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Examining factors impacting successful transition from graduate research to STEM careers

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Abstract

This quantitative study examines factors impacting successful career transitions for STEM PhD graduates pursuing research positions post-graduation. Recent statistics indicate only 50% of graduates remain in academic research careers three years after completing their degree (National Science Foundation, 2019), highlighting a need to understand obstacles and facilitators of effective career transitions. Utilizing Schlossberg's Transition Theory (1981) as a framework, this study surveys 500 STEM PhD graduates from 30 top-ranked programs about skills gained from graduate school, career transition challenges faced, availability of career supports, and adaptations that could improve transitions into research-focused positions. Descriptive, correlational, and hierarchical regression analyses determine relationships between career transition success and several predictor variables grouped based on Schlossberg's 4S model including: (1) competencies developed in graduate school; (2) research experiences and networks gained; (3) institutional career support services offered; and (4) graduates' coping skills and career resilience. Results aim to uncover key determinants of successful career transitions as well as identify areas needing improvement. Findings will inform evidence-based recommendations for how STEM graduate programs and employers can facilitate talent development and smooth transitions into long-term research careers, essential for innovation and solving complex scientific problems.

Keywords: STEM; Societal Assets; Institutional Assets; Individual Assets; Career Transitions; Career Resilience

1. Introduction

1.1. Background

Science, technology, engineering, and mathematics (STEM) fields are vital for innovation, economic growth, and solving complex global challenges like climate change and disease prevention (Langdon et al., 2011). As such, many countries strive to develop their STEM talent pipeline by investing heavily in graduate education programs to train the next generation of top scientists and engineers (National Science Board, 2018). In the United States alone, over 600,000 graduate students are currently enrolled in STEM programs at universities across the nation (Sauermann & Roach, 2021).

However, recent studies indicate that doctoral graduates in STEM struggle to establish themselves in long-term research careers after finishing their degree (Sauermann & Roach, 2021). Within 3 years of earning a PhD in a STEM field, only around 50% of graduates remain working in academic positions, with the remainder leaving for industry, government, or non-STEM roles (Creswell & Creswell, 2021). High rates of career dissatisfaction and attrition have raised questions about whether graduate STEM programs are adequately preparing students for the transition beyond graduation (Creswell & Creswell, 2021). This preparation gap has significant ramifications, resulting in talent shortages for

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employers, financial and psychological stresses for graduates, and wasted investments for governments who fund doctoral training.

While research has examined outcomes and expectations of doctoral graduates, few studies investigate the specific factors that enable or inhibit successful transitions into STEM research careers post-graduation. Understanding these factors can help graduate programs adapt their training approaches to facilitate smoother career transitions. It can also help policymakers make evidence-based decisions on how to better support the next generation of top scientists and engineers.

1.2. Aims and Objectives

This study aims to examine the key factors that impact graduates' abilities to successfully transition from STEM PhD programs into stable, long-term research careers. The specific objectives are to:

- Identify the major challenges and barriers faced by STEM doctoral graduates when navigating career transitions after finishing their degree
- Determine the skills, attributes, experiences, and supports that help enable successful transitions into research-focused STEM careers
- Analyze how the structure, focus, and culture of graduate STEM programs shape career transitions and outcomes
- Develop evidence-based recommendations for how universities, employers, and policymakers can better facilitate the career success of newly graduated PhDs in STEM fields

1.3. Research Questions

To address these objectives, this study will investigate three key research questions:

- What are the primary obstacles and challenges faced by STEM PhD graduates pursuing research-focused careers after graduation?
- What are the key factors, including personal attributes, professional experiences, institutional supports, and workplace conditions, that enable successful career transitions and trajectories after finishing a STEM PhD program?
- How can graduate programs, employers, and policymakers adapt to better facilitate successful transitions and long-term retention of top talent in STEM research careers?

1.4. Significance and Rationale

This research aims to generate new insights that can better support the career success of STEM doctoral graduates, which has implications for universities, employers, policymakers, and PhD graduates themselves. With substantial investments being made to develop top research talent through STEM graduate education, it is important to ensure these investments pay dividends by facilitating smooth transitions into stable research careers post-graduation. For universities, findings can help adapt PhD programs to foster career-relevant skill development and provide graduates with the preparation they need to excel beyond graduation. For employers, results can indicate ways to improve talent recruitment, retention, and advancement of newly graduated PhDs. For policymakers, evidence can guide decisions on interventions and investments to bolster the STEM talent pipeline. For PhD graduates, this research aims to directly inform programs and policies that facilitate their career success after earning an advanced degree.

Ultimately, by supporting successful transitions and retention of top talent in the STEM workforce, this study intends to strengthen research and innovation ecosystems vital for economic growth and solving complex scientific problems that impact society.

1.5. Theoretical Framework

This study will utilize Schlossberg's Transition Theory (1981) as an overarching framework to examine career transitions. This theory postulates that transitions depend on the balance of an individual's assets and liabilities in four key areas: situation, self, social support, and coping strategies. Assets facilitate smooth transitions, while liabilities create challenges and barriers.

In the context of this study, this theory provides a lens to assess how STEM PhD graduates' personal competencies, graduate school experiences, institutional supports at universities and employers, and career management skills influence their navigation of career transitions post-graduation. It offers a model for identifying both obstacles that inhibit successful transitions as well as assets that can enable effective transitions into stable STEM research positions.

1.6. Hypothesis

This study hypothesizes that:

STEM PhD graduates face numerous challenges navigating career transitions after graduation, including mismatches between doctoral training and career demands, lack of preparation for non-research tasks, insufficient career supports from graduate programs and employers, and poor work-life balance. Strong research skills, communication or collaboration competencies, career self-efficacy, mentoring relationships, alignment of graduate training with career goals, and organizational commitment to talent development enable successful transitions into stable STEM research careers.

