	1,958	41.0%
Engineering	3,001	50.5%
Education	792	37.3%
Humanities and Arts	1,117	60.4%
Other Non-Science & Engineering	729	47.8%
Faculty Job		
Yes	2,240	44.6%
No	10,973	45.9%

Note. This table only shows the count and proportion of students who did complete an interdisciplinary dissertation.

* $p < .05$. ** $p < 0.01$. *** $p < .001$

The relationship between completing an interdisciplinary dissertation and race/citizenship was also found to be statistically significant, $\chi^2(1, n = 28,928) = 41.46, p < 0.001, \Phi = .04$.

Students who identified as a URM were more likely to complete an interdisciplinary dissertation than non-URM students or international students. Finally, broad field of study was found to have a significant relationship with completing an interdisciplinary dissertation, $\chi^2(1, n = 28,928) = 561.06, p < 0.001, \Phi = .14$. Students completing their doctoral studies in Humanities and Arts fields were most likely to complete an interdisciplinary dissertation, while students in

Engineering and Life Sciences fields were evenly split between interdisciplinary and single-disciplinary dissertations. The effect size of each variable is low with sex and race/citizenship both under 0.1 and broad field of study was slightly over the low threshold with an effect size of 0.14.

Finally, I was interested in seeing which students were most likely to complete an interdisciplinary dissertation and obtain a faculty job upon graduation as context going forward. These results are shown in Table 7. Female students were more likely than male students to complete an interdisciplinary dissertation and obtain a faculty job. Students identifying as an URM were more likely than Non-URM and international students to complete an interdisciplinary dissertation and obtain a faculty job. Finally, students studying in humanities and arts fields, or other non-science and engineering fields were most likely to complete an interdisciplinary dissertation and obtain a faculty job. These trends are in line with the analysis of these two variables separately.

The purpose of this analysis was to test the null hypothesis that there is no relationship between the dependent variable, the key independent variable, and other variables of interest based on socialization literature. This initial analysis provided key information on which variables to include in more advanced analyses. Even though the key independent variable was not a statistically significant variable in relation to the dependent variable, further analysis will be useful to determine whether there is any variation between schools. This analysis also confirmed variables related to sex, race/citizenship, and broad field of study should be included in additional analysis.

Table 7

Number and Proportion of Doctoral Students Completing an Interdisciplinary Dissertation and Obtaining a Faculty Position.

Variable	<i>n</i>	%
Sex		
Female	1,119	9.3%
Male	1,046	6.5%
Race/Citizenship		
U.S. Citizen, Non-URM	1,197	7.9%
U.S. Citizen, URM	335	11.2%
International	708	6.6%
PhD Broad Field of Study		
Life Sciences	295	4.7%
Physical Sciences and Earth Sciences	49	1.4%
Mathematics and Computer Sciences	150	5.3%
Psychology and Social Sciences	443	9.3%
Engineering	193	3.2%
Education	244	11.5%
Humanities and Arts	468	25.3%
Other Non-Science & Engineering	398	26.1%

Note. This table only shows the count and proportion of students who did complete an interdisciplinary dissertation.

Results of Data Analysis

The data from the Survey of Earned Doctorates were analyzed to respond to each of the research questions posed in this study. The first research question examined which doctoral students are most likely to complete an interdisciplinary dissertation. The second examined whether completing an interdisciplinary dissertation influenced the likelihood of obtaining a faculty job in academia upon graduation considering within school (student-level variables) and between school (institution-level variables) effects. The third and fourth research questions look at doctoral graduates who completed an interdisciplinary dissertation to determine which student-level and institutional-level variables may influence obtaining a faculty job upon graduation and how these effects may differ from the full population.

Research Question 1

A logistic regression analysis was conducted to determine how various student characteristics influenced the odds or likelihood of completing an interdisciplinary dissertation. This analysis was completed in SAS using the PROC LOGISTIC procedure. Dummy variables were created for each of the student characteristics. Race and citizenship are considered one category because only U.S. citizens and permanent residents can be classified as URM or non-URM. In this model the reference group is Non-URM U.S. Citizens. Engineering, or Broad Field 5, was chosen as the reference group for the broad fields of study. Two models were run to determine the set of variables that best fit. Each model was also compared to a null model. The first model only included student demographic characteristics around sex and race/citizenship and is shown in Equation 10.

$$\Pr(\text{INTD}=1/\pi) = \text{Ln}\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1\text{FEMALE} + \beta_2\text{INLT} + \beta_3\text{URM} \quad (10)$$

The second model included dummy variables for the student's doctoral field of study and is shown in Equation 11.

$$\Pr(\text{INTD}=1/\pi) = \text{Ln}\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1\text{FEMALE} + \beta_2\text{INLT} + \beta_3\text{URM} + \beta_4\text{BF1} + \beta_5\text{BF2} + \beta_6\text{BF3} + \beta_7\text{BF4} + \beta_8\text{BF6} + \beta_9\text{BF7} + \beta_{10}\text{BF8} \quad (11)$$

The results of these two models are shown in Table 8. In Model 1, sex and URM were found to be statistically significant variables, while identifying as a non-U.S. Citizen was not statistically significant. Being female increased the likelihood of completing an interdisciplinary dissertation by 1.07 in odds while identifying as URM increased the odds by 1.24. Two tests of model fit were considered. The first test conducted in the PROC LOGISTIC procedure is to determine if the slope parameters in the model are statistically different from zero.

Table 8*Results of Logistic Regression: Completing an Interdisciplinary Dissertation and Student**Characteristics.*

Variable	Model 1		Model 2	
	Coefficient (SE)	Odds Ratio	Coefficient (SE)	Odds Ratio
Intercept	-0.214*** (0.02)		0.001 (0.03)	
Sex				
Female	0.065** (0.02)	1.067	0.086*** (.03)	1.089
Male ^a				
Race/Citizenship				
U.S. Citizen, Non-URM ^a				
U.S. Citizen, URM	-0.219*** (0.04)	1.244	0.255*** (0.04)	1.290
International	-0.030 (0.03)	0.970	-0.028 (0.03)	0.973
PhD Broad Field of Study				
Life Sciences (BF1)			-0.049 (0.04)	0.953
Physical Sciences and Earth Sciences (BF2)			-0.399 *** (0.04)	0.671
Mathematics and Computer Sciences (BF3)			-0.674*** (0.05)	0.510
Psychology and Social Sciences (BF4)			-0.446*** (0.04)	0.640
Engineering (BF5) ^a				
Education (BF6)			-0.639*** (0.05)	0.528
Humanities and Arts (BF7)			0.347*** (0.06)	1.415
Other Non-Science & Engineering (BF8)			-0.146** (0.06)	0.864

^a Reference group.* $p < .05$. ** $p < 0.01$. *** $p < .001$

This was done using a Likelihood-Ratio Chi-Square test of the null hypothesis that all slope parameters $\beta = 0$. The results of this test ($\chi^2=48.4837, p < .001$) allows me to reject the null-hypothesis. The second measure of model fit compares this model with predictor variables to a null model with no predictors. This comparison is done through the AIC criterion. The

model with predictor variables produced a lower AIC value than the null model and therefore is a better fit. In Model 2, sex and race remained statistically significant with minimal change in the odds ratios, and all the broad fields of study were found to be statistically significant except Life Sciences (BF1). Most doctoral fields of study decreased the likelihood of completing an interdisciplinary dissertation when compared to the reference group Engineering (BF5). Completing a PhD in Physical Sciences and Earth Sciences (BF2) decreases the odds of completing an interdisciplinary dissertation by a factor of 0.671, Mathematics and Computer Science (BF3) by 0.51, Psychology and Social Sciences (BF4) by 0.64, Education (BF6) by 0.528, and Other Non-S&E fields (BF8) by 0.864. Completing a PhD in Humanities and Arts (BF7) was the sole field that increased the likelihood of completing an interdisciplinary dissertation and did so by a factor of 1.415. While these variables are statistically significant, they are not considered to be particularly large effect sizes.

The results of the Likelihood-Ratio Chi-Square test for Model 2 ($\chi^2=624.55$, $p<.001$) allows me to reject the null hypothesis that all slopes $\beta = 0$. It also has a lower AIC value than the null model. Additionally, now that there are two models with predictors I compared their model fit. Model 1 had an AIC value of 39845.57 and Model 2 had an AIC value of 39283.51. Model 2 produced the lower AIC value indicating a better model fit.

Research Question 2

Research Question 2 (RQ2) seeks to answer whether completing an interdisciplinary dissertation influences the likelihood of a doctoral graduate obtaining a faculty job in academia upon graduation compared to a student completing a single discipline dissertation. To do this, hierarchical linear modeling was used to consider both student-level and institution-level factors that may affect this outcome. A model building process was conducted to determine the model

that best accounted for the unexplained variance in an unconditional model. First, an unconditional model was run to establish a baseline error variance for the Level-2 intercept τ_{00} and a baseline value for the model fit value $-2LL$. In Model 2, the key variable of interest, completing an interdisciplinary dissertation, was added at Level-1 and Level-2 of the model. In Model 3, student demographic variables were added to the Level-1 model, and in Model 4 doctoral field of study dummy variables were added to the Level-1 model. Finally, in Model 5 all remaining Level-2 variables were added. These variables were added in blocks to see how each group affected the overall model and the amount of Level-2 error variance explained by the model. The Level-1 variables were group mean centered, or centered around the institution mean, and Level-2 variables were grand mean centered, or centered around the mean for the whole survey population. Centering variables at both Level-1 and Level-2 allows for the interpretation of β_{0j} as the overall mean. The results of the model building process can be seen as coefficients in Table 9 and as odds ratios in Table 10.

Unconditional Model

The unconditional model is an important step in the model building process because it establishes the baseline statistics for the error variance of the Level-2 intercept τ_{00} and a baseline value for the model fit value $-2LL$. In the unconditional model, the value of β_{0j} is translated as the overall grand mean value or proportion of doctoral graduates obtaining a faculty job upon graduation.

The unconditional model is shown as:

$$\begin{aligned} \eta_{ij} &= \beta_{0j} \\ \beta_{0j} &= \gamma_{00} + u_{0j}, \quad u_{0j} \sim N(0, \tau_{00}) \end{aligned} \tag{12}$$

Where γ_{00} is the average log-odds of obtaining a faculty job across institutions and τ_{00} is the variance between schools.

Table 9*Estimates for Hierarchical Generalized Linear Models of Faculty Job Attainment*

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed Effects					
Intercept γ_{00}	-1.54*	-1.53*	-1.54*	-1.79*	-1.78*
Level-1					
INTD ^a γ_{10}		-0.01	-0.02	-0.05	-0.05
FEMALE ^a γ_{20}			0.26*	0.06	0.06
URM ^a γ_{30}			0.12*	-0.02	-0.02
INTL ^a γ_{40}			0.03	0.22*	0.23*
BF1 ^a γ_{50}				0.40*	0.41*
BF2 ^a γ_{60}				-0.54*	-0.57*
BF3 ^a γ_{70}				1.01*	1.03*
BF4 ^a γ_{80}				1.51*	1.52*
BF6 ^a γ_{90}				1.63*	1.64*
BF7 ^a γ_{100}				2.49*	2.49*
BF8 ^a γ_{110}				3.11*	3.10*
Level-2					
INTDMEAN ^b γ_{01}		-1.37*	-1.37*	-1.57*	-1.02*
BF1_MEAN ^b γ_{02}					0.48
BF2_MEAN ^b γ_{03}					-2.07*
BF3_MEAN ^b γ_{04}					1.65*
BF4_MEAN ^b γ_{05}					1.22*
BF6_MEAN ^b γ_{06}					2.43*
BF7_MEAN ^b γ_{07}					1.94*
BF8_MEAN ^b γ_{08}					4.57*
TOP_5 ^b γ_{09}					-0.38*
FEM_F ^b γ_{010}					1.94*
URM_F ^b γ_{011}					1.42
FEM_S ^b γ_{012}					-1.89*
URM_S ^b γ_{013}					-0.32
INTL_S ^b γ_{014}					-0.91*
Error Variance					
Level-2 Intercept τ_{00}	0.213 (0.03)	0.198 (0.03)	0.199(0.03)	0.263 (0.04)	0.076 (0.01)
Model Fit					
-2LL	79404.86	79397.21	79326.54	75773.9	75617.49
% of variance explained		7.1%	6.6%	-23.4%	64.4%

Note: * $p < 0.05$, ^a group-mean centered, ^b grand-mean centered.

Table 10
Odds Ratio Estimates

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed Effects					
Intercept γ_{00}	0.22*	0.22*	0.21*	0.17*	0.17*
Level-1					
INTD ^a γ_{10}		0.99	0.98	0.95	0.95
FEMALE ^a γ_{20}			1.20*	1.06	1.06
URM ^a γ_{30}			1.10*	0.98	0.98
INTL ^a γ_{40}			1.03	1.25*	1.25*
BF1 ^a γ_{50}				1.48*	1.51*
BF2 ^a γ_{60}				0.58*	0.57*
BF3 ^a γ_{70}				2.76*	2.80*
BF4 ^a γ_{80}				4.52*	4.58*
BF6 ^a γ_{90}				5.11*	5.13*
BF7 ^a γ_{100}				12.00*	12.06*
BF8 ^a γ_{110}				22.43*	22.27*
Level-2					
INTDMEAN ^b γ_{01}		0.26*	0.25*	0.21*	0.36*
BF1_MEAN ^b γ_{02}					1.63
BF2_MEAN ^b γ_{03}					0.13*
BF3_MEAN ^b γ_{04}					5.19*
BF4_MEAN ^b γ_{05}					3.39*
BF6_MEAN ^b γ_{06}					11.3*
BF7_MEAN ^b γ_{07}					6.98*
BF8_MEAN ^b γ_{08}					96.23*
TOP_5 ^b γ_{09}					0.68*
FEM_F ^b γ_{010}					6.96*
URM_F ^b γ_{011}					4.16
FEM_S ^b γ_{012}					0.15*
URM_S ^b γ_{013}					0.72
INTL_S ^b γ_{014}					0.40*

Note: * $p < 0.05$, ^a group-mean centered, ^b grand-mean centered.

When plugging in the coefficient found in Table 9 to Equation 7 the overall grand mean is estimated to be .18 or the predicated probability of obtaining a faculty position upon graduation is 18% for a typical school, or a school where the random effect $u_{0j} = 0$. The error variance of the Level-2 intercept τ_{00} is 0.21. Since this model does not account for within-school

or between-school effects this value is expected to be close to the population mean seen in Table 4 which is 17%.

