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Preparing Industry Leaders: The Role of Doctoral Education and Early Career Management Training in the Leadership Trajectories of Women STEM PhDs

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Abstract
While gender diversity in leadership has been shown to benefit organizations and promote innovations, women continue to be underrepresented in leadership positions in the industry sector. With increasing numbers of women pursuing PhDs in science, technology, engineering, and mathematics fields, it is critical to examine how PhD programs contribute to the career paths of PhDs. This study examines the role of doctoral education preparation in communication, management, and technical skills, as well as post-PhD early career management training (ECMT), on PhDs' attainment of leadership positions in industry. Data come from the National Science Foundation Survey of Doctorate Recipients, National Science Foundation Survey of Earned Doctorates, and National Research Council Rankings of PhD programs. Using regression analyses, results indicate that ECMT is associated with a higher likelihood of attainment of leadership positions. PhD preparation in management skills also contributes to the attainment of leadership positions. Previous literature has shown that structural inequities and workplace bias contribute to limiting women's progress to leadership positions and that it is critical to address systemic and workplace biases. Research findings suggest that PhD program preparation and increased access to professional development opportunities can help contribute to the enhancement of women's pathways to leadership roles. Structural changes in doctoral education preparation in management skills and increases in ECMT opportunities offered by employers also have the potential to increase the participation of STEM PhDs in leadership roles in industry.

Keywords Gender · Leadership · Industry · Doctoral education

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Although gender diversity in leadership has been shown to benefit organizations and promote innovations (e.g., Joshi, 2014; Virick & Greer, 2012), women continue to be underrepresented in leadership positions in the industry sector. While there have been numerous efforts to promote gender diversity and workforce equity, women still comprise only 6.4% of CEOs in S&P 500 companies (Catalyst, 2020) and only 7.4% of CEOs in Fortune 500 companies (Fortune, 2020). It is well-documented that women tend to face barriers to career advancement and attainment of leadership positions that men do not tend to face (e.g., Eagly & Carli, 2007; Ely et al., 2011; Kossek et al., 2017; Oakley, 2000). In addition to structural barriers, systemic inequities, and workplace biases, studies have found that differences in work experiences, educational attainment, and access to professional development opportunities can also contribute to limiting women's career advancement to leadership positions (e.g., Cook & Glass, 2014; Eagly & Carli, 2007; Gould et al., 2018). As Northouse (2016, p. 401) explains, "Women receive less formal training and fewer developmental opportunities at work than men, both of which likely are related to prejudice against female leaders." The pathways to leadership positions are complex and the reasons for gender differences in the attainment of leadership positions are wide ranging. While addressing career inequality will require a multi-faceted approach to challenge structural and cultural issues, studies have shown that interventions, such as relevant professional development training, can partially help promote women's career advancement (e.g., Ely et al., 2011).

In this study, we investigate specifically the relationships among professional development training during the PhD program, early career management training (ECMT) post PhD completion, and the career paths of men and women in science, technology, engineering, and mathematics (STEM) fields. We focus on STEM PhDs to identify the association between post-PhD ECMT and the attainment of leadership positions in the industry sector. Our study partially addresses arguments that attribute gaps in career outcomes to differences in educational attainment (e.g., Judge et al., 1995; Miller et al., 2015) by examining the career outcomes of STEM professionals who have all earned their doctorates. Given our study's focus on women's paths to leadership positions, we also conduct our analyses disaggregated by gender. Our research questions are as follows:

(1) How is career preparation from PhD programs associated with participation in ECMT, by gender?
(2) How are career preparation from PhD programs and ECMT associated with attainment of leadership positions in industry, by gender?
(3) Among STEM PhDs in leadership positions, does ECMT reduce the time to the first leadership position, by gender?
(4) Among STEM PhDs in leadership positions, how is ECMT associated with salary, size of group managed, and job satisfaction, by gender?

Eagly and Carli's (2007) leadership labyrinth metaphor, which depicts the complex multitude of factors that influence women's access to power and career advancement to leadership roles, informs this study. We use Eagly and Carli's (2007, p. 8) definition of a leader as a "person who exercises authority over other people," and therefore, PhDs with formal leadership positions are identified as leaders in this study. Becker's (1964) human capital theory also informs this work, such that we consider the accumulation of knowledge, habits, social skills, and other attributes in the context of the leadership labyrinth (Northouse, 2016). We analyze data from the National Science Foundation's (NSF's) 1993–2013

Survey of Doctorate Recipients (SDR) matched with institutional and individual information from the Survey of Earned Doctorates.