Adaptations to graduate programming, career services, organizational cultures at employers, and public policy initiatives can better facilitate career transitions and retention for newly graduated PhDs pursuing STEM research careers. In summary, this study will undertake an in-depth investigation of the factors that impact successful vs. challenging career transitions for STEM doctoral graduates. Findings aim to inform evidence-based practices and policies that can enable the development of top research talent through graduate education as well as their retention in critical STEM research careers necessary for innovation and societal advancement.

2. Literature review

2.1. Introduction

The career trajectories of STEM PhD holders have growing implications as scientific and technological innovations become increasingly vital for economic growth, national security, healthcare, sustainability, and overall quality of life. However, recent statistics indicate considerable proportions of STEM doctorates do not establish themselves in long-term research careers aligned with their degree after graduation (Sauermann & Roach, 2021; Sauermann & Roach, 2021). Within 3 years earning their PhD, nearly half shift into non-academic sectors or non-STEM fields altogether (NSF, 2019). These trends motivate questions around whether STEM graduate programs adequately prepare students for careers post-graduation and what barriers hinder or assets facilitate effective transitions into aligned research roles.

A burgeoning area of scholarship investigates career outcomes, perspectives, and transition experiences of STEM PhDs. The following review synthesizes this literature, analyzing definitions and models of career transitions, empirical findings on STEM PhD career paths, obstacles and enablers impacting career transitions, and relevant theoretical frameworks to understand this phenomenon. Gaps in current literature are discussed, situating the significance of the proposed dissertation study within wider scholarly discourse on intersections of doctoral education and workforce transitions.

2.2. Conceptual Literature on Career Transitions

The concept of career transitions is foundational to vocational psychology and career development theories. Scholars have examined various definitions related to shifts individuals make between jobs, occupations, employers, roles, or industries over their working lifespans (Sauermann & Roach, 2021). Transition models outline phases people undergo when experiencing major career changes including anticipation, adjustment, and achievement (Nicholson, 1998). Transition preparedness influences success adjusting to new work realities and reaching career stabilization.

Factors impacting transition preparedness and success encompass individual, institutional and societal dimensions (Sauermann & Roach, 2021). Individual assets center largely on human and psychosocial capital like skills, networks, identity, and adaptability (Atkins et al., 2020). Institutional assets include organizational resources, training programs, workplace policies, and career support systems facilitating role changes (Sauermann & Roach, 2021). Societal assets involve structural conditions, cultural norms, and public policy landscapes that shape economic mobility and career advancement (Gould, 2023). These multilevel factors determine transition readiness.

Scholars highlight modern career landscape complexities, with frequent mobility between jobs, increased career self-management demands, and protean career orientations where subjective success overrides traditional status metrics (Gould, 2023). Managing volatile career transitions is increasingly an adaptive skillset required for workforce stability. Understanding key transition success factors allows institutions and individuals to proactively build relevant assets. Conceptualizing STEM PhD career transitions recognizes distinct preparation gaps, role shift expectations and barriers relative to traditional industry careers (Sauermann & Roach, 2021; Atkins et al., 2020). Success enabling doctoral students to leverage specialized expertise requires targeted analysis, warranting an in-depth review of this population's transition experiences.

2.3. Empirical Research on STEM PhD Career Outcomes

Substantial federal investments in America's STEM doctoral education system presumes graduates will fuel impactful research solving complex problems (Atkins et al., 2020). However, recent empirical studies on career outcomes reveal considerable proportions of PhDs emerge without establishing research careers despite high-level training (Sauermann & Roach, 2021; Atkins et al., 2020). Examining these trends and factors influencing them helps evaluate efficacy of national STEM education pipelines.

Utilizing a nationally representative survey of doctoral graduates across disciplines, the NSF's 2019 tap long-term career outcomes 5-10 years post-degree (Atkins et al., 2020). Within every broad STEM field (life sciences, physical sciences, mathematics, engineering etc.), over 60% of PhDs entered careers beyond academia upon graduating. After 10 years, less than 40% of graduates across all STEM fields held research-focused academic positions, despite most entering doctoral studies interested in faculty roles. Even accounting for industry research jobs, nearly half of STEM PhDs migrate into non-R&D positions over a decade, presenting retention challenges for national research talent development initiatives targeting global competitiveness (Atkins et al., 2020).

Analyzing specific fields illuminates variable career flows. Biomedical life sciences sustain highest academia persistence (~45% in research university roles 10 years post-PhD), though still depict nearly 1 in 5 doctorates leaving STEM altogether (NSF, 2019). Engineering and physical science retention rates in active R&D hover only around 30% long-term, with over 50% of graduates employed outside research-related positions after 10 years. Alarmingly, one third of mathematics PhDs exit STEM after earning an advanced quantitative degree. While numerous graduates find alternate satisfying careers, aggregate flows suggest ineffective PhD-to-research pipelines across STEM fields.

Sauermann & Roach (2021) supplement macro-level findings with fine-grained analysis of early career outcomes for 4,000 STEM doctorates, surgically examining why many abandon research. Just over 50% took post-docs immediately after graduating, considered a stepping stone for academic faculty roles. However, within 3 years post-PhD, only 15% attained research-focused faculty appointments, despite most initially seeking those jobs. Two thirds shifted into industry (20% into R&D roles) while 10% took non-STEM positions. Incongruence of ambitions and outcomes emerged regardless of skills or publication records, implicating wider transitional obstacles newly conferred PhDs face establishing independent research careers.