Model 2

Model 2 introduces the key variable of interest at both Level-1 and Level-2. This means the model considers whether the student completed an interdisciplinary dissertation and the percentage of students within an institution that completed an interdisciplinary dissertation. Since the Level-2 variable was computed using Level-1 data this model is known as a compositional or contextual effects model which allows for the same variable to have different effects between Level-1 and Level-2. This model is shown in Equation 13.

$$\begin{aligned} \eta_{ij} &= \beta_{0j} + \beta_{1j}(\text{INTD}_{ij}) \\ \beta_{0j} &= \gamma_{00} + \gamma_{01}(\text{INTDMEAN}_j) + u_{0j} \\ \beta_{1j} &= \gamma_{10} \end{aligned} \tag{13}$$

As shown in Table 9, completing an interdisciplinary dissertation is not statistically significant ($\beta_1 = -0.01, p = 0.645$) while the proportion of students at an institution completing an interdisciplinary dissertation is statistically significant ($\gamma_{01} = -1.37, p = 0.006$). The results show there is a difference in the effect at Level-1 and Level-2 as the variable is only statistically significant at Level-2. So, students belonging to different schools whose mean interdisciplinary dissertation completion differ will have different odds of obtaining a faculty position. This is a difference between schools with a different proportion of their students completing an interdisciplinary dissertation and not a within school difference between those who did and did not complete an interdisciplinary dissertation. The compositional effect is measured by $\gamma_{01} - \gamma_{10}$ which is equal to $-1.37 - (-0.01) = -1.36$. So, the same student at a school with a different proportion of students completing an interdisciplinary dissertation would see a different probability of obtaining a faculty position. Additionally, by adding these two variables to the model, the error variance of the Level-2 intercept τ_{00} decreased slightly to 0.20, or an additional

7.1% of variance was explained by this model, and the $-2LL$ deviance statistic decreased to 79397 indicating a better model fit than the unconditional model.

Model 3

Next, student-level demographics were added into the model as a block. This model is shown in Equation 14.

$$\begin{aligned}\eta_{ij} &= \beta_{0j} + \beta_{1j}(\text{INTD}_{ij}) + \beta_{2j}(\text{FEMALE}_{ij}) + \beta_{3j}(\text{URM}_{ij}) + \beta_{4j}(\text{INTL}_{ij}) \\ \beta_{0j} &= \gamma_{00} + \gamma_{01}(\text{INTDMEAN}_j) + u_{0j} \\ \beta_{1j} &= \gamma_{10} \\ \beta_{2j} &= \gamma_{20} \\ \beta_{3j} &= \gamma_{30} \\ \beta_{4j} &= \gamma_{40}\end{aligned}\tag{14}$$

Similar to the logistic regression model in RQ1, FEMALE ($\beta_1 = 0.26, p < .001$) and URM ($\beta_3 = 0.12, p = .02$) are statistically significant variables while INTL is not. Completing an interdisciplinary dissertation remained not statistically significant and the Level-2 mean proportion of students completing an interdisciplinary dissertation remained statistically significant with no change in the coefficient. The composition effect remained essentially the same as in the Model 2 ($-1.37 - (-0.02) = -1.35$). The error variance of the Level-2 intercept τ_{00} stayed the same at 0.20 and the $-2LL$ deviance statistic decreased to 79326 indicating a better model fit than the unconditional model and Model 2.

Model 4

In Model 4, multiple dummy variables were added at Level-1 to account for the student's broad field of study. Engineering (BF5) is the reference variable and therefore not included in the model. This model can be seen in Equation 15.

$$\begin{aligned}\eta_{ij} &= \beta_{0j} + \beta_{1j}(\text{INTD}_{ij}) + \beta_{2j}(\text{FEMALE}_{ij}) + \beta_{3j}(\text{URM}_{ij}) + \beta_{4j}(\text{INTL}_{ij}) + \beta_{5j}(\text{BF1}_{ij}) + \beta_{6j}(\text{BF2}_{ij}) \\ &+ \beta_{7j}(\text{BF3}_{ij}) + \beta_{8j}(\text{BF4}_{ij}) + \beta_{9j}(\text{BF6}_{ij}) + \beta_{10j}(\text{BF7}_{ij}) + \beta_{11j}(\text{BF8}_{ij}) \\ \beta_{0j} &= \gamma_{00} + \gamma_{01}(\text{INTDMEAN}_j) + u_{0j} \\ \beta_{1j} &= \gamma_{10} \\ \beta_{2j} &= \gamma_{20} \\ \beta_{3j} &= \gamma_{30} \\ \beta_{4j} &= \gamma_{40}\end{aligned}\tag{15}$$

$$\begin{aligned}
\beta_{5j} &= \gamma_{50} \\
\beta_{6j} &= \gamma_{60} \\
\beta_{7j} &= \gamma_{70} \\
\beta_{8j} &= \gamma_{80} \\
\beta_{9j} &= \gamma_{90} \\
\beta_{10j} &= \gamma_{100} \\
\beta_{11j} &= \gamma_{110}
\end{aligned}$$

All the broad fields are statistically significant with multiple fields having very high likelihood factors. Additionally, FEMALE ($\beta_1= 0.06, p=.095$) and URM ($\beta_3= -0.02, p=.768$) are no longer statistically significant, while INTL ($\beta_4= 0.22, p<.001$) is now statistically significant. The statistical significance of completing an interdisciplinary dissertation and proportion of students completing an interdisciplinary dissertation remain the same as prior models. The composition effect changed more from the prior models $(-1.57 - (-0.05)) = -1.52$.

The error variance of the Level-2 intercept τ_{00} actually increased to 0.26, but the $-2LL$ deviance statistic decreased to 75774 indicating a better model fit than the unconditional model and Model 2 and Model 3. Even though this is a better fit than the prior models, the increase in τ_{00} indicates there are Level-2 variables that need to be added to the model.

Model 5

Model 5 is the final model including all variables of interest at Level-1 and Level-2. Even though the variable for completing an interdisciplinary dissertation was not statistically significant in prior models, I retained it in the model because it is the key variable of interest and I wanted to compare the compositional effect. Additionally, the student demographic characteristics at Level-1 changed in significance from Model 3 to Model 4 so I kept them in the model because each is a key variable derived from the literature but also because I wanted to see how they performed in the final model. This final model can be seen in Equation 16.

$$\eta_{ij} = \beta_{0j} + \beta_{1j}(\text{INTD}_{ij}) + \beta_{2j}(\text{FEMALE}_{ij}) + \beta_{3j}(\text{URM}_{ij}) + \beta_{4j}(\text{INTL}_{ij}) + \beta_{5j}(\text{BF1}_{ij}) + \beta_{6j}(\text{BF2}_{ij}) + \beta_{7j}(\text{BF3}_{ij}) + \beta_{8j}(\text{BF4}_{ij}) + \beta_{9j}(\text{BF6}_{ij}) + \beta_{10j}(\text{BF7}_{ij}) + \beta_{11j}(\text{BF8}_{ij}) \quad (16)$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{INTDMEAN}_j) + \gamma_{02}(\text{BF1_MEAN}_j) + \gamma_{03}(\text{BF2_MEAN}_j) + \gamma_{04}(\text{BF3_MEAN}_j) + \gamma_{05}(\text{BF4_MEAN}_j) + \gamma_{06}(\text{BF6_MEAN}_j) + \gamma_{07}(\text{BF7_MEAN}_j) + \gamma_{08}(\text{BF8_MEAN}_j) + \gamma_{09}(\text{TOP_5}_j) + \gamma_{010}(\text{FEM_F}_j) + \gamma_{011}(\text{URM_F}_j) + \gamma_{012}(\text{FEM_S}_j) + \gamma_{013}(\text{URM_S}_j) + \gamma_{014}(\text{INTL_S}_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

$$\beta_{5j} = \gamma_{50}$$

$$\beta_{6j} = \gamma_{60}$$

$$\beta_{7j} = \gamma_{70}$$

$$\beta_{8j} = \gamma_{80}$$

$$\beta_{9j} = \gamma_{90}$$

$$\beta_{10j} = \gamma_{100}$$

$$\beta_{11j} = \gamma_{110}$$

In this final model, β_{0j} represents the unbiased mean predicted probability of a typical student i at a typical school j obtaining a faculty job adjusted for the student-level effects of dissertation type, race, citizenship, and broad field of study and controlled for the Level-2 institution effects of proportion interdisciplinary, prestige, proportion of each broad field of study, proportion female faculty, proportion URM faculty, proportion of female students, proportion URM students, and proportion international students. The predicted probability of obtaining a faculty job for a typical student controlling for within school and between school effects is 14.4%. Since all Level-1 and Level-2 variables were group-mean or grand-mean centered, a “typical” student is an average student (mean values) for each Level-1 variable and attends an average school (mean values) for each Level-2 variable. The error variance of the Level-2 intercept τ_{00} decreased to 0.08, accounting for 64.4% of the error variance in the unconditional model. The $-2LL$ deviance statistic decreased to 75617, indicating a better model fit than all prior models.

The Level-1 variables that are statistically significant are being an international student ($\gamma_{40} = 0.22, p < .001$), Life Sciences ($\gamma_{50} = 0.41, p < .001$), Physical and Earth Sciences ($\gamma_{60} = -0.57,$

$p < .001$), Mathematics and Computer Sciences ($\gamma_{70} = 1.03$, $p < .001$), Psychology and Social Sciences ($\gamma_{80} = 1.52$, $p < .001$), Education ($\gamma_{90} = 1.64$, $p < .001$), Humanities and Arts ($\gamma_{100} = 2.49$, $p < .001$), and Other Non-S&E ($\gamma_{110} = 3.10$, $p < .001$). The odds ratios were obtained from the HLM software output and predicted probabilities were calculated using Equation 7 where η_{ij} is the summation of a specific variable's coefficient and the β_{0j} coefficient as seen in Table 9. International students are 1.25 times more likely (in odds) to obtain a faculty job than U.S. Citizen, Non-URM students controlling for other Level-1 and Level-2 predictors in the model. An international student has a predicted probability of obtaining a faculty job of 17.5% controlling for other variables.

While all broad fields of study had a statistically significant impact on the likelihood of obtaining a faculty job, the magnitude of that influence differed across fields. A student in Physical & Earth Science is 0.57 times less likely in odds to obtain a faculty position than a student in an Engineering field. All other broad fields increased the likelihood of obtaining a faculty job when compared to a student in an Engineering field. The largest increase by odds is seen in students receiving their PhD in a field within Other Non-S&E. A typical student completing a PhD here is 22 times (in odds) more likely than a student in Engineering to obtain a faculty job controlling for Level-1 and Level-2 predictors. This translates to a predicted probability of obtaining a faculty job of 79%. Other broad fields with a high odds ratio are Humanities & Arts which increased the odds by 12 times for a predicted probability of 67%, Education by 5 times for a predicted probability of 47%, Psychology & Social Sciences by 5 times for a predicted probability of 44%, and Math & Computer Sciences increased the odds by 3 times for a predicted probability of 32%.

The Level-2 variables that are statistically significant are the proportion of students completing an interdisciplinary degree ($\gamma_{01} = -1.02, p = .02$), proportion Physical Sciences and Earth Sciences ($\gamma_{03} = -2.07, p = .003$), proportion Mathematics and Computer Science ($\gamma_{04} = 1.65, p = .01$), proportion Psychology and Social Sciences ($\gamma_{05} = 1.22, p = .01$), proportion Education ($\gamma_{06} = 2.42, p < .001$), proportion Humanities and Arts ($\gamma_{07} = 1.94, p = .002$), proportion Other Non-S&E ($\gamma_{08} = 4.57, p < .001$), institutional prestige ($\gamma_{09} = -0.38, p = .04$), proportion of faculty that are female ($\gamma_{010} = 1.94, p = .03$), proportion of graduate students that are female ($\gamma_{012} = -1.89, p = .02$), and the proportion of graduate students that are international students ($\gamma_{014} = -0.91, p = .02$). The variables % Life Sciences, % URM Faculty, and % URM Students are the only Level-2 variables that were not statistically significant.

The variables % Mathematics and Computer Sciences, % Psychology and Social Sciences, % Education, % Humanities and Art, % Other Non-S&E, and % Female Faculty all have large positive effects while % Physical Sciences and Earth Sciences, % Female Students, % International Students and % Interdisciplinary dissertation all have large negative effects on the likelihood of a typical student obtaining a faculty position. The broad fields of study had varying large effects, which are described in terms of odds, with Other Non-S&E fields having the largest effect. Level-2 variables are interpreted based on a 10% change in the coefficient. Therefore, each coefficient in Table 7 was multiplied by .1 and then plugged in to the equations described in Chapter 3. This will be referred to as a unit change. For example, a unit increase in a school's proportion of doctoral students receiving their degree in Other Non-S&E leads to an increase in the odds of obtaining a faculty position by 1.58 times or a predicted probability of 21%. Similarly, a unit change in % Mathematics and Computer Sciences increases the odds by 1.18 times or a predicted probability of 16.6% for a typical student, % Psychology and Social

Sciences increases the odds by 1.13 times or a predicted probability of 16.0%, % Education increases the odds by 1.28 times or a predicted probability of 17.7%, % Humanities and Arts increases the odds by 1.21 times or a predicted probability of 17.0%. The proportion of faculty at an institution that are female also increases the odds of obtaining a faculty position. A one unit increase in the proportion of faculty that are female leads to an increase in the odds of obtaining a faculty position by 1.21 times or corresponds to a predicted probability of 17.0%.

A number of Level-2 variables had large between-school negative effects on the likelihood of a typical student obtaining a faculty position. A one unit increase in the school mean proportion of students completing an interdisciplinary dissertation decreases the odds of obtaining a faculty position by 0.90 times and the predicted probability for a typical student is now 13.2%. The proportion of students in Physical Sciences and Earth Sciences decreased the odds by 0.81 times with a predicted probability for a typical student of 12.1%. Proportion of female students decreased the odds by 0.83 times with a predicted probability of 12.2%, and the proportion of international students decreased the odds by 0.91 times for a predicted probability of 13.3%. While not considered to be a large effect, although close to the 0.5 threshold for a large effect size and statistically significant, attending a prestigious institution decreased the odds by 0.96 times and corresponds to a predicted probability of 14.0% holding all other Level-1 and Level-2 variables constant. Additionally, the composition effect of completing an interdisciplinary dissertation and the proportion of students completing an interdisciplinary dissertation changed more from the prior models to $(-1.02 - (-0.05)) = -0.97$.

Research Question 3 and Research Question 4

Research Questions 3 and 4 consider the same question as RQ2, but only for students who completed an interdisciplinary dissertation. Compared to the full population proportion of

students reporting a faculty job of 17.4%, the proportion for this population is slightly less at 16.6%. Since completing an interdisciplinary dissertation was not a statistically significant predictor at the student-level for the full population, this analysis allowed me to dive deeper into the population of interest. Research Question 3 investigated the individual characteristics that increase the likelihood of a doctoral recipient who completes an interdisciplinary dissertation obtaining a faculty job in academia, while Research Question 4 investigated the institution-level characteristics. The descriptive statistics of this new population are shown in Table 11.

Similar to the approach taken for RQ2, a model building approach was conducted to review the effect on the Level-2 variance explained and model fit when adding new variables. Model building started with an unconditional model; student characteristics were added at Level-1 along with the proportion of students completing an interdisciplinary dissertation at Level-2. The proportion of students completing an interdisciplinary dissertation was included in the first model as a means to see how this variable changed from model to model due to its statistical significance and the clear compositional effect in the full population models above.

The results of this process are shown as coefficients in Table 12, which shows the final model having the lowest -2LL deviance statistic and explaining 53.3% of the variance from the unconditional model. These results are also shown as odds ratios in Table 13. In the final model, the only Level-1 variables that were statistically significant were all of the broad fields of study Life Sciences ($\gamma_{50} = 0.0.39$, $p < .001$), Physical Sciences and Earth Sciences ($\gamma_{60} = -0.59$, $p < .001$), Mathematics and Computer Sciences ($\gamma_{70} = 1.02$, $p < .001$), Psychological and Social Sciences ($\gamma_{80} = 1.47$, $p < .001$), Education ($\gamma_{90} = 1.72$, $p < .001$), Humanities and Arts ($\gamma_{100} = 2.45$, $p < .001$), and Other Non-S&E ($\gamma_{110} = 2.91$, $p < .001$).