We examine the role of doctoral programs in preparing students with technical, management, and communication skills, and how these skills are associated with the likelihood of PhDs attainment of leadership positions in industry sectors using descriptive and regression analyses. We also examine the effect of ECMT on the time to the first leadership position, salary, number of individuals supervised, and job satisfaction using propensity score matching procedures to account for the non-randomness of receiving such training. Our analyses are conducted including the full sample, as well as separately for women and for men.

Our research findings provide important information and context for preparing the next generation of STEM leaders to help advance social justice, reduce career inequality, and to promote economic and national interests (Kossek & Buzzanell, 2018). Graduate programs and industry stakeholders can apply our research findings to the ways they offer or shape their leadership training programs as a means to diversify leadership roles in industry and business organizations. After all, how leadership is broadly conceptualized through doctoral education socialization and through employer practices have implications for who envisions potential careers in leadership (e.g., Ely et al., 2011). Prospective STEM PhDs, as well as STEM PhDs who have ambitions to enter industry and to obtain leadership positions, can also potentially use these findings to determine whether to engage in post-PhD management training. By focusing on doctoral education preparation and ECMT, we contribute to discussions regarding how PhD programs and employers can help prepare STEM graduate students and PhDs for a wider range of careers and increasing levels of responsibility.

Literature Review

STEM Doctoral Education and Professional Development

In 2013, over 43% of STEM PhDs worked in business organizations (Selfa & Proudfoot, 2014). Scientists and engineers with advanced-level academic training play a critical role in leading and supporting innovations. STEM PhDs bring relevant skills to leadership positions that can help advance their organizations in a number of ways, including enhancing human resources management practices, improving alignment of organizational activities with technical objectives, and promoting scientific and technological innovation (Biddle & Roberts, 1994; Lee et al., 2010; Roberts & Biddle, 1994). Although STEM PhDs can contribute significantly to the industry sector, STEM doctoral programs tend to provide relatively few opportunities for exploring and preparing for career pathways beyond tenure-track faculty and academic research positions (Hancock & Walsh, 2016; O'Meara et al., 2014). Indeed, there is widespread and longstanding concern that doctoral programs may not be providing STEM PhD students with enough preparation in professional skills (Hancock & Walsh, 2016; Manathunga et al., 2009; O'Meara et al., 2014). The number of jobs requiring both technical and professional skills have fast outpaced jobs requiring only technical skills in the last three decades (Deming, 2017).

Professional skills include those related to communication, teamwork, and leadership (Balcar, 2014; Deming, 2017; Heckman & Kautz, 2012; Laker & Powell, 2011), and these skills are essential in evolving labor market and work functions (Borghans

et al., 2014). Research has shown that communication, leadership, and teamwork skills are associated with higher salaries and career advancement (Balcar, 2014; Deming, 2017; Weinberger, 2014). Balcar (2014) found a consensus in the literature that there are significant wage returns to professional skills, which can help close the gender wage gap. Meanwhile, Weinberger (2014) found that jobs requiring both technical and professional skills carry an earnings premium, which suggests that PhD programs that combine training in professional skills with training in technical skills can be particularly advantageous for STEM PhD students.

Understanding how STEM PhD programs prepare students for work in industry, particularly in leadership roles, is critical. Doctoral education is a socialization process that provides graduate students with an understanding of future careers. Accordingly, Austin (2002) argues that doctoral education programs should prepare their students for professional practice in advanced scientific endeavors. Platow (2012) affirmed this, providing empirical evidence that PhDs' self-perceived acquisition of PhD-related attributes, including professional skills (e.g., communication, teamwork, management and leadership skills) is associated with post-PhD employment outcomes, such as salary and productivity. Professional development is closely related to an individual's employability and career success (Deming, 2017). Andrews and Higson (2008) studied graduates' and employers' perspectives, and found that many graduates feel they lack professional skills, such as communication and presentation skills. They also found that employers associate these skills with a graduate's employability and potential for success. Thus, there are opportunities for PhD programs to contribute to helping prepare their graduates for the workforce and for the pursuit of leadership positions. By focusing on professional skills, PhD programs also have a role in helping shape how their students conceptualize their careers and leadership potential through socialization, identity development, skills training, and career preparation.