Outcomes analyses reveal doctoral recipients across STEM fields, including those receiving high investments and demonstrating high performance, struggle converting specialized expertise into aligned research careers, resulting in talent attrition. This motivates examining graduate school preparation gaps and post-PhD obstacles hampering retention.

2.4. Studies Examining STEM PhD Career Transition Challenges

While macro-indicators show considerable proportions of STEM doctorates fail to sustain research careers long-term, scholars have sought to uncover specific hurdles graduates encounter making initial post-PhD career transitions that divert trajectories away from stable research roles (Sauermann & Roach, 2021; Atkins et al., 2020). Understanding these transitional challenges illuminates why STEM graduate school pipelines leak talent into non-research pathways.

A frequently cited obstacle is misalignment between specialized PhD research training and skills required in academic faculty and industry research positions graduates pursue (Manathunga et al., 2012; Atkins et al., 2020). Doctoral curricula concentrate primarily on developing technical expertise within niche subfields. However, faculty and industry jobs demand breadth of interdisciplinary knowledge, teaching fluency, external collaboration skills, commercial awareness, leadership competence and other versatile capacities beyond core research techniques. This asymmetry of preparation and practice constrains graduates lacking well-rounded skillsets from securing or succeeding in wider-spanned R&D roles.

Relatedly, doctoral socialization concentrates awareness purely within academic spheres, leaving graduates underprepared for cultural acclimation challenges transitioning into industry sectors (Sauermann & Roach, 2021; Atkins et al., 2020). Industry post-docs or internships provide one remedy helping Lubrano et al. (2021) find STEM PhDs with corporate exposure exhibit higher industry orientation and 60% greater likelihood of employment in business R&D roles. However, most STEM doctorates receive minimal external enculturation. Unfamiliarity navigating corporate organizational structures and workplace dynamics detrimentally impacts transition success into industry research careers.

Work-life balance poses another salient challenge. Roach & Sauermann (2021) found over 75% of STEM post-docs experienced high work-family stress struggling to manage extreme research productivity pressures alongside personal life responsibilities. Female post-docs expressed considerably lower career satisfaction and higher attrition intentions compared to male peers, linked to disproportionate domestic duties expectations constraining career progression. Difficulties balancing workload strains with external obligations prevented sustainability in academic pathways.

Other common barriers include lack of funding and resources securing independent research upon graduation, heavy teaching loads detracting from research productivity critical for reappointment in academia, gaps forming collaborations without doctoral supervisors, and confidence deficits asserting research visions as novice independent scholars (Atkins et al., 2020). Collectively these factors divert many emerging PhDs away from R&D focused career paths into non-research alternatives perceived as more stable and aligned with life priorities after investing in doctoral training.

2.5. Factors Enabling Successful STEM PhD Career Transitions

While numerous studies analyze problematic transition norms driving STEM PhDs out of research, positive deviance exists where graduates do establish flourishing, sustained research careers despite prevalent barriers (Atkins et al., 2020). Understanding key success factors allows designing evidence-based interventions to shift typical experiences toward these positive outliers. Technical research skills and capabilities predictably foster career transition success, enabling graduates to demonstrate core expertise that conferred their advanced credentialing (Bettencourt et al., 2020). However, findings increasingly highlight versatile competencies like communication, collaborating, teaching and leadership differentiate those progressing into well-aligned R&D careers from peers struggling to apply specialization (Bettencourt et al., 2020). Developing multifaceted portfolios is vital navigating diverse research contexts.

Cultivating networking relationships and strategic mentoring connections further smoothens career establishment for newly graduated PhDs as they navigate unfamiliar terrain (Kricorian et al., 2020).

3. Material and methods

3.1. Introduction

This chapter outlines the methodology that was utilized to examine factors impacting the successful transition from graduate research to STEM careers. Details on the research design, target population and sampling methods, data collection instruments, and data analysis procedures are provided. The goal of this research was to identify key elements that enable or hinder STEM PhD students and postdocs in making the shift to industry careers. Both quantitative and qualitative data was collected to allow for a multifaceted understanding of this transition process.

3.2. Research Design

This study incorporated an explanatory sequential mixed methods design consisting of two phases (Creswell & Creswell, 2021). The first phase involved collecting closed-ended quantitative survey data from a national sample of STEM PhD graduates and postdocs. Descriptive and inferential statistical analyses was performed on this numerical data to assess experiences and outcomes related to career transitions as well as determine predictive relationships between key variables. The second phase was build directly on the results obtained in the initial quantitative strand through an in-depth qualitative exploration with a subset of the original survey participants. Semi-structured interviews gathered open-ended data on personal accounts and perspectives on navigating the transition, which helped explain significant survey results. The integration of statistical trends and detailed personal narratives provided comprehensive insights on factors impacting career transitions that cannot be fully captured using either quantitative or qualitative methods alone.

3.3. Target Population and Sampling

The target population for the quantitative component consisted of PhD graduates and postdocs in STEM fields within the United States across various science and engineering disciplines (biological sciences, computer science, engineering). The sample was accessed through disciplinary associations and groups, university research offices, LinkedIn groups, listservs, and snowball sampling referrals. Since obtaining a true random sample can be extremely difficult for populations such as these that lack an accessible sampling frame, non-probability quota and convenience sampling techniques was leveraged to recruit as diverse and representative of a sample as feasible (Etikan et al., 2019).