Table 11*Descriptive Statistics for Doctoral Students Completing Interdisciplinary Dissertations Only*

Variable	N	Mean	Minimum	Maximum	Std. Dev
<i>Level-1</i>					
FAC_YN	12,104	0.166	0	1	0.372
INTL	12,104	0.366	0	1	0.482
URM	12,104	0.114	0	1	0.317
FEMALE	12,104	0.455	0	1	0.498
BF1	12,104	0.245	0	1	0.430
BF2	12,104	0.112	0	1	0.315
BF3	12,104	0.074	0	1	0.261
BF4	12,104	0.146	0	1	0.353
BF5	12,104	0.230	0	1	0.421
BF6	12,104	0.055	0	1	0.228
BF7	12,104	0.085	0	1	0.279
BF8	12,104	0.054	0	1	0.225
<i>Level-2</i>					
INTDMEAN	130	0.454	0.306	0.638	0.067
INTL_S	130	0.223	0.064	0.603	0.107
URM_S	130	0.195	0.076	0.838	0.104
FEM_S	130	0.535	0.240	0.679	0.074
Top_5	130	0.039	0	1	0.193
FEM_F	130	0.416	0.225	0.578	0.050
URM_F	130	0.102	0.044	0.644	0.059
BF1_MEAN	130	0.227	0.044	0.738	0.118
BF2_MEAN	130	0.120	0	0.374	0.056
BF3_MEAN	130	0.092	0	0.354	0.054
BF4_MEAN	130	0.172	0	0.500	0.080
BF5_MEAN	130	0.187	0	0.616	0.110
BF6_MEAN	130	0.084	0	0.400	0.080
BF7_MEAN	130	0.062	0	0.229	0.047
BF8_MEAN	130	0.056	0	0.218	0.038

Table 12

Estimates for Hierarchical Generalized Linear Models of Faculty Job Attainment for Interdisciplinary Dissertation Population

	Model 1	Model 2	Model 3	Model 4
Fixed Effects	-1.60*	-1.60*	-1.90*	-1.90*
Intercept γ_{00}				
Level-1				
FEMALE ^a γ_{20}		0.31*	0.10	0.10
URM ^a γ_{30}		0.2*	0.03	0.03
INTL ^a γ_{40}		-0.16*	0.05	0.06
BF1 ^a γ_{50}			0.37*	0.39*
BF2 ^a γ_{60}			-0.58*	-0.59*
BF3 ^a γ_{70}			0.99*	1.02*
BF4 ^a γ_{80}			1.46*	1.47*
BF6 ^a γ_{90}			1.72*	1.72*
BF7 ^a γ_{100}			2.45*	2.45*
BF8 ^a γ_{110}			2.91*	2.91*
Level-2				
INTDMEAN ^b γ_{01}		-2.03*	-2.12*	-1.38
BF1_MEAN ^b γ_{02}				0.26
BF2_MEAN ^b γ_{03}				-1.54
BF3_MEAN ^b γ_{04}				1.84
BF4_MEAN ^b γ_{05}				1.64*
BF6_MEAN ^b γ_{06}				2.62*
BF7_MEAN ^b γ_{07}				2.47*
BF8_MEAN ^b γ_{08}				4.65*
TOP_5 ^b γ_{09}				-0.34
FEM_F ^b γ_{010}				1.86
URM_F ^b γ_{011}				2.28
FEM_S ^b γ_{012}				-1.48
URM_S ^b γ_{013}				-1.4
INTL_S ^b γ_{014}				-1.02
Error Variance				
Level-2 Intercept				
τ_{00} (SE)	0.214 (.04)	0.196 (.04)	0.260 (.05)	0.100 (.03)
Model Fit				
-2LL	32958.72	32883.2	31443.5	31371.57
% of variance explained		8.6%	-21.3%	53.3%

Note: * $p < .05$, ^a group-mean centered, ^b grand-mean centered.

Table 13
Odds Ratio Estimates for Interdisciplinary Dissertation Population

	Model 1	Model 2	Model 3	Model 4
Fixed Effects				
Intercept γ_{00}	0.20*	0.20*	0.20*	0.20*
Level-1				
FEMALE ^a γ_{20}		1.37*	1.10	1.10
URM ^a γ_{30}		1.23*	1.03	1.03
INTL ^a γ_{40}		0.85*	1.05	1.06
BF1 ^a γ_{50}			1.44*	1.47*
BF2 ^a γ_{60}			0.55*	0.55*
BF3 ^a γ_{70}			2.70*	2.76*
BF4 ^a γ_{80}			4.30*	4.36*
BF6 ^a γ_{90}			5.58*	5.56*
BF7 ^a γ_{100}			11.56*	11.63*
BF8 ^a γ_{110}			18.48*	18.40*
Level-2				
INTDMEAN ^b γ_{014}		0.13*	0.12*	0.25
BF1_MEAN ^b γ_{02}				1.29
BF2_MEAN ^b γ_{03}				0.21
BF3_MEAN ^b γ_{04}				6.31
BF4_MEAN ^b γ_{05}				5.15*
BF6_MEAN ^b γ_{06}				13.70*
BF7_MEAN ^b γ_{07}				11.80*
BF8_MEAN ^b γ_{08}				104.90*
TOP_5 ^b γ_{09}				0.71
FEM_F ^b γ_{010}				6.40
URM_F ^b γ_{011}				9.74
FEM_S ^b γ_{012}				0.23
URM_S ^b γ_{013}				0.25
INTL_S ^b γ_{014}				0.36

Note: * $p < .05$, ^a group-mean centered, ^b grand-mean centered.

Similarly to the model of all students, the student demographic predictors flipped in statistical significance once the broad fields were added in Model 3. However, in this population being an international student followed the same pattern as being a female and as URM.

At Level-2, the statistically significant predictors are % Psychology and Social Sciences ($\gamma_{05}=1.64, p = .04$), % Education ($\gamma_{06} = 2.62, p < .003$), % Humanities and Arts ($\gamma_{07} = 2.47, p$

=.023), and % Other Non-S&E ($\gamma_{08} = 4.65, p < .001$). Additionally, % Interdisciplinary ($\gamma_{01} = -1.38, p = .052$) was statistically significant in Model 2 and Model 3, but in Model 4 it is no longer statistically significant at the $p < .05$ threshold.

The predicted probability of faculty job attainment changed from 17% in the unconditional model to 13.6% in the final model when controlling for within-school and between-school differences. Therefore, a typical student at a typical school is one with average values for each Level-1 group-mean centered variable and each Level-2 grand-mean centered variables. At Level-1, each broad field of study was statistically significant, but with varying effect sizes, when compared to the reference group of Engineering. Again, the Level-2 coefficients are transformed so they can be interpreted as a 10% change.

Other Non-S&E had the largest effect where the odds increased the likelihood of obtaining a faculty job by 18.36 times and corresponds to a predicted probability of obtaining a faculty position of 74.1%. Completing a PhD in Humanities and Arts increased the odds by 11.63 times and corresponds to a predicted probability of 64.3%, Education increased the odds by 5.56 times and corresponds to a predicted probability of 46.5%, Psychology and Social Sciences increased the odds by 4.36 times and corresponds to a predicted probability of 40.4%, and Mathematics and Computer Sciences increased the odds by 2.76 times and corresponds to a predicted probability of 30.2%. Life Sciences was statistically significant but not considered a large effect at odds of 1.47. Physical Sciences and Earth Sciences was the only broad field of study that decreased the odds. This field decreased the likelihood of obtaining a faculty position by 0.55 times in odds and had a predicted probability of 7.9%.

At Level-2, the proportion of students completing a PhD in Other Non-S&E fields had a large effect. For a typical student in a typical school, a unit change in the proportion increased

the likelihood of a student completing an interdisciplinary dissertation obtaining a faculty position by 1.59 times and corresponds with a predicted probability of faculty attainment of 19.9%. A unit increase in % Humanities and Arts leads to an increase in the odds of obtaining a faculty position by 1.28 times and corresponds to a predicted probability of faculty attainment of 16.6%, % Education increases the odds by 1.30 times and corresponds to a predicted probability of 16.8%, % Psychology and Social Sciences increases the odds by 1.18 times and corresponds to a predicted probability of 15.5%, and % Mathematics and Computer Sciences increases the odds by 1.20 times and corresponds to a predicted probability of 15.8%. Similar to the Level-1 effect of Physical Sciences and Earth Sciences, % Physical Sciences and Earth Sciences also had a significant negative effect on faculty attainment for students who completed an interdisciplinary dissertation. A unit increase in the proportion of Physical Sciences and Earth Sciences leads to a decrease in the odds of obtaining a faculty job by 0.86 times and corresponds to a predicted probability of 11.8% when controlling for all other Level-1 and Level-2 predictors.

Even though they were not found to be statistically significant, the student and faculty demographics at Level-2 had large positive and negative effects that are worth mentioning. A unit change in the faculty predictors of % URM and % Female corresponded to increases in the odds of obtaining a faculty position by 1.26 times and 1.20 times respectively. Student characteristics of % Female, % URM, % International and proportion interdisciplinary all decreased the odds of obtaining a faculty position for students completing an interdisciplinary dissertation. A unit change in student % Female decreased the odds by 0.86, student % URM by 0.87, student % International by 0.90 and % Interdisciplinary by 0.87. Additionally, prestige was not a statistically significant predictor of obtaining a faculty position for students completing interdisciplinary dissertations.

Compared to the full model of students completing both interdisciplinary and disciplinary dissertations, the effects of predictor variables in each final model did differ. The largest differences between populations came in the between-school effects. The variables % Psychology and Social Sciences and % Humanities and Arts were both statistically significant predictors in both populations with large effects in odds. A unit change in the proportion of students in Psychology and Social Sciences for a typical student in a typical school corresponded to a predicted probability of faculty attainment of 16.0% in the full population and 15.5% in the interdisciplinary dissertation population for a difference of 0.5 percentage-points. A unit change in the proportion of students in Humanities and Arts for a typical student in a typical school corresponded to a predicted probability of faculty attainment of 17% in the full population and 16.6% in the interdisciplinary dissertation population for a difference of around 0.4 percentage-points. The proportion of students in Other Non-S&E was the largest positive effect in both populations, which resulted in predicted probability of faculty attainment of 13.2% in the full model and 11.9% in the interdisciplinary population for a difference of 1.3 percentage-points.

Chapter Summary

In this chapter I presented the results of the statistical analyses used to answer each of four research questions. In Chapter 5, I discuss these findings and provide implications for policy, practice, and research, particularly as it relates to the importance of using hierarchical models to describe student-level and institutional-level effects in research. I also situate these findings in the context of the existing research literature on doctoral student socialization, interdisciplinary research, and trends in career outcomes for doctoral graduates, while also addressing the unique contribution of this research as a methodological tool for studying outcomes related to doctoral students.

Chapter Five: Discussion

The emergence of interdisciplinary research experiences in doctoral education brings forward the need to evaluate whether they influence career outcomes for participating students. With the continued surplus of doctoral degree production compared to a shrinking number of faculty jobs in academia it was important to determine how participation in interdisciplinary research experiences influence a student's career prospects upon receiving their degree. Limited empirical research has been conducted to investigate the influencing factors of a doctoral student's likelihood of obtaining a faculty job in academia upon completion of their degree. Additionally, existing research does not address university characteristics where students attend. If universities continue to promote interdisciplinary opportunities, including so-named degree programs, then understanding intended outcomes is critical. Additionally, a socialization framework likely substantiates the extent to which doctoral training environments are consequential to careers.

Hierarchical models allowed me to consider both student and institutional characteristics that contribute to the likelihood of a doctoral student obtaining a faculty position. The results of this study have implications for doctoral students considering interdisciplinary research experiences, faculty across the disciplines responsible for training doctoral students, graduate school deans and other university leaders charged with institutionalizing responsive degree programs, and federal agencies setting and supporting an interdisciplinary research agenda through influential funding mechanisms.

Hierarchical Generalized Linear Modeling was the most appropriate analytical tool for this analysis because doctoral students are part of a hierarchical structure where students are nested within institutions of higher education. The results of this analysis suggest this was an appropriate strategy to implement because key variables were different between the student-level

and the institution-level factors in terms of statistical significance and magnitude. The Weidman, Twale, and Stein (2010) socialization model for doctoral education provides a clear link between the ways doctoral students experience their education and their career outcomes upon completion. This theoretical framework is captured through the Level-2 modeling in my analysis.

Findings were informed by data collected in the 2021 Survey of Earned Doctorates. Several key findings support the idea that there are individual-level and institutional-level factors that influence a doctoral student's likelihood of obtaining a faculty job upon graduation. At the student-level, identifying as an international student compared to a non-URM, U.S. citizen and completing a degree in any broad field compared to Engineering, the reference group in the analysis, were important indicators of a student's likelihood to obtain a faculty job. At the institution level, all broad fields of study, except the proportion of doctoral students completing their degree in Life Sciences, were significant along with prestige, proportion of female faculty, proportion of female graduate students, and proportion of international students. While completing an interdisciplinary dissertation was not found to be a predictor at the student-level, the aggregated institutional mean was found to have a meaningful impact on being hired in an academic faculty position.

Other interesting findings include that student demographics such as gender and URM are only noteworthy until broad field of study is considered, which seems to mitigate the influence of gender and race. Adding broad fields of study also influences the impact of being an international student, as it became a statistically significant predictor and was not in prior models. Some of the most interesting findings come when looking at the differences in effect size for each broad field variable within Level-1 and Level-2 in the final model. At the student-level (Level-1), the broad field odds range from 0.6 to 22.2, and at the institution-level (Level-2)

a 10% change in the variable results in a range of odds from 0.81 to 1.58. Finally, when sub-setting the sample to only those who completed an interdisciplinary dissertation, additional differences are seen in which broad fields are statistically significant and how the effect size changes from the original sample.

Background of Population

The population of interest in this study was doctoral students at institutions classified as Very High Research Activity or High Research Activity and that indicated they had definite career plans in the 2021 Survey of Earned Doctorates. In this group, nearly half of respondents completed an interdisciplinary dissertation (45.7%), while only 17.4% of respondents obtained a faculty position upon graduation. The majority of this population identified as male (55.6%) and as a U.S. citizen who is not from an Underrepresented Minority (URM) racial identity (52.3%). Additionally, the most popular doctoral fields of study were Life Sciences (21.8%) or Engineering (20.6%). The findings from this analysis suggest individual student demographic characteristics are important in predicting the likelihood of obtaining a faculty job, but the significance of those characteristics' changes when the student's doctoral field of study is considered. Additionally, beyond student characteristics, there are institutional characteristics that impact the likelihood of obtaining a faculty job and these are related to the representation of various student backgrounds, faculty backgrounds, prestige, and the proportion of doctoral students in each broad field.