Management and Leadership Training

Previous studies have generally found leadership training to have positive effects on attainment of leadership positions (e.g., Boaden, 2006) and on other career outcomes, such as wages (e.g., Kuhn & Weinberger, 2005). There is also a line of research focusing on leadership development in higher education. For example, Brungardt (1997) reviewed the literature on leadership development and education, and indicated that while many leadership development programs are considered to be effective, their level of effectiveness depends on various factors related to the training, such as level of preparedness of the trainee, composition of the training group, and feedback received by the trainee (Bass & Stogdill, 1990). Other studies offered ways to develop high quality leadership programs in higher education (e.g., Klimoski & Amos, 2012). Hotho and Dowling (2010) provided empirical evidence that the effectiveness of leadership development programs depends on participants' interaction with the programs and that individual factors and organizational context shape these interactions. Nevertheless, leadership training programs, irrespective of content, may provide participants with increased confidence and skills to pursue leadership positions. That is, by providing training and support to their employees, employers can encourage leadership aspirations, as well as promote an organizational shift in how employees, in general, support women leaders (e.g., Ely et al., 2011).

Gender Differences in Attainment of Leadership Positions

Previous studies have found that across education background and employment, women are more likely than men to face barriers in career advancement and attainment of leadership positions (Kossek et al., 2017; Fritz & van Knippenberg, 2018). These gaps may stem from individual-level differences in career interests and goals, gender biases in role expectations and self-assessments, and/or differential effects of family formation. At the organizational level, lack of support and role models, implicit and explicit bias in the workplace, availability of work-life initiatives, and other biased structures play a role in women's progression into leadership positions (e.g., Blake-Beard, 2001; Chanland & Murphy, 2018; Fritz & van Knippenberg, 2018). Oakley (2000) argued that it is more difficult for women to obtain senior management and leadership positions due to a lack of career opportunities, gender-based stereotypes, and differences in socialization experiences. Because women have fewer opportunities for career development than men, employers hiring for leadership positions tend to believe that women are less likely to aspire to leadership positions than men (Hoobler et al., 2014).

Work-family conflict also plays a role in women's career trajectories (e.g., Correll et al., 2007; Hoobler et al., 2009; Linehan & Walsh, 2000; Singh et al., 2018). Hoobler et al. (2009), for example, suggest that managers' biased perceptions that women have greater work-family conflict, rather than the actual levels of work-family conflict, impedes women's promotability. Meanwhile, Eagly and Carli (2007) directly demonstrate that the division of household responsibilities between men and women influence women's access to power and leadership in the workplace. Women, on average, spend more time on childcare and household duties compared to men (Catalyst, 2020; Hochschild & Machung, 1990). Because the long hours required for managerial positions have the potential to conflict with household responsibilities, support from families, friends, and other sources may also help facilitate the pursuit of leadership positions.

Ibarra et al. (2013) proposed that while women once experienced deliberate exclusion, "second-generation gender bias" now inadvertently excludes women through cultural assumptions and organizational structures and interactions that place women at a disadvantage. Ely et al. (2011) referred to leadership development as "identity work" and argued that gender bias in the culture and in organizations creates barriers for women's identity work. Such barriers may particularly hinder the career advancement and leadership attainment for women in the workplace. DeRue and Ashford (2010) suggested that internalization of a professional identity may be especially beneficial for women. To consider themselves and to be considered by others as leaders prior to or just as they enter the workforce in business sectors can potentially motivate women to further explore their leadership interests and to pursue opportunities to practice leadership as they progress along their career paths (Day & Harrison, 2007). Ely et al. (2011) also called for leadership programs, particularly for women, that facilitate their advancement into more senior positions. They argued that focused leadership training for women that aims at constructing and internalizing leader identity can facilitate women's trajectories toward senior leadership positions. Furthermore, Gipson et al. (2017) argued that women leadership programs should place a deeper focus on the unique issues faced by women leaders and the context of the organization.

Conceptual Framework

Our conceptual framework is informed by Eagly and Carli's (2007) metaphor of a leadership labyrinth, which encompasses the multitude of factors that can influence a woman's advancement into a leadership position. Northouse (2016) depicts this leadership labyrinth to focus on the three main antecedents of attainment of leadership positions: (1) human capital, (2) gender differences, and (3) prejudice. While all three groups of factors interact in complex ways to generate the prevailing patterns in the gender composition of leaders in the industry sector, our study focuses on human capital and on gender differences. As Becker (1964) explains, human capital refers to education, work experience, and developmental opportunities, and their effects on labor market attainment. We investigate gender differences in terms of home-work conflict because research has shown that women are more likely than men to have higher shares of the childcare and household duties, perhaps leaving less time to focus on career advancement (e.g., Catalyst, 2020; Eagly & Carli, 2007; Hochschild & Machung, 1990).