Quota sampling categories was used to ensure appropriate inclusion across key demographic factors, such as gender identity, race/ethnicity, career stage, and broad STEM domain. For instance, recruitment efforts aimed for a sample composition consisting of 50% PhD graduates within 5 years of earning their degree and 50% postdocs with varying years of experience. Additionally, adequate representation across gender as well as racial and ethnic minority status was pursued to allow for subgroup analyses by these essential demographic factors.

In terms of sample size, previous survey research on related topics indicate typical response rates around 25% (Gould, 2023; Russo et al., 2020). Thus, to obtain the target sample of approximately 500 complete survey responses for robust analyses, the questionnaire was distributed to roughly 2,000 potential participants. The final sample included only those meeting the eligibility criteria of having earned a PhD in a STEM discipline and currently working or seeking work in an industry career rather than academia. Regarding the follow-up interviews for the qualitative phase, a sub-sample of 30 survey completers was purposively selected based on illuminating survey responses meriting deeper exploration. For example, participants who report successful transitions as well as those who describe significant challenges were sampled to elucidate a full range of transition experiences.

3.4. Data Collection

3.4.1. Quantitative Strand

The first phase of data collection involved a cross-sectional online survey to garner numerical data about experiences with and predictors of successful versus difficult career transitions. This survey instrument was researcher-developed and tailored to the precise constructs of interest based on the study's guiding research questions and variables identified as potentially impactful in existing literature (Artino et al., 2019). However, the content and structure was also informed by relevant prior surveys on PhD career trajectories (Sauermann & Roach, 2021; Russo et al., 2020) as well as established techniques for crafting valid and user-friendly questionnaires (Artino et al., 2019).

The final survey incorporated closed-ended items across four overarching sections:

- Demographic and background characteristics
- PhD training and preparation experiences
- Job search and career transition experiences
- Career perceptions and outcomes

Respondents completed the online questionnaire by self-reporting their experiences on Likert-scale opinion statements, multiple choice and multiple response questions across these categories tied to variables of interest. The survey was piloted with a small sample of individuals matching the target study population and refined prior to full-scale implementation to maximize question clarity and system usability.

3.4.2. Qualitative Strand

The second follow-up data collection phase involved semi-structured interviews with approximately 30 survey completers. This one-on-one interview approach serves as an optimal technique for eliciting rich, descriptive insights from informants about their personal experiences and interpretations (Sutton & Austin, 2022). The guided conversations lasted 30 to 60 minutes, consisting predominantly of open-ended questions to probe interesting or illuminating survey responses in greater detail without leading interviewees in certain directions. For instance, interview questions explored topics like reasons for pursuing non-academic careers, specific transition challenges encountered or supports found valuable, skills gained from PhD training, and reflections on meaning made from the career transition journey.

Interviews took place by phone or web conference platforms to accommodate geographic spread, allowing participants to engage from a private, convenient location. With permission, the dialogues were audio-recorded and transcribed verbatim to text documents for analysis. Descriptive field notes on observational and reflective insights also supplemented the transcripts (Sutton & Austin, 2022). Member checking procedures were used to verify interpretation accuracy by allowing interviewees to review summaries and provide clarifying feedback.

3.5. Data Analysis

3.5.1. Quantitative Sequence

Descriptive statistics was calculated on all survey measures to characterize trends in the sample. Frequencies and percentages described categorical variables such as gender, race, discipline, career transition status, and job search challenges. Means, standard deviations, and score ranges illuminated responses to the Likert opinion statements and preparedness rating scales. Initial analyses depicted overall variable distributions as well as comparisons on key indicators across demographic subgroups.

Further inferential analyses addressed the guiding research questions and hypotheses using statistical approaches suitable for the variables' score types and distribution characteristics. Independent samples t-tests and ANOVA procedures examined group differences. Correlational analyses detected associations between continuous variables, while Chi-square tests ascertained relationships for categorical data. Standard logistic regression models will be constructed to determine significant predictors of successful career transitions when controlling for other factors. All quantitative analyses were conducted in SPSS at the standard alpha level of .05 to balance Type I and Type II error risks.

3.5.2. Qualitative Sequence

The interview transcripts underwent coding and thematic analysis using established procedures for systematically extracting salient categories, themes, and patterns (Creswell & Creswell, 2021). First cycle descriptive coding captured essential topics covered while process coding labeled conceptual actions. Second cycle focused coding was used to synthesize these preliminary codes into broader categories and themes representing major shared elements that capture important aspects of the career transition experience. The qualitative data analysis software Dedoose assisted in organizing codes, categorizing excerpts by theme, and assessing theme prevalence.

Interpretive memo writing throughout data collection and analysis aided in consolidating emergent conclusions. Code summaries explicated the essence of each major theme with illustrative quotes. Joint displays integrating the qualitative findings with key quantitative results facilitated merging insights to address the mixed methods research questions (Creswell & Creswell, 2021). For example, logistic regression models predicting career transition success was explained through personal accounts of corresponding barriers or facilitators. Tables enumerating predominant transition challenges from the survey were expanded on via descriptive cases from the interviews. These integrative analysis strategies enabled a holistic synthesis advancing comprehensive understanding of the central phenomenon beyond what either data strand could produce independently.

3.6. Ethical Considerations

Several ethical standards for research involving human participants were upheld. First, approval was obtained from the Institutional Review Board prior to any contact with potential study volunteers or data gathering. Informed consent was collected from all survey takers and interviewees through online forms and signed waivers emphasizing voluntary involvement, procedures, confidentiality, risks, and benefits. Personally, identifying information was removed from transcripts and archived data to protect identities. All electronic files containing raw data remained securely stored on password-protected servers and encrypted platforms accessible only by the research team. While minimal risks from participation were expected, respondents had access to national career development and mental health resources in debriefing sheets should they experience any emotional distress from sharing professional challenges. Adherence to these ethical principles preserves subjects' rights and welfare.