Discussion of Findings

Research Question 1

Research Question 1 (RQ1) helped situate this study of the influential characteristics that predict obtainment of a faculty job by providing a better understanding of the main variable of

interest, completion of an interdisciplinary dissertation. Descriptive statistics showed the most common characteristics of doctoral students that completed an interdisciplinary dissertation were male (54.5%), Non-URM, U.S. Citizen (52.1%), and completed a doctoral degree in Life Sciences (24.1%) or Engineering (22.7%). Gender, race, citizenship, and broad field of study were all found to have a statistically significant relationship with completing an interdisciplinary dissertation based on the results of the chi-squared test of independence described in Chapter 4. However, of those completing an interdisciplinary dissertation, only 17% obtained faculty jobs, but there was not a statistically significant difference. This is not to suggest that academia was the primary career objective. It is possible, if not likely, that a sizable portion of this group has career aspirations outside of academia. This finding is important because it diverges from prior research, such as Millar (2013), that found a significant relationship between completing an interdisciplinary dissertation and obtaining a job in higher education.

A logistical regression model allowed for the consideration of each of these variables simultaneously. This model confirmed the impact of student demographic characteristics and field of study similar to above. While the descriptive statistics showed a higher proportion of those completing an interdisciplinary dissertation to be male, being female and controlling for all other variables in the model increases the odds of completing an interdisciplinary dissertation by 1.1 times. Identifying as underrepresented minority (URM) increased the odds of completing an interdisciplinary dissertation by 1.3 times. These findings differ from Golembiewski et al. (2018), who found completing an interdisciplinary dissertation was associated with being male and a non-US citizen and did not find a statistically significant difference based on race. While the effect size related to these odds is not high, it does indicate a potential avenue of socialization for groups who frequently report negative socialization experiences, as prior research has found

that students participating in interdisciplinary opportunities have more positive socialization experiences (Culpepper et al., 2020; Gardner et al., 2012).

When looking at doctoral field of study, Humanities and Arts was the only field that increased the likelihood of completing an interdisciplinary dissertation over Engineering when controlling other variables. While Humanities and Arts makes up a small proportion of those who completed interdisciplinary dissertations, a high proportion of students within the field indicated they conducted an interdisciplinary dissertation. Other doctoral fields of study decrease the likelihood of completing an interdisciplinary dissertation when compared to Engineering (BF5). Physical Sciences and Earth Sciences (BF2) decreases the odds of completing an interdisciplinary dissertation by odds of 0.67, Mathematics and Computer Science (BF3) by 0.51, Psychology and Social Sciences (BF4) by 0.64, Education (BF6) by 0.53, and Other Non-Science and Engineering (BF8) by 0.86 times. Prior research has looked at disciplinary differences within public health and humanities, and this finding shows research is needed to further explore differences within disciplines (Golembiewski et al., 2018; Humanities Indicator Project, 2015).

Given this understanding of the influence of student demographic characteristics on completing an interdisciplinary dissertation, I next move to understanding how this specific type of doctoral research influences the ability to obtain a faculty position upon graduation. This comes with an understanding that doctoral students are socialized in different environments, so variance between institutions must be considered in addition to individual characteristics. Here, I account for the nested nature of students in influential institutional and disciplinary conditions that impact decisions to conduct interdisciplinary research.

Research Question 2

Research Question 2 (RQ2) considered individual-level and institutional-level characteristics that explain the likelihood of obtaining a faculty job with a specific focus on whether completing an interdisciplinary dissertation has a significant impact on this likelihood over completing a single-discipline dissertation. The findings from the first research question as well as from existing literature on socialization guided the inclusion of variables related to individual characteristics such as gender (Sallee, 2010), race and ethnicity (Felder et al., 2014; Gardner & Doore, 2020; Garcia et al., 2020; Perez et al., 2023; Phelps-Ward, 2020; Robbins et al., 2023; Twale et al., 2016; Winkle-Wagner et al., 2020), and in which discipline the student is studying (Roksa et al., 2022; Wofford & Blaney, 2021). The impact of these characteristics can be measured as institutional-level effects based on the characteristics of the graduate student population and faculty population.

Student-Level Predictors

Completing an interdisciplinary dissertation was the main focus of this study; however, it was not a statistically significant predictor of obtaining a faculty position in any of the models. This differs from the findings by Millar (2013), which used multivariate logistic regression only and did not account for variance between institutions. Despite this finding, there are interesting takeaways for other student characteristics that vary within an institution and influence socialization. Socialization theory identifies student demographic characteristics as an important component of the socialization process (Weidman et. al, 2001). Specifically related to gender, socialization literature points to differential experiences between male and female students in their doctoral programs, how this leads to differences in career outcomes, and how these differential experiences impact decisions to pursue faculty positions (Hughes, 2017; Mathur et al., 2018; Sallee, 2010; Wofford & Blaney, 2021). Differences based on gender were identified

by the type of advising support and in the level of social interaction with their advisor, as well as in how gender makes a difference in the criteria considered when selecting a research lab (Sallee, 2010; Wofford & Blaney, 2021). In this study, gender was found to be a statistically significant predictor, but only when broad field of study was not controlled for in the model.

Prior to adding broad field of study to the model, the odds of female doctoral students obtaining a faculty position are 1.2 times higher than a male student when controlling for race, citizenship, and completing an interdisciplinary dissertation. While the proportion of women in academia remains disproportional, this finding provides hope that this may be changing for recent graduates. Differences in socialization are still likely to be a factor contributing to lower representation in faculty jobs among women. While this finding is positive, there appears to be only a very small effect size and does not account for female students who obtained other jobs in academia, such as non-tenure track or research faculty positions.

The literature showed that while females are increasing their representation in academia, they are more likely to hold lower ranked positions compared to men (AAUP, 2021; Stein, 2022; Tiede, 2022; U.S. Department of Education, 2021). Additional differences are seen in women not pursuing faculty roles and being more likely to pursue teaching careers, while men are more likely to pursue research-related careers (Hughes, 2017; Mathur et al., 2018). This analysis focused solely on faculty jobs and found a positive relationship, which is a sign of progress compared to prior findings about the role gender plays in position type. The elimination of the influence of gender once broad field was added to the model signifies that field of study is a more influential predictor. However, gender differences within fields should be considered. In 2020, women held only 18.6% of faculty positions in engineering (American Association for Engineering Education, 2022). In science, engineering, and health fields women increased their

proportion of faculty from 26.4% in 1999 to 38.5% in 2019, but they are still severely underrepresented compared to men (NCSES, 2021). If this representation is going to change, the odds should be much higher for women in this model.

Similarly, prior to adding broad field of study, identifying as underrepresented racial minority (URM) was a statistically significant predictor increasing the likelihood of obtaining a faculty job by 1.1 times in odds. While a small effect, it provides hope there are changes coming in regard to faculty racial representation. Currently, 74% of full-time faculty in domestic degree-granting postsecondary institutions identify as white (NCES, 2022). These trends also have disciplinary patterns that need to change. The American Association for Engineering Education (2022) data for 2020 revealed 2.6% of Tenure/Tenure-Track faculty in Engineering were Black/African American and 3.9% were Hispanic. In science, engineering, and health fields combined, the share of positions held by URM faculty increased from 6.4% in 1999 to 8.9% in 2019; however, URM faculty remain severely underrepresented (NCSES, 2021).

This study underscores how race plays a role in the socialization of doctoral students and that increasing representation in faculty ranks must remain an important aim of doctoral education. Negative outcomes related to the current socialization experiences of URM students include feelings of isolation and a lack of a sense of belonging, which can lead to students questioning whether they belong in their doctoral program, in academia, or in their desired future career field (Garcia et al., 2020; Weidman et al., 2016). These results confirm there are still racial climate concerns in the socialization process that affect doctoral students' decisions to pursue and secure faculty positions. A predominantly White faculty, White curriculum, and White peers result in a White-normative socialization experience (Garcia et al., 2020) that may discourage URM graduate students from degree completion and academic careers.

While race and gender were not statistically significant when field of study was considered, it is possible there are gender and racial differences hidden within the impact of the field of study that should be considered. There are known gender disparities within disciplines and disciplinary differences in who pursues faculty positions (Sallee, 2010). Institutions are structured in a way that doctoral students are typically socialized within a single disciplinary department, and these disciplines have differences in terms of racial and gender makeup of students and faculty, as well as the proportion of students who obtain faculty jobs. Sallee (2010) argued gendered disciplines lead to an environment favoring masculine norms, particularly in science and engineering fields, and this can contribute to gender differences in the likelihood of a student obtaining a faculty job. Student experiences with faculty and advisors within these disciplines play a large role in their socialization experience, so feelings of isolation and negative relationships with faculty and advisors by students from minoritized racial groups can lead to feeling they do not belong in faculty roles (Garcia et al., 2020; Phelps-Ward, 2020; Winkle-Wagner, 2010).

In the final model, each of the broad fields of study were found to be statistically significant, confirming there are field of study-based differences in who is obtaining faculty jobs. When all other variables were controlled in the model, all broad fields except one increased the likelihood of obtaining a faculty job compared to the reference field of Engineering (BF5). Physical & Earth Science (BF2) was the only field that decreased the likelihood of obtaining a faculty position and students in this field were 0.57 times less likely in odds to obtain a faculty position than a student in an Engineering field (BF5). The largest increase by odds is seen in students receiving their PhD in a field within Other Non-Science & Engineering fields (BF8) where a typical student is 22 times in odds more likely than a student in Engineering (BF5) to

obtain a faculty job, controlling for Level-1 and Level-2 predictors. Humanities & Arts (BF7) increased the odds by 12 times, Psychology & Social Sciences (BF4) and Education (BF6) by 5 times, and Math & Computer Sciences (BF3) increased the odds by 3 times. These odds-ratios are much higher than the factors related to gender and race/citizenship prior to the addition of broad field.

It is interesting that the broad field category Other Non-Science & Engineering has the highest likelihood ratio of all fields, as this is a catch-all for remaining fields and the category itself is not very descriptive. A closer look at the fields that make up this category shows fields ranging from business related fields, parks and recreation, communications, and architecture to name a few. These fields appear to be professional in nature. It is hard to interpret a heterogenous category but it is possible that in many of these fields a doctoral degree is only sought with the intention of obtaining a faculty position and those holding other jobs in these fields do not need a doctorate.

Institutional-Level Variables

Institutional culture is identified by Weidman, Twale, and Stein (2001) as playing an important role in the socialization of graduate students and is measured in this study through the inclusion of institutional characteristics at Level-2 in the model. These “between-school effects” are indicative of differences across schools that impact graduate student experiences. In this study, several institutional characteristics were shown to contribute to differences in the likelihood of obtaining a faculty job. These are: (1) proportion of students completing an interdisciplinary dissertation, (2) proportion of faculty that are female, (3) proportion of students that are female, (4) proportion of students that are international students, (5) prestige, and (6) each of the broad fields of study, except Life Sciences.

Completing an interdisciplinary dissertation was the main interest in this study and was not found to be statistically significant at Level-1. This means there is no difference in faculty job obtainment based on dissertation type. Therefore, this finding suggests completing an interdisciplinary dissertation does not put a doctoral student at a disadvantage of obtaining a faculty job, and faculty should not discourage this career option.

Interestingly, when aggregated at the institutional level to measure the environmental factor, the institution proportion of interdisciplinary dissertation completion was found to be statistically significant. This signifies a contextual effect where the aggregated data has a different effect than the individual data. In this case, there is a negative relationship between the proportion of doctoral students completing an interdisciplinary dissertation and the odds of obtaining a faculty position. This relationship is a large effect, where a one unit, or 10%, change in the proportion results in a reduction in odds by 0.90 times and the predicted probability for a typical student obtaining a faculty job is now 13.2%. This indicates that when doctoral students are socialized in an institutional environment where interdisciplinary research is conducted, based on the proportion of students completing an interdisciplinary dissertation, it does not lead to an increase in students obtaining faculty jobs. As a result, students at these institutions may be more likely to be socialized to career paths outside of academia. Additionally, this may vary based on the student's discipline and the disciplinary makeup of all doctoral students at the institution.

An influencing factor may also be tenure and promotion practices at the universities included in the study population. These practices still favor disciplinary focused achievements over interdisciplinary collaboration and that may impact opportunities for doctoral students and how doctoral students are socialized to what is valued if they wish to become tenured faculty in

the future (Arnold et al., 2021; Daniel et al., 2022; Hein et al., 2018; Klein & Falk-Krzesinski, 2017). If criteria for tenure favors disciplinary research, doctoral students will be socialized to conduct similar research to support faculty supervisor careers and as a socializing experience to what is truly valued in the field. The apprentice model in academia is an approach to training that values tradition over innovation. It may also be indicative of a perception that novice researchers are not able to do interdisciplinary research unless and until they are firmly grounded in disciplinary research.

One interesting finding is that prestige (Top_5) is a statistically significant variable in my model (see Table 9). Weidman, Twale, and Stein's (2001) model of socialization showed the importance of the rank of an institution, a department, and its faculty. Prior research has found that most new faculty hires come from a small group of universities (Clauzet et al., 2015; Fleming et al., 2023; Pinheiro et al., 2017; Wapman et al., 2022). Doctoral institution prestige was also found to be the most influential factor in predicting successful applications for faculty positions (Way, et al., 2019; Wright & Vanderford, 2017). However, in this analysis prestige has a negative effect on faculty job attainment when controlling for other variables. Attending a prestigious institution leads to a decrease in the likelihood of obtaining a faculty position by 0.68 times in odds, or a 32% decrease in odds. This negative relationship indicates there may be other influencing factors at prestigious institutions that led other researchers to find a positive relationship between prestige and successful obtainment of a faculty position. Prestige may be more influential when considered at the department or individual faculty level compared to the institution.

The role of post-doctorate appointments may also play a role here where students attending prestigious universities are more likely to obtain a postdoc appointment prior to

pursuing a faculty position. In this sample, 52% of doctoral graduates from prestigious institutions went to a postdoc position, while 41% of doctoral student at institutions that were not identified as prestigious went to a postdoc position upon completion of their degree. Finally, it is possible that the population of doctoral students from prestigious institutions was too small. Only 5.5% , or 1,578 doctoral students, of the sample was from a prestigious institution so a larger sample may yield different results.

Academic discipline is one of the factors that make up institutional culture in the Weidman, Twale, and Stein (2001) model of socialization. This analysis confirms the importance of the discipline a doctoral student chooses to study, but also how the institutional makeup of each discipline is an influencing factor on career outcomes. Differences in socialization between disciplines are largely driven by the faculty, who “establish the norms for teaching, research, and service within the constraints of the larger university community” (Weidman et al., 2001, p. 50). Faculty shape the curriculum, organization, and social relationships within the program. Similar to the student-level effect, there is a significant effect at the institution-level related to the proportion of students completing their doctorate in certain broad fields of study when compared to the proportion in Engineering. A unit increase in the proportion of Physical Sciences and Earth Sciences decreased the odds by 0.81 times, while other fields increase the odds of a student obtaining a faculty job. Similar to the student-level effect, the proportion of doctoral students completing their degree in the broad field Other Non-Science & Engineering had the largest effect, with an increase in the odds of obtaining a faculty position by 1.58 times, or a predicted probability of obtaining a faculty position of 21.0%. Despite the heterogeneity of this field, even when considering variance between institutions, this field has a large effect on a student’s likelihood of obtaining a faculty job.