Our study tests whether education, work experience, professional developmental opportunities, and work-home conflict are associated with STEM PhDs' attainment of leadership positions, by gender. We illustrate our conceptual model in Fig. 1, which is adapted from Northouse's diagram of the leadership labyrinth. Our sample is comprised of only PhDs, and we control for PhD discipline. We also take into account the National Research Council (NRC) ranking of the PhD's doctoral program, as well as discipline and year of PhD entry. In terms of education, our variables also include doctoral preparation in technical, communication, and management skills.

For work experience, we include a variable that indicates the first post-PhD employment sector/position (academia, industry, government, or postdoctoral research scholar). In terms of post-PhD professional development opportunities, our primary variable of interest is participation in early career (post-PhD) management training. Although we do not have information regarding the content of the management training, we provide descriptive statistics regarding duration and reasons PhDs provided for pursuing the ECMT.

Previous research has shown that women's likelihood of being promoted to leadership positions may be hampered by employers' perceptions that women are more likely to be impacted by work-family conflict (Eagly & Carli, 2007; Hoobler et al., 2009) and by women's higher shares of household responsibilities (Eagly & Carli, 2007; Hochschild & Machung, 1990). To address potential gender differences related to work-home conflict, we include variables on marital status and whether the PhD has young dependents under the age of six in the household. Our models also include variables on individual-level demographic characteristics, including gender, race/ethnicity, and U.S. citizenship.

Data

We analyzed data from the NSF Survey of Doctorate Recipients (SDR) (survey waves 1993–2013) merged with data from the NSF Survey of Earned Doctorates (SED). Our sample includes individuals who (a) received a PhD in a STEM field (bioscience, computer science, engineering, mathematics, statistics, and physical sciences), (b) participated in at least one of the 1997, 1999, and 2001 SDR waves, (c) worked in the industry sector on or after the 2003 NSF SDR survey wave, and (d) responded to at least four survey waves of

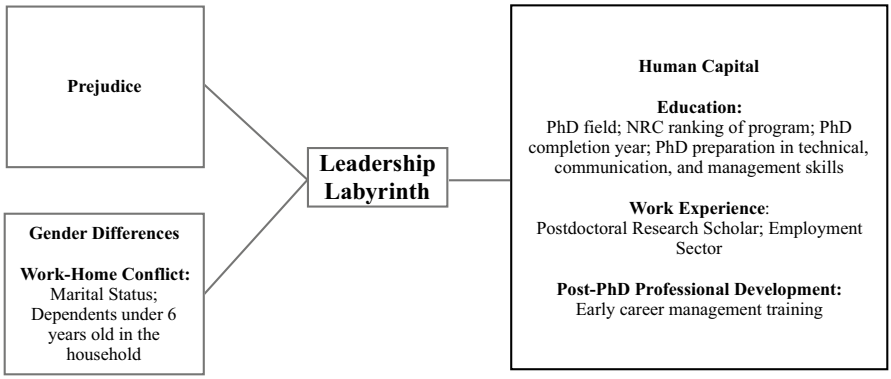

Fig. 1 Conceptual model of the leadership labyrinth. Adapted from Leadership Theory and Practice, by P. G. Northouse, 2016, 7th ed., Thousand Oaks, CA, Sage Publishing, p. 400

the NSF SDR and indicated working in the industry sector. Our qualitative conclusions are robust to reasonable alternatives to criterion (d), such as when we limit the sample to individuals who worked in industry for at least three or five SDR waves in total. The resulting dataset includes 4,092 respondents with demographic, doctoral education preparation, and employment information. The NSF SDR data are preprocessed by "hot-deck imputation" (Proudfoot, 2014), such that there are no missing values in the variables we analyzed. In the sections that follow, we describe the variables we used in our analyses and then provide descriptive statistics.

Variables

Demographic and PhD Program Characteristics

The demographic variables include gender (female = 1 and male = 0), race/ethnicity (African American/Black, Hispanic/Latinx, Asian, White, and Other), U.S. citizenship, and age at PhD completion. Additionally, we include variables for marital status and whether there are young dependents under 6 years old in the household. For PhD program-level variables, we incorporate PhD field, PhD completion year, and PhD program ranking from the NRC. We grouped the NRC rankings into quartiles and not ranked.