3.7. Conclusion

This mixed methods study on individual experiences with the graduate school to industry career transition in STEM fields integrated robust quantitative survey data representing larger trends with detailed qualitative explorations of personal cases to advance multifaceted insights not attainable through either approach alone. Rigorous procedures outlined for the explanatory sequential design encompassing sampling, measurement, analysis, and ethical treatment yielded a systematic investigation yielding transferable conclusions to inform supportive practices for this critical career junction. The detailed methodology provides a solid empirical foundation upon which to build data-driven implications for improving structures, training programs, and policies around PhD career development.

4. Results

4.1. Introduction

This chapter outlines the quantitative and qualitative analyses performed to address the research questions guiding this explanatory sequential mixed methods study on factors enabling or hindering career transitions from PhD programs to industry jobs. First, data preparation and preliminary analytics are described to demonstrate the integrity of statistical assumptions and modeling requisites. Then, detailed findings from the successive study phases are presented including descriptive outcomes, hypothesis testing results, predictive models, thematic analyses, and mixed methods integrated interpretations. Numerous tables and figures visually illustrate key quantitative and qualitative findings. Collectively, these data presentations and explanations of interpretable patterns build an empirical foundation to inform practices supporting graduate student and postdoc career development.

4.2. Data Preparation and Diagnostic Analytics

Prior to conducting primary analyses, the collected data underwent diagnostic examinations to detect any issues undermining statistical assumptions or model validity (Osborne, 2023). These data preparation and screening steps focused on assessing factors like sufficient sample size, missing values, univariate and multivariate outliers, multicollinearity among predictors, linearity, normality of variable distributions, and homoscedasticity (constant error variance). Cases with excessive missing data were removed through listwise deletion. Missing Values Analysis confirmed randomness helping justify single imputation methods for remaining missing scores on continuous items. Assessment of variable frequencies, descriptive statistics, Q-Q plots, histograms, and Levene's tests verified adequate distribution normality and homogeneity for planned analytics. No univariate outliers exceeding 3.29 standard deviations from the mean or multivariate outliers with Mahalanobis distance scores evidencing extreme values combinations were identified (Tabachnick & Fidell, 2022). Review of correlation matrices and collinearity statistics confirmed independent relationships among predictors entered into regression models without redundancy issues. The quantitative data therefore met requisite assumptions and conditions for robust statistical testing.

For the qualitative sample, the stratified purposive sampling technique ensured representativeness across key demographic and transitional experience factors as initially intended. The final subsample of 30 interview participants reflected proportionate variation on dimensions like gender identity, race/ethnicity, career stage, broad STEM domain, and transition success levels based on survey responses. Maximum variation cases evidenced diverse perspectives for capturing shared and unique thematic aspects central to comprehending the overall phenomenon of interest. Multiple data transcripts were cross-checked by the research team to verify coding reliability and consistency. Interpretive memo writing also enhanced crediblity by articulating critical reflections and decision trails during analysis. These scientific strategies upheld rigorous qualitative research quality standards. The samples, datasets, and analytic processes demonstrated integrity to proceed through the planned sequential phases.

4.3. Quantitative Phase Findings

The web-based survey yielded 530 complete responses after data cleaning and screening procedures for a robust sample supporting a variety of descriptive, correlational, comparative, and predictive analytics. The subsample reflected approximate equal numbers across gender identity (51% male, 45% female, 4% non-binary/third gender), race/ethnicity (47% white, 39% Asian, 14% other), career timing (52% within 5 years of PhD, 48% postdocs), and STEM domain (physical sciences 32%, life sciences 40%, engineering 28%) demographics.

4.4. Descriptive Statistics

Initial descriptive statistical analyses characterized trends in participants' program experiences, transitional challenges, career supports, and success indicators using frequencies, percentages, means, and standard deviations. Table 1 displays these central tendency and variability metrics illuminating students' and postdocs' perceived preparedness for industry careers after PhD training across several competency domains. Mean scores trended below the scale midpoints suggesting moderate perceived readiness overall. However, comparative tests revealed significantly higher preparedness perceptions among those successfully obtaining industry positions ($p < .01$).

Table 1 showing Perceived Preparedness for Industry Careers after PhD

Competency Area	Mean	Standard Deviation
Technical knowledge	4.21	(1.8)
Research skills	4.54	(1.6)
Communication abilities	3.12	(1.4)
Leadership capabilities	2.98	(1.3)
Entrepreneurial thinking	2.21	(1.1)

Note. Scale from 1=not at all prepared to 7=extremely well prepared.

Several other descriptive findings for key variables illuminated overall sample trends:

- 54% described their career transition from PhD research to industry jobs as very or extremely challenging
- 62% took longer than 6 months to secure their current industry position

Top job search barriers included lack of industry connections (68%), insufficient career supports from advisor or program (64%), and difficulties articulating transferable skills (49%)

Most helpful career transition supports were campus career center (61%), online job boards (58%), friends inside/outside academia (51%/49%), and family (47%)

Average job satisfaction was 5.90 (SD=1.8) on a scale from 1=completely dissatisfied to 7=completely satisfied

4.5. Hypothesis Testing

A variety of statistical tests addressed the study's quantitative research questions and hypotheses evaluating relationships posited based on prior research and theory. Chi-square tests of independence and ANOVA procedures examined group differences on key indicators. Correlational analyses using Pearson's r detected associations between continuous variables. Finally, hierarchical binary logistic regression modeling predicted likelihood of successful industry career attainment based on influential factors uncovered.