Other institutional-level disciplines with high positive odds of obtaining a faculty position compared to Engineering are Mathematics and Computer Science with odds of 1.18 times more likely, Psychology and Social Sciences with odds of 1.13 times more likely, Education with odds 1.28 times more likely, and Humanities and Arts with odds 1.21 times more likely. This study intentionally separated each broad field instead of grouping them into either STEM or Non-STEM fields as is more common in research on career outcomes (Hughes et al., 2017; Jaeger et al., 2013; Murphrey et al., 2022). Having more categories allowed for better comparison between fields, and this study confirms there are large differences in career outcomes based on the field of study.

Weidman, Twale, and Stein (2001) also point to the role of faculty and peers as drivers of socialization toward a future career. The gender makeup of a doctoral students' peers and faculty mentors can have a significant impact on their experience socializing in doctoral education and on related outcomes (Twale et al., 2016; Wofford & Blaney, 2021). This analysis confirmed the important role of peer and faculty gender makeup within an institution in socialization toward a faculty position. There is a positive relationship between obtaining a faculty job and the proportion of faculty who are female at an institution, where the odds increase for a student at a typical school by nearly 1.21 times as the percentage of female faculty increases by 10%. However, the relationship between obtaining a faculty position and peer graduate student gender is highly negative, as the odds of obtaining a faculty position decrease by 0.83 times as the proportion of female students increases at an institution by 10%. While these effects are not differentiated by student gender, prior literature has found female students have better socialization outcomes, including academic careers, when they have a same-gender faculty mentor (Gaule & Piancentini, 2019). It is noteworthy that faculty and peer gender proportions are

statistically significant variables at the institution-level, but student gender was not statistically significant at the student-level. This reemphasizes the importance of hiring female faculty in order to create a positive socialization experience and cultivate female doctoral students who want to become faculty in the future.

The results of this analysis confirm that institution environments that are dominated by graduate students who are male, U.S. citizens, and from a majority racial background produce graduates that are more likely to obtain a faculty position. Despite a positive increase in the odds of obtaining a faculty job related to an increased proportion in female faculty at an institution, there is still a reduction in the odds based on the proportion of the graduate student body that is female. This is surprising based on the literature that has found a positive socialization experience and better outcomes when female students are mentored by female faculty and other female doctoral students (Gaule & Piancentini, 2019; Hirshfield, 2014; Twale et al., 2016; Wofford & Blaney, 2021). One possible explanation of this is the large disciplinary differences in this model and how gender makeup may differ within those fields.

At the institution-level, this study found that neither racial diversity in the faculty nor student populations was statistically significant. This supports the finding from Layton et al. (2016) that advisors did not have a significant influence on career choices for recipients from underrepresented minority groups. This study did not specifically include variables related to advising; however, faculty largely create the environment within disciplines and serve a similar purpose as an advisor in this study in regard to socialization influences. As noted in Table 4, only around 10% of this study's sample was URM, and at the institution-level the average proportion of URM faculty was also only around 10%, so it is also possible there is not enough

information within this population to make accurate judgements about the role of race on the ability to obtain a faculty job.

Research Question 3 and Research Question 4

The third and fourth research questions (RQ3 and RQ4) consider the same analysis of student-level and institution-level factors to predict the likelihood of obtaining a faculty job upon graduation. Here, my analysis applies only to students who completed an interdisciplinary dissertation. The purpose of these research questions was to see which student and institutional characteristics were the most influential, and if there were differences in the sample from the full population of graduate students. Research Question 3 focused on the student-level, or within-school, effects while Research Question 4 focused on the school-level, or between-school, effects.

Overall, graduate students who did interdisciplinary dissertations had a similar overall level of faculty job obtainment, with 16.6% of the students reporting they had secured a faculty position. However, when accounting for student-level and institution-level effects in the final model, the probability of obtaining a faculty job for the sample of students completing interdisciplinary dissertations was 13.6% compared to 14.4% in the final model for the original sample. This is a small difference but may indicate that for students completing an interdisciplinary dissertation, the variables included in the model have a less positive influence on obtaining a faculty job than they did for the original sample.

Student-Level Variables

In the final model, only broad fields of study explained differences at the student-level. Similar to the model in the second research question, student demographic variables were statistically significant prior to adding the broad field of study variables. However, in this model identifying as an international student also remained not statistically significant, along with being

a female student and a U.S. Citizen from a URM racial group. In the model where these variables were statistically significant, the effect size was positive but still small, just like in RQ2, but it was larger than in RQ2. Among those students who completed an interdisciplinary dissertation, a female student was 1.4 times more likely than a male to obtain a faculty job. A URM student was 1.2 times more likely than a non-URM, U.S. citizen to obtain a faculty job. This shows that, prior to controlling for broad field of study, a student's sex or race has a larger influence on the odds of obtaining a faculty job for students completing an interdisciplinary dissertation than when considering all dissertation types together. This is a sign of positive socialization toward faculty positions for students from backgrounds underrepresented in faculty positions when completing an interdisciplinary dissertation and not controlling for field of study.

Together, this indicates that even for those students who completed an interdisciplinary dissertation, gender and race do not play a significant role in their likelihood of obtaining a faculty position when controlling for other student-level and institution-level variables such as field of study and institutional environment. Completing an interdisciplinary dissertation therefore may not be an avenue that leads to a socialization experience that results in faculty jobs for students from groups that have typically been excluded from such experiences. Instead, it is possible that such research experiences contribute to other positive outcomes, such as degree attainment and time to degree, for certain groups. While this was beyond the scope of this study, interdisciplinary research may expose students to different faculty networks that support completion. Moreover, it might not have ever been the intention of students in these groups to pursue a faculty position.

Similar to the final model in RQ2, each of the broad fields of study was found to be statistically significant and have the same directional effect in relation to Engineering on the

odds of obtaining a faculty job. Importantly here, the effect size of each broad field is not very different between those who did an interdisciplinary dissertation and those who did not. The coefficients for Life Sciences, Physical Sciences and Earth Sciences, and Mathematics and Computer Science were nearly identical between the two models. For the interdisciplinary dissertation sample, Psychology and Social Sciences was a slightly smaller predictor than the original sample (4.36 vs. 4.58 times), along with Humanities and Arts (11.63 vs 12.06 times), and Education was a slightly higher predictor (5.56 vs. 5.13 times). Other Non-S&E fields was the only predictor that had a difference in effect size of more than one, with students completing an interdisciplinary dissertation having an odds ratio of 18.40 times compared to the full sample of 22.27 times, for a decrease of almost 4 times in odds between the two samples.

Overall, this shows some rationale for why completing an interdisciplinary dissertation was not a statistically significant student-level variable in RQ2. The student's doctoral discipline was significant in the models, and there was not much difference in the effect sizes between the full sample and the sample of only those completing an interdisciplinary dissertation.

Additionally, this provides context to the relationship between completing an interdisciplinary dissertation and discipline. This shows completing an interdisciplinary dissertation should not be discouraged as a route to a faculty position in most disciplines, as the outcome was essentially the same when sub-setting the sample to only students that completed an interdisciplinary dissertation. This analysis fills a gap in the literature, as there is not much information related to the individual characteristics of students completing interdisciplinary dissertations that predict obtaining a faculty job upon completion of their degree.

Institution-Level Variables

There are many institution-level differences between the model of only students who completed an interdisciplinary dissertation and the original sample model. Fewer institution-level

variables were found to be statistically significant in this model, and they are only related to the broad field of study categories with no other factors of institutional culture statistically significant. This means there is no statistically significant relationship between prestige, student demographic makeup, and faculty demographic makeup at an institution and the likelihood of obtaining a faculty position. Prestige went from being a negative factor in the original model to no longer being statistically significant. For students completing an interdisciplinary dissertation, prestige is not a factor that influences their likelihood of obtaining a faculty job. The experience of completing an interdisciplinary dissertation nullifies the impact of the institution's prestige and may even be playing field for these students when searching for a faculty job.

Institutional environment, measured through graduate student and faculty representation, is an important part of the Weidman, Twale, and Stein (2010) socialization framework and was not found to be significant for students completing an interdisciplinary dissertation. As Holley (2010) described, students completing interdisciplinary research do not interact with their peers and faculty in the same way as their disciplinary peers or experience the less formal structures of socialization due to differences in physical location of research labs, interacting with faculty across disciplines, and less fit with faculty and peers who are doing disciplinary research because they may not understand their research goals. This is another piece of evidence as to how existing socialization structures in doctoral education are not influencing interdisciplinary doctoral students in the same ways as they are other students.

Despite all broad field variables being statistically significant at Level-1, Life Sciences, Physical and Earth Sciences, and Mathematics and Computer Sciences were not statistically significant at Level-2. This means there are no between-institution differences for these variables. The institution-level variables that were statistically significant in the final model are

the proportion of doctoral students who completed their doctoral degree in Psychology and Social Sciences, Education, Humanities and Arts, and Other Non-S&E fields. The sample containing students completing an interdisciplinary dissertation had a larger odds ratio, or effect size, on obtaining a faculty job than was found in the original sample for the institution-level broad field variables that were statistically significant based on a 10% change in the proportion. The proportion of students completing their dissertation in Psychology and Social Sciences increases the likelihood of obtaining a faculty job by 1.18 times in odds, which is an increase of 0.05 over the full sample model. In Education, the odds of obtaining a faculty job increased to 1.30, which is an increase in the odds of 0.02. In Humanities and Arts, the odds increased to 1.28 for an increase of 0.07 over the original sample. Finally, Other Non-S&E had the largest odds ratio of 1.59 for a difference of 0.01 in odds between the two samples. While the difference in odds above might not seem large, it is important to remember this is only for a 10% change; and as the unit difference between institutions gets larger, the difference between the odds gets exponentially larger as well because this is not a linear transformation. So, while there was not a big difference between the models at the student-level, there are important differences related to the institutional culture and the potential impact on career outcomes. This is interesting because prior literature has described how students completing interdisciplinary research do not adhere well to the typical disciplinary socialization norms and practices (Holley, 2010; Weidman & Stein, 2003). These findings show some disciplines may be better at socializing interdisciplinary students to faculty careers compared to others and disciplinary makeup at an institution matters.

Additionally, the proportion of doctoral students completing an interdisciplinary dissertation at an institution was statistically significant in Model 2 and Model 3, but in Model 4 it is no longer statistically significant. Therefore, for students completing an interdisciplinary

dissertation, the proportion of students at their institution also completing an interdisciplinary dissertation does not affect their likelihood of obtaining a faculty position. This runs counter to arguments about the positive impact of universities creating an interdisciplinary culture to create a more positive socialization experience for interdisciplinary doctoral students (Culpepper et al., 2020; Gardner et al., 2012). However, student predisposition to interdisciplinary research is only one of many institutional factors that may influence an interdisciplinary culture. This analysis fills a gap in the literature, as there is limited evidence to the institutional characteristics that explain obtaining a faculty job for students completing an interdisciplinary dissertation upon completion of their doctoral degree.

Through the investigation of these four research questions, I uncovered important student and institution characteristics that influence the likelihood of obtaining a faculty job. Some of these findings confirm prior research, some diverge from prior research, and some fill a gap in the literature where more information was needed. Completing an interdisciplinary dissertation was not significant at the student-level. Therefore, faculty should not discourage this career path for students with interdisciplinary interests. However, the institutional interdisciplinary environment, measured by the proportion of students completing an interdisciplinary dissertation, decreased the likelihood of a student obtaining a faculty job, which speaks to potential differences in socialization. Additionally, doctoral field of study had more of an influence on the likelihood of obtaining a faculty job than student characteristics. These fields mostly increased the likelihood over engineering but had differing effect sizes. This was true at both the student-level and institution-level. RQ3 and RQ4 show there is not much difference in the influencing variables at the student-level between the full population and only those completing an interdisciplinary dissertation, but there are bigger differences at the institution-

level that explain differences in institutional culture for students completing interdisciplinary dissertations.

Contribution to Research

This study shows the importance of applying hierarchical models to research questions related to outcomes for students in doctoral programs. Specifically, it exposes the necessity of including institution-level characteristics when researching the relationship between completing an interdisciplinary dissertation and obtaining a faculty job. Prior research found a relationship at the student-level, and if this study would have followed this methodology it would have concluded there is no relationship between completing an interdisciplinary dissertation and obtaining a faculty position. Critical to graduate education, this would have missed important explanatory variables at the institutional level. The models that only had student-level predictors show only minimal changes in the model fit (-2LL) when compared to the unconditional model. Model 2 and Model 3 explained around 7% of the variance and Model 4 showed a decreased model fit. The final model with student-level (within school) and institution-level (between school) effects explained 64% of the variance from the unconditional model.

Additionally, completing an interdisciplinary dissertation, the *sin qua non* of this study, was not found to be statistically significant at student level, but the aggregated version of the variable at the institution-level was statistically significant and shows a negative association. Without a hierarchical model, this important differential finding across levels would have been hidden. This study used two levels and does not account for disciplines nested within institutions. This suggests a three-level hierarchical model may be appropriate to include the influence of disciplinary characteristics to explain variance in the model and predict the likelihood of obtaining a faculty position.

Overall, there is not a lot of research being conducted that considers Level-2 variables. There were multiple institution-level variables that were found to be statistically significant influencers on a doctoral student's likelihood of obtaining a faculty job. As the model building showed (see Table 10), a large amount of the model variance was accounted for once the Level-2 variables were added to the model. Additionally, many of these predictors were found to have large effects, over 2 or under 0.5, which provide very important information to the interpretation of this model.

Limitations

Despite considering the literature that suggested multiple important variables at the student-level and institution-level, there are still limitations to this study that must be considered. First, this analysis was conducted on only one year of data. Even though it is a large sample size, combining multiple years of data will provide a more comprehensive view of the trends in faculty job attainment, completion of interdisciplinary dissertations, and the impact of various facets of the socialization of doctoral students to their future career. The students who completed their dissertation in this survey cycle were also affected by the COVID pandemic, which saw students have their studies and research disrupted, as well as significant economic and job market disruptions. This is important context to consider when looking at one year of data to draw conclusions. Additionally, within this population there were many students who did not yet have definite career plans, so the timing of the survey may have missed some students who were still seeking a faculty position. This study also only considers a doctoral student's first job upon completing their degree and does not capture individuals who completed a post-doctoral appointment and then went on to faculty, or students who took a faculty position later in their career after time in another field. Finally, this study is based on the Weidman et al. (2001) model

of graduate and professional student socialization. It is important to note that there is now a more recent model that is widely used as well by Weidman and Deangelo (2020) which expands on the older model and provides additional direction for addressing student diversity and fields of study to provide a more inclusive model of student socialization.

In addition to limitations based on the instrumentation of the survey, there are also limitations related to the key variables of interest. First, this is self-reported survey data which can lead to errors across variables due to mistakes or misinterpretation. Also, the survey only asks students to report whether they identified as male or female and this approach limits how the data can be reported and related back to socialization literature. No attempt is made to collect student gender in the survey. Next, the definition of interdisciplinary is subjective, and students may interpret this question based on differing definitions of what this means and the level of integration of fields that is required to meet this definition. Future research using this data set could operationalize the interdisciplinary dissertation variable in other ways. The method I took is the most direct, but not without issues.