Career Preparation from PhD Program

The 1997, 1999, and 2001 SDR waves include a set of questions regarding perceived level of career preparation for respondents who recently obtained their PhDs (within six years of the survey). Survey respondents were asked to indicate a rating on a scale from 1 to 3 with 1 as "very adequate," 2 as "somewhat adequate," and 3 as "not adequate" to the following question: "In terms of preparing you for a career, how adequate was your doctoral program or training in each of the following areas?" The 11 areas include oral communication skills, computer skills, establishing contacts, research integrity/ethics, problem-solving skills, subject matter knowledge, management/administrative skills, quantitative skills, teaching skills, collaboration/teamwork skills, and writing skills.

We reverse-scored the raw ratings in each area of career preparation such that a score of 0 represents "not adequate," 1 represents "somewhat adequate," and 2 represents "very adequate." Because many of the skills are related to each other, we categorized the different skills into three clusters: (1) technical skills, which include computer, research integrity/ethics, problem-solving, subject matter knowledge, and quantitative; (2) management skills, which include establishing contacts, management/administrative, and collaboration/teamwork; and (3) communication skills, which include oral communication, teaching, and writing. This grouping is also confirmed by an exploratory factor analysis when we set the number of factors to three (Appendix Table 9). The factor scores of technical, management, and communication skills are then normalized to a mean of 0 and standard deviation of 1 across all individuals. We used these standardized scores in our analyses.

Early Career Management Training (ECMT)

Participation in ECMT is drawn from the NSF SDR survey question, "During the past year, in which of the following areas did you receive training?" The NSF SDR 1993 through 2003 survey waves included this survey question. The resulting binary variable is equal to 1 if the respondent indicated that they received management training, and 0 if they did not specify management training. In our analyses, we focused on the PhDs who participated in ECMT prior to obtaining a leadership position.

Employer Sector and Early Work Experience

Our study focuses on STEM PhDs employed in the industry sector. We defined an individual as employed in industry if they indicated the employer sector to be business/industry in the NSF SDR. In terms of early work experience, our analyses incorporate the first job sector/position after PhD completion, such as employment in industry, academia, or government, or as a postdoctoral research scholar.

Leadership Position

We defined the attainment of leadership position based on the respondent's job title indicated in the NSF SDR. STEM PhDs who reported their job title as mid- or top-level managers were indicated as holding a leadership position. Prior to 2003, the SDR included only two job codes for leadership positions: "Top and Mid-Level Managers, Executives, Administrators" and "Other Management Related Occupations," whereas for the 2003 and later survey waves, the job codes provided are more specific. For SDR waves from 2003 onward, we selected all relevant job codes to define leadership positions, including: "Computer and Information Systems Managers," "Engineering Managers," "Medical and Health Services Managers," "Natural Sciences Managers," "Other Mid-Level Managers," "Other Management Related Occupations," and "Top and Mid-Level Managers, Executives, Administrators."

Career Outcome Variables

We calculated years to leadership as the number of years elapsed between PhD completion and attainment of the first leadership position. The career outcome variables are extracted from the first survey year that the PhD obtained a leadership position. The salary variable

is adjusted for inflation using the Consumer Price Index, and is in 2013 dollars. We transformed the salary variable into a natural log for analysis. Group size is the number of individuals supervised by the PhD in the leadership position. The job satisfaction variable is based on the survey question, "How would you rate your overall satisfaction with the principal job you held?" We coded the responses as a binary variable with individuals indicating "very satisfied" as "1," and "0" otherwise.

Descriptive Statistics

Table 1 presents the descriptive statistics of our sample. There are two columns: the first column represents our entire sample and the second column is limited to PhDs who held leadership positions in the industry sector. Certain variables (e.g., U.S. citizenship) are time variant, and our calculations are based on the status that the respondent indicated on their first completed SDR survey. Overall, 25% of STEM PhDs working in industry hold leadership positions, and among PhDs with leadership positions, 32% reported participating in ECMT. Women comprise 34% of STEM PhDs working in industry and 30% of STEM PhDs with leadership positions in industry. The NSF SDR primarily surveyed PhDs who remained in the U.S. post PhD graduation during the specified survey waves, and therefore, the sample is primarily comprised of U.S. citizens. The PhD sample is also primarily White and Asian with degrees in biological sciences, physical sciences, and engineering.