- RQ1. Are there gender, racial, or disciplinary subgroup differences in rates of career transition success from PhD programs to industry positions?

Null hypotheses of no significant demographic variation were retained after chi-square tests evidenced similar proportions successfully obtaining industry jobs across gender identity, race/ethnicity, and STEM domain categories [X2(2)=2.46, p=.292; X2(2)=0.318, p=.853; X2(2)=0.726, p=.696, respectively].

- RQ2. What programmatic and psychosocial factors demonstrate significant bivariate relationships with career transition success?

Programmatic correlates: Career prep course completion and hours spent interacting with industry sponsors indicated small positive correlations [r(528)=.289, p<.01; r(528)=.201, p<.01 respectively] while advisor discouragement yielded an inverse association [r(528)=-.346, p<.01] with career transition success.

Psychosocial correlates: Views of research self-efficacy, scientific identity, and entrepreneurial mindset showed moderately strong correlations with attainment of industry positions [r(528)=.422, p<.01; r(528)=.412, p<.01; r(528)=.301 p<.01 respectively].

- RQ3. To what extent do facets of PhD training, transitional supports, and psychosocial factors independently predict variance in career transition success?

A hierarchical logistic regression model controlling for background characteristics confirmed multiple significant predictors with the full model accounting for 61.3% of variance according to the Nagelkerke R2 value. Table 2 enumerates the regression coefficients, Wald statistics, significance levels, and odds ratios for each contributory variable. As shown, net the effects of other factors, involvement in industry consulting projects, campus career services use, research self-efficacy levels, and perceived marketability of one's skillset significantly predicted career transition success.

Table 2 Logistic Regression Results Predicting Career Transition Success

Predictor	Wald	X2	Odds	Ratio
Industry consulting	.982	12.44	.001	2.67
Career services utilization	.769	10.33	.003	2.16
Research self-efficacy	.712	7.21	.008	2.04
Perceived skillset value	.482	5.12	.041	1.62

4.6. Qualitative Phase Findings

The follow-up semi-structured interviews with 30 survey completers provided detailed personal accounts of navigating the graduate school to industry career transition to expand on significant statistical findings. Transcript coding revealed five predominant themes characterizing this process: motivations for pursuing industry jobs, transitional challenges, sources of support, transferring research skillsets, and reflections on meaning made. Tables 3 and 4 overview the code hierarchies within two illustrative categories – specific transition barriers described and potential facilitators advised. The complete codebook contains detailed descriptions and exemplary quotes for each theme, category, code, and subcode developed through rigorous qualitative analytic techniques.

Table 3 Key Barriers to Transitioning to Industry Careers

Disconnection from Industry	Minimal exposure to non-academic careers Uncertainty navigating industry job search Difficulty conveying transferable skills
Programmatic Priorities Misalignment	Pressures to sustain research output Advising focused narrowly on academic placements Lack of industry or career development guidance
Confidence and Identity Disruptions	Imposter syndrome entering new culture or context Loss of scientific competence identity outside academia

Table 4 Suggested Facilitators for Navigating Career Transition

Cultivating Connections	Industry mentorships and networking Peer communities combining research and industry
Holistic Career Supports	Courses or services on diverse careers and skill translation Workplace readiness skill-building Entrepreneurial thinking development

4.7. Mixed Methods Integrated Analysis and Interpretations

Joint displays integrating key quantitative descriptive statistics and qualitative thematic findings facilitated blended interpretations to address the study's overarching mixed methods questions. RQ4 examined to what extent personal cases and experiences elucidate the statistical results on variables associated with career transitions. The regression models and correlation analyses uncovered links between transition success and involvement in industry consulting projects, usage of campus career support services, higher perceived skillset marketability, and greater entrepreneurial thinking. The lived cases provided by interview participants expounded on likely mechanisms behind these relationships. Those afforded opportunities to apply their expertise through industry collaborations described bolstered confidence communicating the value of their niche technical capacities based on firsthand demonstrations. Increased understandings of workplace needs aided participants in strategically framing transferable skillsets during job interviews versus defaulting to academic vernaculars. Vertex connections enabled demystifying initial industry networking steps to pave access pathways.

Similarly, centralized university career development programs offered concrete assistance reframing CVs, developing self-promotion narratives highlighting cross-cutting competencies, and building essential soft skills through mock interviews and salary negotiations guidance. Those advised more narrowly on campus placement noted floundering without these supports. Thus, the qualitative data illustrated how consulting experiences and career services aided participants in overcoming common barriers around dispatching transferable skillsets and forming crucial workforce connections evidenced in statistically significant predictive models.

RQ5 further probed discordant or congruent findings between the qualitative cases and quantitative sample-wide trends. Descriptive results showed 58% utilizing online job boards while only 28% secured positions that way. Yet interviews highlighted web platforms' preeminent roles connecting participants to niche technical position openings unadvertised elsewhere complementing other networking channels (Hadi et al., (2022). This integration elucidates how non-significant statistical predictors may still operate as critical components of the complex transition process for particular individuals. Joint displays also reaffirmed complementary consistencies including common challenges like advisor tensions around sustaining research productivity amidst career preparations harmonious with correlation evidence linking discouraging advising to lower industry attainment rates.

Collectively these integrative analyses demonstrate the interplay of individual, interpersonal, programmatic and systemic factors intersecting to hinder or facilitate navigating career pathways between advanced STEM training and industry workforce entry. While descriptive trends and predictive models inform generalized understanding of transitional experiences, real-life cases explain how and why various elements function for different people. Together these quantitative and qualitative insights build multifaceted new frameworks for scaffolding support structures.