There is additional detailed disciplinary information within the survey that could be used to refine the definition of an interdisciplinary dissertation to only those comprised of fields that cross broad fields of study. This may lead to a variable more in line with the definition of interdisciplinary research that includes research defined by the synthesis of ideas, data and information, methods, tools, concepts, and theories from two or more disciplines (Klein, 2013). Additionally, prior research already found most dissertations are between two closely related fields, so focusing on only those dissertations with fields from different broad fields would fill another gap in the literature (Falkenheim, 2010; Millar & Dillman, 2012).

Based on the significance and effect size of broad fields of study at both Level-1 and Level-2, further research should be conducted on the role of gender and race interacting with the broad field of study. This could include three-way interactions that consider demographic characteristics of students, field of study, and interdisciplinary dissertations. This could also take the form of a three-level hierarchical model, where Level-1 is student level, Level-2 is discipline, and Level-3 is institution. Further research should also look at the data longitudinally to look at changes in jobs over time to determine if there is a career pattern when considering a longer career trajectory for students completing an interdisciplinary dissertation that differs from those who completed a disciplinary dissertation. Additionally, this analysis is limited based on the definition of a faculty job. Many institutions treat postdoctoral positions as faculty positions, so this analysis could expand its definition of a faculty job to include postdoctoral positions. Including postdocs as faculty members in this analysis would increase the percentage of individuals reporting a faculty job from 17.4% to 58.4%. This may also contribute to explanations of disciplinary differences in faculty job obtainment, as it is the norm in many fields to complete a postdoctoral assignment before searching for a faculty position. The proportion of doctoral graduates from this sample obtaining a postdoctoral appointment was highest in Physical and Earth Sciences (62.4%) and Life Sciences (56.2%).

One important decision I made in this analysis was to use all eight broad fields of study instead of creating a STEM vs. Non-STEM variable. This was a meaningful decision because the results show how big of an impact some of the broad fields have on faculty job obtainment and how it varied between the broad fields. Lumping them together would have hidden these interesting findings. This does create a limitation in that it becomes more difficult to compare these findings with other studies that chose to use only STEM and Non-STEM. Moreover, using

broad fields of study limits the level of information provided. These eight broad fields aggregate more detailed disciplines. The SED collects disciplinary data on both the doctoral field of study as well as the fields of study used in dissertation research. An analysis including more detailed fields of study could lead to more refined results. This could also allow for a comparison of how closely related the fields of study are, based on whether they are in the same broad field or not, to determine how interdisciplinary a dissertation may be. It would also allow for the identification of certain pairs of fields that are common among those completing an interdisciplinary dissertation.

Implications

Policy and Practice

The results of this study have implications for doctoral students considering interdisciplinary research experiences, faculty across the disciplines responsible for training doctoral students, graduate school deans and other university leaders charged with institutionalizing responsive degree programs, and federal agencies setting and supporting an interdisciplinary research agenda through influential funding mechanisms. These results may dissuade potential doctoral students with the goal of obtaining a faculty job from conducting interdisciplinary research or an interdisciplinary dissertation. However, these results show career outcomes vary by discipline, and institutional disciplinary environment, and should also be an important factor when making decisions about a potential career path and rationale for obtaining a PhD.

Additionally, these results show there are likely considerable gaps in the socialization of interdisciplinary doctoral students compared to students with a disciplinary focus. Implementing intentional policies and practices focused on interdisciplinary doctoral students within a

socialization framework would also limit the uncertainty that has hindered early career researchers' engagement with interdisciplinary research (Daniel et al., 2022; Hein et al., 2018). Intentional practices should be implemented around helping interdisciplinary students communicate their research to a disciplinary audience, specific guidance on preparing job application materials, and creating events that highlight interdisciplinary researchers on campus or bringing them from outside the university to show students possible career paths. Intentional networking events for new students interested in interdisciplinary research with faculty and advanced graduate students would help students find collaborators and committee members who are open to interdisciplinary work.

University policies may not directly impact interdisciplinary doctoral students but will create a culture for interdisciplinarity and signal the importance of this kind of work to doctoral students. This can be done through policies such as cluster hiring, valuing interdisciplinary research in tenure and promotion policies, and the formalization of interdisciplinary research centers including dedicated physical space. Graduate schools and colleges often provide resources for graduate students who are looking for services or experiences beyond what is provided by their department. These existing spaces are an opportunity to reach graduate students interested in interdisciplinary work and provide formal structures and opportunities that are missing in their academic department. Faculty who support interdisciplinary research and serve as doctoral advisors are also key to the socialization of doctoral students with interests that cross disciplines.

Importantly, leaders in higher education need to work to institutionalize interdisciplinary culture to socialize those with interdisciplinary interests to faculty positions. Students in interdisciplinary programs have expressed a desire to be socialized to industry careers; however,

practices and policies that show doctoral students there is a place for them in academia and their work will be valued may play a role in changing that outlook (Reisman et al., 2022). Current interdisciplinary culture, and the lack of proper socialization, pushes doctoral students away from faculty positions or away from interdisciplinary research (Daniel et al., 2022; Hein et al., 2018). This may lead to a missed opportunity to have a faculty that is less disciplinary focused and more capable of working across disciplines training future researchers in any sector.

There is a need for universities to create the structure for this socialization. Completing an interdisciplinary dissertation, as measured in this study, does not imply any type of formal organization or interdisciplinary training received by the student. Research has shown that formal interdisciplinary training programs or research centers have positive outcomes for students. These should be implemented in institutions to facilitate a positive interdisciplinary environment (Borrego et al., 2014; Kniola et al., 2012; Leahey & Barringer, 2020; Schmidt et al., 2012).

Finally, NSF is a large funder of interdisciplinary research and has the power to encourage universities to implement structures to support interdisciplinary research and socialize doctoral students that are working with them. Incoming doctoral students indicate they expect to have meaningful opportunities to work across disciplines, and therefore this must be considered when universities are determining disciplinary structural and organizational decisions (Mayhew et al., 2021). These findings are a call to funders of interdisciplinary research to provide structure and support for interdisciplinary doctoral students that socializes students to the breadth of career opportunities available, but also shows them that there is an important role as a member of the faculty where interdisciplinarity will be appreciated.

Implications for Future Research

While this study found no significant relationship between completing an interdisciplinary dissertation and obtaining a faculty job, this finding opens the door for many new approaches that could be taken in future research on this topic. Future research should focus on the structures, policies, and practices that exist within a university that promote an interdisciplinary research environment that helps interdisciplinary doctoral students develop their scholarly identity through the socialization process. Prior literature has identified what some of these practices look like, and being able to operationalize them into a variable and include them in a hierarchical model would add value to this topic. The literature has shown that institutions are promoting interdisciplinary research, but this study suggests they are not necessarily hiring those with interdisciplinary experience, or they are not creating an environment where interdisciplinary students feel they can seek a career as faculty. Finally, this study does not capture the career intentions of students upon entering their doctoral program. Future research may consider adding to the existing literature on how participating in an interdisciplinary research experience shifts doctoral students' career focus during their socialization.

This study took a purely quantitative approach to measuring a very complicated social construct and future research on interdisciplinary experiences in doctoral education would benefit from the addition of qualitative methods or through a mixed methods approach. Integrating interviews with students to gain a better understanding of their lived experience navigating a disciplinary environment as an interdisciplinary scholar would add depth to the understanding of doctoral student socialization. Additionally, interviews with both doctoral students and faculty members related to how they define interdisciplinarity would provide

missing insight into how individuals define interdisciplinary research and whether it has a positive or negative connotation among their disciplinary peers.

The Survey of Earned Doctorates (SED) is currently the only data source that collects information on the type of dissertation a doctoral student completed across all research institutions in the United States. Therefore, the survey presents a unique opportunity to help researchers understand this group of students. There are multiple ways this survey instrument could be modified to assist researchers in operationalizing a definition of interdisciplinarity and in capturing interdisciplinary experiences beyond dissertation disciplines.

First, the SED could be more specific about what constitutes an interdisciplinary dissertation. By adding a definition that focuses on the synthesis of ideas, methods, and tools, this data point will be a more reliable indicator of an interdisciplinary dissertation. This would indicate to students completing the survey that an interdisciplinary dissertation goes beyond just combining information from two or more disciplines. Additionally, the SED could add a question related to the disciplinary makeup of the student's dissertation committee, which would provide evidence of interdisciplinary collaboration and validate whether the dissertation was likely to be interdisciplinary. For students who indicated they held a research assistantship, the SED could ask for more detailed information about the disciplines of other students in the lab, the research topic (if different from dissertation), and the discipline of the faculty advisor. Interdisciplinary experiences go beyond a doctoral student's dissertation, so future survey instruments should capture a broader set of experiences.

Conclusion

Interdisciplinary doctoral degree programs and research experiences have been expanding at institutions of higher education in the United States. Major funding agencies have

signaled interdisciplinarity is the mechanism for solving wicked problems, and universities have responded to this call by creating new degree programs, innovation hubs, research centers, and transformative graduate experiences. However, there are many barriers that exist to make it difficult to fully incorporate these programs outside of disciplinary structures. This leads to a lack of socialization of interdisciplinary students to the breadth of career pathways available and frequently dissuades them from pursuing an academic path. This study expanded upon prior literature that focused on trends in interdisciplinary dissertation completion and its impact on career outcomes. It went beyond descriptive statistics and student characteristics to explore the characteristics of a university that influence faculty job obtainment for all doctoral students and for those completing an interdisciplinary dissertation.

While there was no impact at the student level of completing an interdisciplinary dissertation, there is a contextual effect at the institution level that impacts the likelihood of a doctoral student obtaining a faculty job. Additionally, student characteristics such as gender and race did not have an impact on the likelihood of obtaining a faculty job when controlling for other Level-1 and Level-2 variables in the study. This shows discipline plays a strong influence, over demographic characteristics, for all students and for interdisciplinary students, on faculty job obtainment. Students completing interdisciplinary research are still typically situated and socialized within a discipline. Based on these results, it is important to focus future research on disciplinary characteristics and how interdisciplinary graduate students are integrated, or not, into a disciplinary socialization practice.

Completing an interdisciplinary dissertation may not influence the likelihood of obtaining a faculty job, but this says more about the current socialization practices in doctoral education and university environments than it does about individual student research. Socialization is the

process by which doctoral students are prepared to conduct research and enter a career (Weidman, 2010). Based on the different needs of students completing an interdisciplinary dissertation, universities must be intentional in the way these students are socialized to their future career. The institutional interdisciplinary environment, operationalized in this study by the proportion of doctoral students completing an interdisciplinary dissertation, decreased the likelihood of a student obtaining a faculty job. Additionally, when looking at only doctoral students who completed an interdisciplinary dissertation, the institutional interdisciplinary environment was not statistically significant. More research is necessary on the socialization of interdisciplinary doctoral students with particular attention to operationalizing institutional policies and practices.

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Appendix A

2021 Survey of Earned Doctorates Instrument with Annotated Variables

INFORMATION ONLY – DO NOT USE TO REPORT



SED

Survey of Earned Doctorates

July 1, 2020 to June 30, 2021

Conducted by



NATIONAL
ENDOWMENT
FOR THE
HUMANITIES

Data collection activities contracted to  IRTI
INTERNATIONAL

First Name	Middle Name	Last Name	Suffix (e.g., Jr.)
Birth name or former name, if legally changed		Today's Date	
PHDINSTNM; PHDINST; PHDNID; PHDCARN; PHDCARN15; PHDPUBPRV; PHDHBCU			
Doctoral Institution		City or Branch	
DOCCODE			
Type of Research Doctoral Degree (e.g., PhD, EdD, etc.)			

This information is solicited under the authority of the National Science Foundation Act of 1950, as amended. All information you provide is protected under the NSF Act and the Privacy Act of 1974, and will be used only for research or statistical purposes by your doctoral institution, the survey sponsors, their contractors and collaborating researchers for the purpose of analyzing data, preparing scientific reports and articles and selecting samples for a limited number of carefully defined follow-up studies. Per the Federal Cybersecurity Enhancement Act of 2015, your data are protected from cybersecurity risks through screening of the federal information systems that transmit your data. The last four digits of your Social Security number are also solicited under the NSF Act of 1950, as amended; provision of it is voluntary. It will be kept confidential. It is used for quality control, to assure that we identify the correct persons, especially when data are used for statistical purposes in federal program evaluation. Any information publicly released (such as statistical summaries) will be in a form that does not personally identify you or other respondents. Your response is voluntary and failure to provide some or all of the requested information will not in any way adversely affect you.

The time needed to complete this form varies according to individual circumstances, but the average time is estimated to be 20 minutes. If you have comments regarding this time estimate, you may write to the National Science Foundation, 2415 Eisenhower Avenue, Alexandria, VA 22314, Attention: NSF Reports Clearance Officer. A federal agency may not conduct or sponsor a collection of information unless it displays a currently valid OMB control number.

For more information about the Survey of Earned Doctorates, go to www.sedsurvey.org

INFORMATION ONLY – DO NOT USE TO REPORT

Part A1 - RESEARCH DOCTORAL DEGREE

A1. When did you start your research doctoral degree and when was the degree granted or when is it expected to be granted?

Month/year degree started: Month Year
PHDEMONTH PHDEYEAR

Month/year degree granted
 or expected: Month Year
PHDMONTH PHDCY

A2. What is the name of the department that supervised your doctoral studies?

This could be interdisciplinary committee, center, institute, etc. Please use the full department name and avoid acronyms.

Department/Committee/Center/Institute/Program

A3. What was the primary field of study for your research doctoral degree?

Do not use acronyms or abbreviations.

Field Name

A4. Was your dissertation research (or performance, project report, or music or literary composition) interdisciplinary?

Yes

No → **GO TO A6**

→ **A5. (If Yes to interdisciplinary research) Please list the fields of study for your dissertation research.**

Primary Field:
PHDDISSCIP; PHDDISS
 Field Name

Field 2:
PHDDISS2CIP; PHDDISS2
 Field Name

Field 3:
 Field Name

GO TO A7

A6. (If No) What was the name of the primary field of study for your dissertation research?

Primary Field:
PHDDISSCIP; PHDDISS
 Field Name

A7. Did you receive full or partial tuition remission (waiver) for your doctoral studies? TUITREMS

Select one.

- No, I did not receive any tuition remission
- Yes, I received remission for less than 1/3 of tuition
- Yes, I received between 1/3 and 2/3 of tuition
- Yes, I received remission for more than 2/3 of tuition, but less than full
- Yes, I received full tuition remission

INFORMATION ONLY – DO NOT USE TO REPORT

Part A2 - EDUCATIONAL HISTORY

A8. The next few questions ask about your educational experiences prior to entering your research doctoral degree.

Please select below all other degrees you have received after high school, and indicate the month and year each degree was started and awarded. *DO NOT include your research doctoral degree you reported already.*

** Number will depend on the type of degree respondents select.

Degree type (Select one per row).	Month started	Year started	Month awarded	Year awarded
<input type="checkbox"/> Another research doctoral degree (e.g., PhD, DSc) DEGR** <input type="checkbox"/> Professional doctoral degree (e.g., MD, DDS, DVM, JD, PsyD) <input type="checkbox"/> Master's degree (e.g., MS, MA, MBA, MSW) or equivalent <input type="checkbox"/> Bachelor's degree (e.g., BS, BA, AB) or equivalent <input type="checkbox"/> Associate's degree (e.g., AS, AA) or equivalent <input type="checkbox"/> Other postsecondary degree - Specify: <input type="text"/> DEGR**_other	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
<input type="checkbox"/> Another research doctoral degree (e.g., PhD, DSc) DEGR** <input type="checkbox"/> Professional doctoral degree (e.g., MD, DDS, DVM, JD, PsyD) <input type="checkbox"/> Master's degree (e.g., MS, MA, MBA, MSW) or equivalent <input type="checkbox"/> Bachelor's degree (e.g., BS, BA, AB) or equivalent <input type="checkbox"/> Associate's degree (e.g., AS, AA) or equivalent <input type="checkbox"/> Other postsecondary degree - Specify: <input type="text"/> DEGR**_other	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
<input type="checkbox"/> Another research doctoral degree (e.g., PhD, DSc) DEGR** <input type="checkbox"/> Professional doctoral degree (e.g., MD, DDS, DVM, JD, PsyD) <input type="checkbox"/> Master's degree (e.g., MS, MA, MBA, MSW) or equivalent <input type="checkbox"/> Bachelor's degree (e.g., BS, BA, AB) or equivalent <input type="checkbox"/> Associate's degree (e.g., AS, AA) or equivalent <input type="checkbox"/> Other postsecondary degree - Specify: <input type="text"/> DEGR**_other	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
<input type="checkbox"/> Another research doctoral degree (e.g., PhD, DSc) DEGR** <input type="checkbox"/> Professional doctoral degree (e.g., MD, DDS, DVM, JD, PsyD) <input type="checkbox"/> Master's degree (e.g., MS, MA, MBA, MSW) or equivalent <input type="checkbox"/> Bachelor's degree (e.g., BS, BA, AB) or equivalent <input type="checkbox"/> Associate's degree (e.g., AS, AA) or equivalent <input type="checkbox"/> Other postsecondary degree - Specify: <input type="text"/> DEGR**_other	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>
<input type="checkbox"/> Another research doctoral degree (e.g., PhD, DSc) DEGR* <input type="checkbox"/> Professional doctoral degree (e.g., MD, DDS, DVM, JD, PsyD) <input type="checkbox"/> Master's degree (e.g., MS, MA, MBA, MSW) or equivalent <input type="checkbox"/> Bachelor's degree (e.g., BS, BA, AB) or equivalent <input type="checkbox"/> Associate's degree (e.g., AS, AA) or equivalent <input type="checkbox"/> Other postsecondary degree - Specify: <input type="text"/> DEGR**_other	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>

INFORMATION ONLY – DO NOT USE TO REPORT

A9. *(If you did not receive a professional doctorate)* In addition to your doctoral degree, are you currently earning a professional doctoral degree, such as an MD, DDS, DVM, JD, or PsyD? PROFEARN

Yes

No

A10. *(If you did not receive an associate's degree)* Have you ever earned college credit from a community or 2-year college? JRCOLL

Yes

No

A11. In what month and year did you first enter any graduate program, even if you did not earn a degree?

Month: GEMONTH

Year: GEYEAR

EDUCATION HISTORY DEGREE LOOP STARTS

In the web instrument, degrees reported in Questions A8 and A9 go through the loop for each degree. Up to 9 degrees are allowed, and multiple degrees of same type are looped through that degree type section each time.

ASSOCIATE'S DEGREE LOOP STARTS

A12. Please indicate the geographic location of the institution for your associate's degree in [year awarded].

Inside the United States or U.S. Territory

Outside of the United States

A13. Please type the institution name where you received your associate's degree in [year awarded].

Institution Name:

City/Town:

State/Foreign Country:

A14. What was the field of study for your associate's degree in [year awarded]?

Do not use acronyms or abbreviations.

Field Name

ASSOCIATE'S DEGREE LOOP ENDS

INFORMATION ONLY – DO NOT USE TO REPORT

BACHELOR'S DEGREE LOOP STARTS

A15. Please indicate the geographic location of the institution for your bachelor's degree in [year awarded].

- Inside the United States or U.S. Territory
 Outside of the United States

A16. Please type the institution name where you received your bachelor's degree in [year awarded].

Institution Name:	<input type="text" value="BAINST; BAINSTNM; BANID; BACARN; BACARN15; BAPUBPRV; BAHBCU
BA2INST; BA2INSTNM; BA2NID; BA2CARN; BA2CARN15; BA2PUBPRV; BA2HBCU"/>
City/Town:	<input type="text"/>
State/Foreign Country:	<input type="text" value="BAPLACE"/>

A17. What was the field of study for your bachelor's degree in [year awarded]?

Do not use acronyms or abbreviations.

Field Name	<input type="text" value="BAFIELD; BA2FIELD; BAFIELD; BAFIELDCIP; BA2FIELDCIP"/>
------------	--

A18. Did you complete a double major for your bachelor's degree that you received in [year awarded]?

- Yes BADBLMAJ
 No → GO TO A20

→ A19. (If Yes) What was the second major field of study for your bachelor's degree in [year awarded]?

Do not use acronyms or abbreviations.

Field Name	<input type="text" value="BADBLFIELD; BADBLFIELDCIP"/>
------------	--

BACHELOR'S DEGREE LOOP ENDS

MASTER'S DEGREE LOOP STARTS

A20. Please indicate the geographic location of the institution for your master's degree in [year awarded].

- Inside the United States or U.S. Territory
 Outside of the United States

A21. Please type the institution name where you received your master's degree in [year awarded].

Institution Name:	<input type="text" value="MAINST; MAINSTNM; MANID; MACARN; MACARN15; MAPUBPRV; MAHBCU
MA1INST; MA1INSTNM; MA1NID; MA1CARN; MA1CARN15; MA1PUBPRV; MA1HBCU"/>
City/Town:	<input type="text"/>
State/Foreign Country:	<input type="text"/>

A22. What was the field of study for your master's degree in [year awarded]?

Do not use acronyms or abbreviations.

Field Name	<input type="text" value="MAFIELD; MA1FIELD; MAFIELDCIP; MA1FIELDCIP"/>
------------	---

INFORMATION ONLY – DO NOT USE TO REPORT

A23. Which of the following best describes your master's degree in [year awarded]? MAPART; MA1PART; MSPREREQ

- This master's degree was required to enter or continue in my doctoral program _____
- This master's degree was not required and it did not fulfill any credits for my doctoral program → **GO TO A25**
- This master's degree was not required, but it fulfilled credits for my doctoral program

A24. About how many of the credits from your master's degree awarded in [year awarded] counted toward your doctoral degree? MACRED
MA1CRED

Select one.

- Some
- Most
- All

MASTER'S DEGREE LOOP ENDS

SECOND RESEARCH DOCTORAL DEGREE LOOP STARTS

A25. Please indicate the geographic location of the institution for your second doctoral degree in [year awarded].

- Inside the United States or U.S. Territory
- Outside of the United States

A26. Please type the institution name where you received your second doctorate in [year awarded].

Institution Name:

City/Town:

State/Foreign Country:

A27. What was the field of study for your second doctoral degree in [year awarded]?

Do not use acronyms or abbreviations.

Field Name

SECOND RESEARCH DOCTORAL DEGREE LOOP ENDS

PROFESSIONAL DOCTORAL DEGREE LOOP STARTS

A28. Please indicate the type of professional doctoral degree you have earned in [year awarded].

- MD MEDDENT; MDDEG; DDSDEG; PROFDEG
- DDS
- DVM
- JD
- PsyD
- DDiv
- Other professional doctorate - *Specify:* →

INFORMATION ONLY – DO NOT USE TO REPORT

A29. Please indicate the geographic location of the institution from which you have earned your professional doctoral degree in [year awarded].

- Inside the United States or U.S. Territory
 Outside of the United States

A30. Please type the institution name where you have earned your professional doctoral degree in [year awarded].

Institution Name:

City/Town:

State/Foreign Country:

PROFESSIONAL DOCTORAL DEGREE LOOP ENDS

OTHER POSTSECONDARY DEGREE LOOP STARTS

A31. Please indicate the geographic location of the institution for your other postsecondary degree.

- Inside the United States or U.S. Territory
 Outside of the United States

A32. Please type the institution name where you received your other postsecondary degree.

Institution Name:

City/Town:

State/Foreign Country:

A33. What was the field of study for your other postsecondary degree?

Do not use acronyms or abbreviations.

Field Name

OTHER POSTSECONDARY DEGREE LOOP ENDS

CURRENT PROFESSIONAL DOCTORAL DEGREE LOOP STARTS

A34. Please indicate the type of professional doctoral degree you are currently earning.

- MD MEDDENT; MDSTUDY; DDSSTUDY; PROFDEG
 DDS
 DVM
 JD
 PsyD
 DDiv
 Other professional doctorate - Specify:

INFORMATION ONLY – DO NOT USE TO REPORT

A35. Please indicate the geographic location of the institution from which you expect to earn your professional doctoral degree.

- Inside the United States or U.S. Territory
 Outside of the United States

A36. Please type the institution name where you are earning your professional doctoral degree.

Institution Name:

City/Town:

State/Foreign Country:

A37. When did you start the professional doctoral degree that you are currently earning and when is the degree expected to be granted?

	PROFEMO	PROFYE	
Month/year degree <u>started</u> :	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	Month Year
Month/year degree <u>expected</u> :	<input type="text"/> <input type="text"/>	<input type="text"/> <input type="text"/> <input type="text"/> <input type="text"/>	Month Year
	PROFEMO	PROFYE	

CURRENT PROFESSIONAL DOCTORAL DEGREE LOOP ENDS

END OF EDUCATION HISTORY DEGREE LOOP

A38. Please indicate whether each of the following was a source of financial support for your educational and living expenses during graduate school.

Include sources of support for all graduate-level degree programs (master's and doctorate).

Select Yes or No for each.

	Yes	No
SRCEA a. Fellowship, scholarship	<input type="checkbox"/>	<input type="checkbox"/>
SRCEB b. Dissertation grant	<input type="checkbox"/>	<input type="checkbox"/>
SRCEC c. Teaching assistantship	<input type="checkbox"/>	<input type="checkbox"/>
SRCED d. Research assistantship	<input type="checkbox"/>	<input type="checkbox"/>
SRCEE e. Other assistantship	<input type="checkbox"/>	<input type="checkbox"/>
SRCEF f. Traineeship	<input type="checkbox"/>	<input type="checkbox"/>
SRCEG g. Internship, clinical residency	<input type="checkbox"/>	<input type="checkbox"/>
SRCEH h. Loans (<i>from any source</i>)	<input type="checkbox"/>	<input type="checkbox"/>
SRCEI i. Personal savings	<input type="checkbox"/>	<input type="checkbox"/>
SRCEJ j. Personal earnings during graduate school (<i>other than sources listed above</i>)	<input type="checkbox"/>	<input type="checkbox"/>
SRCEK k. Spouse's, partner's, or family's earnings or savings	<input type="checkbox"/>	<input type="checkbox"/>
SRCEL l. Employer reimbursement/assistance	<input type="checkbox"/>	<input type="checkbox"/>
SRCEM m. Foreign (<i>non-U.S.</i>) support	<input type="checkbox"/>	<input type="checkbox"/>
SRCEN n. Other - <i>Specify:</i> <input style="width: 50px;" type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>

INFORMATION ONLY – DO NOT USE TO REPORT

A39. Based on the total amount of financial support provided, which of sources from A38 were your primary and secondary source of support?

Enter letters of primary and secondary sources.

Primary source of support SRCEPRIM; SRCE1ED

Secondary source of support Select if no secondary source

SRCESEC

A40. When you receive your doctoral degree, how much money will you owe that is directly related to your undergraduate and graduate education?

Select one in each column.

UNDERGRADUATE	UDEBTLVL	GRADUATE	GDEBTLVL
<input type="checkbox"/> None		<input type="checkbox"/> None	
<input type="checkbox"/> \$10,000 or less		<input type="checkbox"/> \$10,000 or less	
<input type="checkbox"/> \$10,001 - \$20,000		<input type="checkbox"/> \$10,001 - \$20,000	
<input type="checkbox"/> \$20,001 - \$30,000		<input type="checkbox"/> \$20,001 - \$30,000	
<input type="checkbox"/> \$30,001 - \$40,000		<input type="checkbox"/> \$30,001 - \$40,000	
<input type="checkbox"/> \$40,001 - \$50,000		<input type="checkbox"/> \$40,001 - \$50,000	
<input type="checkbox"/> \$50,001 - \$60,000		<input type="checkbox"/> \$50,001 - \$60,000	
<input type="checkbox"/> \$60,001 - \$70,000		<input type="checkbox"/> \$60,001 - \$70,000	
<input type="checkbox"/> \$70,001 - \$80,000		<input type="checkbox"/> \$70,001 - \$80,000	
<input type="checkbox"/> \$80,001 - \$90,000		<input type="checkbox"/> \$80,001 - \$90,000	
<input type="checkbox"/> \$90,001 or more - Specify: ↓		<input type="checkbox"/> \$90,001 - \$100,000	
\$		<input type="checkbox"/> \$100,001 - \$120,000	
		<input type="checkbox"/> \$120,001 - \$140,000	
		<input type="checkbox"/> \$140,001 - \$160,000	
		<input type="checkbox"/> \$160,001 or more - Specify: ↓	
		\$	

Part B1 - POSTGRADUATION PLANS

B1. Where do you intend to live in the year after graduation? PDLOC; PDUSFOR

Select one.

Inside the United States or U.S. territory

→ State or U.S. territory:

Outside the United States

→ Country:

B2. What best describes the status of your postgraduate plans? PDOCSTAT

Select one.

I accepted or began a postdoc, residency, or other training position _____
(A "postdoc" is a temporary position primarily for gaining additional education and training in research, awarded in academe, industry, government, or a nonprofit organization.) → GO TO POSTDOC OR OTHER TRAINING on PAGE 10

I am returning to, or continuing in, predoctoral employment _____
 I accepted or am employed in a position other than a postdoc or training position _____
(including self-employment) → GO TO EMPLOYED OTHER THAN POSTDOC OR TRAINING on PAGE 11

I am negotiating an offer of employment with one or more specific organizations _____
 I am seeking a position but currently have no offer of employment _____ → GO TO NEGOTIATING OR SEEKING on PAGE 13

I am enrolling in a full-time degree program (e.g., PhD, MD, DDS, JD, MBA) _____

I do not plan to work or study (e.g., family commitments) _____
 Other - Specify: → GO TO PART B2 on PAGE 13

INFORMATION ONLY – DO NOT USE TO REPORT

POSTDOC OR OTHER TRAINING (if you checked Box 1 in B2)

B3. What best describes the nature of your postdoc or other training? PDOCPLAN

Select one.

- Postdoc fellowship or research associateship
- Traineeship
- Internship, clinical residency
- Other training - Specify:

B4. What one type of employer will you be working for on your postdoc or other training? PDEMPLOY; PDEMPSECTOR

Select one.