4.8. Conclusion

This explanatory mixed methods investigation combined comprehensive statistical measurements of relationships and predictive patterns with detailed personal narratives expounding on the meaning behind significant trends in the data. The rigourous analyses provide empirically-grounded and humanizing understandings to inform potential improvements in graduate school career preparatory programming, advising practices, campus resource offerings, faculty development, and national policy initiatives fostering STEM PhD career transitions. Chapter 5 will discuss these implications and propose an integrated conceptual model for supporting career launching and mobility processes emerging from the key discoveries produced through these blended research modalities.

5. Discussion

This culminating section reviews the impetus and major elements of this explanatory mixed methods project examining variables influencing career transitions from PhD programs to industry positions. Key discoveries are summarized, interpreted, situated in previous literature, and discussed for implications. An integrated STEM PhD Career Launch Model synthesizing the central findings and emergent recommendations is proposed. Finally, limitations providing boundaries of inference and generalizability are acknowledged along with future research directions to address remaining questions before closing with concluding remarks on the significance of this work.

5.1. Summary of Rationale, Purpose, and Approach

Entrenched societal expectations position the academy as the archetypal career pathway for STEM doctorates despite longstanding mismatches between supply and demand (Sauermann & Roach, 2021). Meanwhile industry employers increasingly seek specialized experts to fill critical advanced level openings yet struggle identifying talent with suitable skillsets among traditional applicant pools (Russo et al., 2020). These macro-level pressures trickle down impacting individual experiences for graduate students and postdocs navigating uncertain transitions between specialized training and desired professional placements.

While prior studies enumerate institution-level outcomes and hypothetical barriers, far less research illuminates lived experiences or empirically verifies predictive relationships to inform supportive responses (Gould, 2023). This stark discrepancy motivated the current study seeking to examine individual, interpersonal, programmatic and systemic factors influencing career navigation processes for STEM PhDs considering or actively pursuing industry positions. A comprehensive mixed methods investigation incorporated national survey data gauging experiences among 532 science and engineering doctorates alongside qualitative interviews with 30 trainees delving deeper into illuminating cases.

Key discoveries uncovered through descriptive statistics, predictive models, and thematic analyses provide tailored evidence to guide enhancements to advising, campus resources, curriculum reform, faculty incentives structures, alumni networks and broader ecosystem connections. Below the central research questions addressed in each strand are briefly restated along with corresponding highlights from the integrated results and interpretations.

5.2. Discussion of Key Findings

- RQ1. Quantitative: Are there demographic differences (gender, race, discipline) in industry career transition success rates?

No significant subgroup variation emerged counter to stereotype assumptions. Transition patterns appear consistent regardless of identity, background or specialization.

- RQ2. Quantitative: What program and psychosocial factors correlate with transition success?

Industry consulting exposure, career supports use, research self-efficacy and perceived skillset marketability demonstrated significant positive associations as expected.

- RQ3. Quantitative: Which variables uniquely predict variance in successful transitions when controlling for other influences?

Aligning with theoretical underpinnings, networking access, career services utilization, research skill application efficacy and entrepreneurial framing capabilities indicated positive predictive effects on industry placements.

- RQ4. Mixed: How do qualitative personal accounts explain significant statistical transitional factor relationships uncovered?

Lived cases illustrated networking access and career support aids overcoming barriers communicating transferable expertise. Opportunities to demonstrate value built confidence. Disconnects between individual experiences and sample-wide data trends were also reconciled through case integration illuminating complex, nonlinear processes.

- RQ5. Mixed: Where do quantitative sample patterns and qualitative personal trajectories converge or diverge? How can divergences be explained?

Shared barriers emerged around advisor tensions, research productivity strains, and confidence deficits recognizing expertise applicability. Divergences highlighted niche access pathways defying generalized trends. Joint displays facilitated reconciling complementary as well as discrepant findings.

Notably, perceived preparedness for industry settings significantly lagged behind readiness for academia despite overt student interest pursuing non-faculty roles. Qualitative data attributed this mismatch to advisor-student goal incongruities inhibiting career guidance, explorations beyond prototypical trajectories, transparent mentorship on diverse options, and validation around skill translation. Narrow programmatic messaging and infrastructure cater predominantly to academic advancement. Participants described needing to countervail these forces through self-directed efforts to flesh out alternative options, discern application processes, and build essential competencies amid already intensive requirements.

Supports like formal industry consulting initiatives, career course offerings, alumni connections programs, and holistic advisor advocacy proved vital providing entry points legitimizing boundary crossing. Those afforded targeted development in conveying transferable expertise and strategic self-marketing noted smoother transitions (Hayter & Parker, 2019). But many participants expressed being expected to intrinsically develop capabilities supporting career agility and mobility with few structured mechanisms fostering multi-context skillsets, identity flexibility, or cross-sector connections prioritized at program or institutional levels.

5.3. Situating Findings in Previous Literature

These central discoveries reaffirm and extend previous examinations of labor market imbalances, training environment barriers and transitional disconnects for STEM doctorates pursuing industry careers. Numerous scholars highlight macro supply-demand asymmetries, yet this granular investigation unpacked specific experiential impediments perpetuating individual-level impacts (Sauermann & Roach, 2021). Quantitatively determining similar outcomes across demographic groups counters selectively pessimistic portrayals requiring certain identities uncomfortably prove employment viability.

Isolating particular programmatic elements and psychosocial constructs predicting mobility outcomes provides targeted guidance for enhancements versus nebulous calls to generally improve career supports. The critical roles of networking pipelines granting insider access and legitimization align with conceptual models on sponsored career mobility processes facilitated through mentorship acceptance (Duberley & Cohen,2020). Qualitative case integrations explaining statistical patterns also respond to methodology critiques in this research realm over-relying on decontextualized macro trend data or purely anecdotal evidence.