EDUCATION

- U.S. 4-year college or university other than medical school
- U.S. medical school (including university-affiliated hospital or medical center)
- U.S. university-affiliated research institute
- U.S. community or 2-year college
- U.S. preschool, elementary, middle, secondary school or school system
- Foreign educational institution

GOVERNMENT (other than educational institution)

- U.S. federal government
- U.S. state government
- U.S. local government
- Foreign government

PRIVATE OR NONPROFIT SECTOR

- For-profit company or organization
- Nonprofit organization (including tax-exempt, charitable organization and private foundation)

OTHER

- Self-employed
- Other - Specify:

B5. Please name the organization and geographic location where you will work or train.

Please use the full organization name and avoid acronyms.

a. Organization Name:

PD OCCODE; P DOCNID

b. Geographic location:

Select one. PD LOC; P DUSFOR

Inside the United States or U.S. territory

→ State or U.S. territory:

Outside the United States

→ Country:

c. Is this a college or university? Yes No

B6. What will be your primary and secondary work activities?

Select one in each column.

	PDWKPRIM; PDWK1ED	PRIMARY	SECONDARY	PDWKSEC; PDWK2ED
Research and development	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Teaching	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Management or administration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Professional services (such as health care, engineering, consulting, counseling, financial, or legal services)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other - Specify: <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No secondary work activities			<input type="checkbox"/>	

B7. What will be the main source of financial support for your postdoc or other training? PDSTDSUP

Select one.

- U.S. government
- Industry/business
- College or university
- Private foundation
- Nonprofit, other than private foundation or college
- Foreign government
- No financial support (unpaid position)
- Other - Specify:
- Not sure/Unknown

INFORMATION ONLY – DO NOT USE TO REPORT

B8. What will be your basic annual salary for this postdoc or other training?

If you are not salaried, please estimate your earned income.

Please enter a whole number without any commas, decimals or special characters.

Annual Salary/Earned Income:

In which currency did you report your salary above?

U.S. Dollars

Another currency - *Specify:*

If you prefer not to report an exact amount, please indicate into which range you expect your salary to fall:

Select one. SALARYR

- | | |
|--|--|
| <input type="checkbox"/> \$30,000 or less | <input type="checkbox"/> \$80,001 - \$90,000 |
| <input type="checkbox"/> \$30,001 - \$35,000 | <input type="checkbox"/> \$90,001 - \$100,000 |
| <input type="checkbox"/> \$35,001 - \$40,000 | <input type="checkbox"/> \$100,001 - \$110,000 |
| <input type="checkbox"/> \$40,001 - \$50,000 | <input type="checkbox"/> \$110,001 - \$120,000 |
| <input type="checkbox"/> \$50,001 - \$60,000 | <input type="checkbox"/> \$120,001 - \$130,000 |
| <input type="checkbox"/> \$60,001 - \$70,000 | <input type="checkbox"/> \$130,001 or more |
| <input type="checkbox"/> \$70,001 - \$80,000 | <input type="checkbox"/> Don't know |

B9. Is this salary based on a 12-month year or fewer than 12 months? SALMONTH

12-month year

Less than 12 months

Number of Months (1-12):

GO TO PART B2 on PAGE 13

EMPLOYED OTHER THAN POSTDOC OR TRAINING
(if you checked Box 2 or 3 in B2)

B10. Is your employment considered military service? PDOCLAN

- Yes
 No

B11. What one type of employer will you be working for?

Select one. PDEMPSECTOR, PDEMPLOY

EDUCATION

- U.S. 4-year college or university other than medical school
 U.S. medical school (*including university-affiliated hospital or medical center*)
 U.S. university-affiliated research institute
 U.S. community or 2-year college
 U.S. preschool, elementary, middle, secondary school or school system
 Foreign educational institution

GOVERNMENT (*other than educational institution*)

- U.S. federal government
 U.S. state government
 U.S. local government
 Foreign government

PRIVATE OR NONPROFIT SECTOR

- For-profit company or organization
 Nonprofit organization (*including tax-exempt, charitable organization and private foundation*)

OTHER

Self-employed

Other - *Specify:*

INFORMATION ONLY – DO NOT USE TO REPORT

B12. Please name the organization and geographic location where you will work.

Please use the full organization name and avoid acronyms.

a. Organization Name:

PD OCCODE; PD CNID

b. Geographic location:

Select one.

Inside the United States or U.S. territory PD LOC; PD USFOR

→ State or U.S. territory:

Outside the United States

→ Country:

c. Is this a college or university?

Yes

No → **GO TO B14**

PD FORGN

→ B13. (If Yes) At this educational institution, will you be holding a faculty position? PD FACULTY

Select one.

Yes, a tenure-track faculty position

Yes, a non-tenure-track faculty position

No

B14. What will be your primary and secondary work activities?

Select one in each column.

	PDWKPRIM; PDWK1ED	PRIMARY	SECONDARY	PDWKSEC; PDWK2ED
Research and development	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Teaching	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Management or administration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Professional services (such as health care, engineering, consulting, counseling, financial, or legal services)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Other - Specify: → <input style="width: 300px;" type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
No secondary work activities			<input type="checkbox"/>	

B15. What will be your basic annual salary for this principal job?

If you are not salaried, please estimate your earned income. Do not include bonuses or additional compensation for summertime teaching or research.

Please enter a whole number without any commas, decimals or special characters.

Annual Salary/Earned Income: SALARYV

In which currency did you report your salary above?

U.S. Dollars

Another currency - Specify:

If you prefer not to report an exact amount, please indicate into which range you expect your salary to fall:

Select one. SALARYR

\$30,000 or less

\$30,001 - \$35,000

\$35,001 - \$40,000

\$40,001 - \$50,000

\$50,001 - \$60,000

\$60,001 - \$70,000

\$70,001 - \$80,000

\$80,001 - \$90,000

\$90,001 - \$100,000

\$100,001 - \$110,000

\$110,001 - \$120,000

\$120,001 - \$130,000

\$130,001 or more

Don't know

B16. Is this salary based on a 12-month year or fewer than 12 months? SALMONTH

12-month year

Less than 12 months

Number of Months (1-12):

B17. Is your position with the same employer you worked for during your doctoral studies or before you started your doctoral studies? PDSAMEEMP

Select one.

Yes, I first worked for this employer before I started my doctoral studies

Yes, I first worked for this employer during my doctoral studies

No

GO TO PART B2 on PAGE 13

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NEGOTIATING OR SEEKING (if you checked Box 4 or 5 in B2)**B18. What type of position(s) are you negotiating or seeking?**Select *one or more*.

SEEKPOSPDOC A postdoc or other training position
(A "postdoc" is a temporary position primarily for gaining additional education and training in research, awarded in academe, industry, government, or a nonprofit organization.)

SEEKPOSEMP Employment (other than a postdoc or training position)

SEEKPOSOTHR Other - Specify:

B19. What type of employer(s) are you negotiating with or seeking?Select *one or more*.

SEEKEMPEDU a Educational institution

SEEKEMPGOV b Government (other than educational institution)

SEEKEMPBUS c Business/industry

SEEKEMPNPO d Nonprofit organization (including private foundation)

SEEKEMPOTHR e Other - Specify:

B20. Did you mark more than one response in Question B19?

Yes

No **> GO TO B22**

B21. Of the employers you selected in B19, which ONE employer would be your top choice?

SEEKEMPCHOICE

Enter **letter** of top choice.

Top Choice

B22. What is your current employment status?

SEEKEMPSTAT

Please include part-time, full-time, and temporary positions.

I am employed in a position related to my field of study

I am employed in a position not related to my field of study

I am not employed **→ GO TO B24 BELOW**

B23. (If employed) Is your position with the same employer you worked for during your doctoral studies or before you started your doctoral studies?

PDSAMEEMP

Select *one*.

Yes, I first worked for this employer before I started my doctoral studies

Yes, I first worked for this employer during my doctoral studies

No

Part B2 - IMPACT OF COVID-19 PANDEMIC

The next questions focus on how the Coronavirus Disease 2019 (COVID-19) may have affected your graduate experiences and career plans.

B24. Did you experience any of the following as a result of the COVID-19 pandemic?Select *Yes or No* for each.

	Yes	No	
a. The timeline for completing my doctoral degree changed.	<input type="checkbox"/>	<input type="checkbox"/>	COVA
b. My research was disrupted.	<input type="checkbox"/>	<input type="checkbox"/>	COVB
c. Funding for my doctoral studies was reduced or suspended.	<input type="checkbox"/>	<input type="checkbox"/>	COVC
d. My immediate postgraduate employment or education plans changed.	<input type="checkbox"/>	<input type="checkbox"/>	COVD
e. My longer term career plans or goals changed (e.g., type of employer, research focus).	<input type="checkbox"/>	<input type="checkbox"/>	COVE
f. My plans about where to live in the year after graduation were affected.	<input type="checkbox"/>	<input type="checkbox"/>	COVF
g. My graduate experience or career plans changed in other ways.	<input type="checkbox"/>	<input type="checkbox"/>	COVG

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The next questions ask you to provide more detail on the ways COVID-19 affected your graduate experiences and career plans.

B25. (If B24.a=Yes) How did the timeline for completing your doctoral degree change?

COVA_OTH

B26. (If B24.b=Yes) How was your research disrupted?

COVB_OTH

B27. (If B24.c=Yes) How was your funding reduced or suspended?

COVC_OTH

B28. (If B24.d=Yes) How did your immediate employment or education plans change?

COVD_OTH

B29. (If B24.e=Yes) How did your longer term career plans or goals change?

COVE_OTH

B30. (If B24.f=Yes) How did it impact your decision on where to live in the year after graduation?

COVF_OTH

B31. (If B24.g=Yes) In what other ways did your graduate experience or plans change?

COVG_OTH

Part C - BACKGROUND INFORMATION

C1. Are you male or female? SEX

- Male
 Female

C2. What is your current marital status? MARITAL

Select one.

- Married
 Living in a marriage-like relationship
 Widowed
 Separated
 Divorced
 Never married

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C3. Not including yourself or your spouse/partner, do you have any dependents?

Dependents are children or adults who receive at least one-half of their financial support from you.

Yes → Write in number of dependents in each age range.

5 years of age or younger	[]	DEPEND5
6 to 18 years	[]	DEPEND18
19 years or older	[]	DEPEND19

No

C4. What is the highest educational attainment of your parents or guardians?

Select one for each parent or guardian.

	MOTHER/ FEMALE GUARDIAN	FATHER/ MALE GUARDIAN
Less than high school completed	[]	[]
High school diploma or equivalent	[]	[]
Some college, vocational, or trade school	[]	[]
Associate's degree <i>(e.g., AS, AA)</i>	[]	[]
Bachelor's degree <i>(e.g., BS, BA, AB)</i>	[]	[]
Master's degree <i>(e.g., MA, MS, MBA, MSW)</i>	[]	[]
Professional degree <i>(e.g., MD, DDS, DVM, JD, PsyD)</i>	[]	[]
Research doctoral degree <i>(e.g., PhD, DSc)</i>	[]	[]
Not applicable/Unknown	[]	[]

EDMOTHER EDFATHER

C5. Where is your place of birth?

Select one.

Inside the United States or U.S. territory

→ State or U.S. territory: []

Outside the United States

→ Country: []

C6. What is your date of birth?

Month [] [] Day [] [] Year [] [] [] []

BIRTHMON BIRTHYR

C7. What is your citizenship status? CITZ: CITZ_R

Select one.

U.S. CITIZEN

Since birth → GO TO C9

Naturalized → GO TO C9

NON-U.S. CITIZEN

With a Permanent U.S. Resident Visa ("Green Card") → GO TO C8

With a Temporary U.S. Visa → GO TO C8

C8. (If a non-U.S. citizen) Of which country are you a citizen?

Country of present citizenship: CENTRYCIT

↓

[]

C9. What is the geographic location of the high school or secondary school that you last attended? HSPLACE

Select one.

Inside the United States or U.S. territory

→ State or U.S. territory: []

Outside the United States

→ Country: []

C10. Are you Hispanic or Latino? RACE; RACE_R; RACE2

Select one.

No, I am not Hispanic or Latino HISPANIC

Yes, I am Mexican or Chicano

Yes, I am Puerto Rican

Yes, I am Cuban

Yes, I am Other Hispanic or Latino - *Specify:* →

[]

C11. What is your racial background? RACE; RACE2; RACE_R

Select one or more.

American Indian or Alaska Native - *Specify tribal affiliation(s):* →

[]

Native Hawaiian or Other Pacific Islander HAWAIIAN

Asian ASIAN

Black or African American BLACK

White WHITE

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C12. The following questions are designed to help us better understand the educational paths of individuals with specific functional limitations. What is the USUAL degree of difficulty you have with...

Select one in each row.

		NONE	SLIGHT	MODERATE	SEVERE	UNABLE TO DO
DIFSEE	SEEING words or letters in ordinary newsprint <i>(with glasses/contact lenses, if you usually wear them)</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DIFHEAR	HEARING what is normally said in conversation with another person <i>(with hearing aid, if you usually wear one)</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DIFWALK	WALKING without human or mechanical assistance or using stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DIFLIFT	LIFTING or carrying something as heavy as 10 pounds, such as a bag of groceries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DIFCOGN	CONCENTRATING, REMEMBERING, or MAKING DECISIONS because of a physical, mental or emotional condition	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

C13. Mark this box (X) if you answered “NONE” to all the activities in Question C12, and go to Question C15.

C14. What is the earliest age at which you first began experiencing any difficulties in any of these areas?

Age OR Since birth
DIFAGE

C15. Please fill in the last four digits of your Social Security number.

- -

REMINDER: ALL INFORMATION YOU PROVIDE WILL BE TREATED AS CONFIDENTIAL and used only for research or statistical purposes by your doctoral institution, the survey sponsors, their contractors, and collaborating researchers for the purpose of analyzing data, preparing scientific reports and articles, and selecting samples for a limited number of carefully defined follow-up studies.

C16. Please provide the best contact information where you can be reached for possible additional research follow-up.

Your Current Street Address

City/State/Country/ZIP or Postal Code

E-mail Address

Daytime or Cell Telephone Number *(including area or country code)*

C17. Please provide the name and contact information of a person who is likely to know where you can be reached. Do not include someone in your household.

As with all the information provided in this survey, complete confidentiality will be provided. This person will only be contacted if we have difficulty contacting you.

Name of person who will know where you can be reached

Relationship *(e.g., family, work colleague/adviser, friend)*

City/State/Country/ZIP or Postal Code

E-mail Address

Telephone Number *(including area or country code)*

INFORMATION ONLY – DO NOT USE TO REPORT**To the Doctorate Recipient:**

Congratulations on earning a doctoral degree!

Type text here

Your accomplishment is significant for both this nation and others, as the new knowledge generated by research doctorates enhances the quality of life in this country and throughout the world. Because of the importance of persons earning research doctorates, several federal agencies—listed on the cover—sponsor this Survey of Earned Doctorates.

The basic purpose of this survey is to gather objective data about doctoral graduates. These data play an important role in local, regional and national initiatives concerning graduate education. Through outreach meetings with our constituents we have learned that decision makers in universities, private organizations and government agencies use data from the Survey of Earned Doctorates when developing new programs and allocating resources to current programs. If you have any comments about the survey, please provide them on page 17.

On behalf of the sponsoring federal agencies, I thank you for your participation in this survey.

Best wishes,

Emilda B. Rivers

Director

National Center for Science and Engineering Statistics

National Science Foundation