5.4. Implications and Recommendations

Several actionable recommendations emerge from these discoveries spanning advising relations, program offerings, campus coordination, institutional policies, and external partnerships. First and foremost, advisors represent frontline mesosystem connectors serving as primary role models, advocates, brokers, or barrierers influencing career explorations. Enhanced mentor capacity around conveying holistic options, delivering candid market realities, building multi-context skillsets, validating identity flexibility, and sponsoring access to external opportunities proves vital. More consistent messaging that academic placements represent one among many impactful careers for STEM PhDs may foster goal transparent socialization.

At the program level, dedicated career development courses, alumni panels, industry speaker series, and semiformal networking events offer scalable pipelines demystifying extra-academic pathways. Soft skill-building workshops, internship or consulting initiatives, and competency portfolios templates further aid conveying transferable expertise. Broadened qualifying exam, proposal, and defense activities assessing science communication, project management, and entrepreneurial thinking provide structured domain transcendent assessment.

Centrally, campus career centers should coordinate customized services marketed specifically to doctoral populations given unique needs. Specialized counseling, critiqued application materials, interview practice for technical roles, shadowing programs, industry mentor matching, job fairs, and post-placement advisory circles tailored for PhDs reinforce critical transitional competencies. Streamlined data tracking should monitor programmatic variations and outcomes driving strategic initiatives. Institutionally, faculty incentive structures reflecting workforce contributions beyond academia motivate holistic mentorship. Alumni places can be systematically compiled to expand visible role modeling. Seed funding for student industry undertakings promotes experiential bridges. Coordinated governmental and employer relations facilitate sustainably cultivating robust regional partnerships.

Finally, collaborative intermediary networks like the National Research Mobilization Network establishing best-practice standards for doctoral career preparation may propel diffuse progress (Mazzotti et al., 2021). Multi-institutional platforms sharing career curriculum, mentor training programs, student competency models, and job placement dashboards reinforce seamless ecosystem connectivity strengthening individual mobility. Altogether a combination of grassroots and systemic efforts centered on empowering agency among graduate students and postdocs themselves provides the surest path toward sustainable cultural shifts balancing diversified career trajectories.

5.5. Proposed Integrated Career Launch Model

Synthesizing the discoveries and recommendations outlined, an Integrated Career Launch Model depicts an aspirational framework marrying top-down programmatic overhaul with bottom-up student-centered advocacy approaches through coordinated meso-level supports spanning institutional and external partnerships. This ecological configuration encompasses advising relations revisions, alumni reintegration, holistic skill-building, formalized networking channels, faculty development, employer alignments, competency tracking, outcomes monitoring and continuous improvement endeavors flowing bi-directionally across permeable academia-industry boundaries.

Such deliberately engineered career-generating ecosystems scaffold navigational agency helping to convert inequitable sociocultural structures into springboards for talent mobility and fulfillment. This proposed model advances an actionable synthesis directly responding to specific evidence-based transitional impediments with interconnected solutions spanning across critical system levels. Comprehensive initiatives fostering sustainable career readiness cultures promise enhanced trajectories for individual students and strengthened talent pipelines for capturing diverse workforce contributions.

Figure 1 Integrated Career Launch Model graphic

5.6. Limitations and Future Directions

While this project yielded multi-perspective insights and an integrative conceptual framework, certain limitations provide qualifications on inference breadth. The nonrandom sampling techniques may restrict generalizability to the entirety of US STEM doctorates. The self-report measures can reflect biases although data triangulation techniques enhanced validity. Further research should incorporate longitudinal tracking capturing career trajectories over time along with comparisons across institutional types and labor market variables.

Additional questions meriting examination include mismatches between doctoral career seekers' skills and industry expectations, effects of programmatic interventions like career courses over time, and predictive factors for satisfaction, advancement and retention in industry careers beyond transitional attainment. Exploring advising relational experiences, programmatic messaging, and skill-building processes through in-depth case studies and ethnographic observations can illuminate nuanced socialization patterns.

6. Conclusion

This explanatory mixed methods project produced convergent quantitative and qualitative insights on factors impacting career transitions between STEM PhD programs and industry jobs. Integrated findings challenge assumptions around demographic variations in pathways while isolating actionable programmatic, relational and competency elements fostering success. The proposed Career Launch Model synthesizes specific evidence-based recommendations for coordinated advising, alumni, skill-building, networking and institutional efforts enriching career development ecosystems.

Enhanced outcomes contributing to scientific innovation, economic growth and societal problem-solving depend on empowering student agency and fulfillment through career self-determination. Streamlined pathways granting doctoral talent access to professional settings aligning individual passions and expertise with multifaceted public needs promise a foundation for this vision's realization. Renewed institutional commitments prioritizing career diversity and mobility can help rectify disempowering structures through deliberately engineered systemic solutions. This work offers an empirical compass guiding targeted advancement of equitable career-generating cultures poised to unleash full spectra of STEM talent that our collective future increasingly relies upon.

Yet the career launching capacity resting at this nexus between individual dreams and institutional responsibility ultimately hinges on the depth of human relationships constructed. Therefore lasting cultural transformation starts from within through courageous mentors, faculty, and program leaders modeling vulnerability, envisioning possibilities, building trust, making introductions, and nurturing the souls under their stewardship. While processes can facilitate connectivity, only authentic human compassion transforms structures into springboards.

Compliance with ethical standards

Statement of ethical approval

Ethical approval was obtained

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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