Although the NSF SDR does not provide information regarding the content or delivery of the ECMT received, it provides some information regarding the duration and reasons for participation. Table 2 presents the survey respondents' reasons for participating in ECMT, disaggregated by gender. Over 70% of women and of men STEM PhDs who participated in management training did so to increase advancement opportunities and because training was required/expected by their employer. About 69% of men and of women participated in ECMT to acquire further skills and knowledge, whereas less than 12% participated in ECMT for licensure/certification.

The survey question pertaining to the duration of training is available from only one wave of the SDR (1997). From this survey wave, the majority of women (66%) and men (57%) participated in management training that was 1–3 days in duration. Around 30% of women and men participated in ECMT that was 4–7 days in duration, and less than 2% participated in training greater than 30 days.

Methods

We investigated the role of career preparation from PhD programs and ECMT in the career outcomes of STEM PhDs. We describe the methods we used to address our four research questions below.

Research Question 1: How is Career Preparation from PhD Programs Associated with Participation in ECMT, by Gender?

We used Logit regression to examine whether career preparation from the PhD program is associated with participation in ECMT using the following equation:

Table 1 Descriptive statistics

	Full sample	PhDs with leadership positions
Gender		
Men	66.5	70.3
Women	33.5	29.7
Race/ethnicity		
African American/Black	5.3	5.5
Asian	26.8	28.3
Hispanic/Latinx	7.2	6.9
White	59.9	58.1
Other	0.8	1.1
U.S. citizenship		
U.S. citizen	73.9	74.4
Permanent resident	13.0	13.7
Temporary resident	13.1	11.8
Degree field		
Biological science	39.1	35.4
Computer science	4.9	6.2
Physical science	23.3	23.2
Engineering	28.9	33.6
Math and statistics	3.7	1.6
PhD program NRC ranking		
First quartile	36.2	36.7
Second quartile	25.9	25.9
Third quartile	17.3	16.8
Fourth quartile	10.3	10.3
Not ranked	10.3	10.4
Participation in ECMT and leadership		
ECMT	22.2	31.8
Leadership position	24.8	100.0
Career outcomes		
Years to leadership	–	9.44
Salary in 2013 dollars	–	$115,773
Group size managed	–	5.78
Job satisfaction	–	0.45
N	4092	1013

$$\ln\left(\frac{p_i}{1-p_i}\right) = \boldsymbol{X_i\beta} + \boldsymbol{CT_i r} + Gender_i\delta + \varepsilon_i \quad (1)$$

In Eq. (1),p_i denotes the probability that individual i participated in ECMT; $\boldsymbol{X_i}$ is a vector denoting the individual and PhD program characteristics; $\boldsymbol{CT_i}$ denotes the technical, management, and communication career preparation responses of individual i; and $Gender_i$ equals "1" when respondent i indicated "female," and "0" otherwise. We used $\boldsymbol{\beta}$, $\boldsymbol{r}$, and δ to denote the regression coefficients, and ε_i denotes the Logit error term.

Table 2 Reasons for participating in early career management training (ECMT)

	Women	Men
Increase advancement opportunities	74.0	79.3
Facilitate occupation change	38.5	39.3
Required/expected by employer	76.7	77.7
Licensure/certification	11.8	8.3
Learn skills for recently acquired position	44.3	39.3
Acquire further skills/knowledge	68.9	68.5
N	296	613

Sample includes PhDs who participated in ECMT. Missing values are omitted from calculations based on an item-by-item basis

The vector of $\boldsymbol{X_i}$ includes race/ethnicity, U.S. citizenship, response to whether the PhD has a disability, age at completion of PhD degree, PhD field, NRC PhD program ranking, and the PhD completion year fixed effect. We also controlled for the first post-PhD employment sector/position of the individual (academia, industry, government, postdoctoral research position, or other). The model also includes variables related to marital status and whether the respondent has young dependents under the age of 6. Some of the variables are time variant (e.g., U.S. citizenship), and in these cases, we used the first observed value across the respondent's completed SDR waves. In addition to estimating this model using the full sample (Table 3), we also disaggregated our analyses by gender (Table 4). In the analyses focusing on the subsamples of women and of men, we estimate Eq. 1 with the exception of the variable $Gender_i$.

Research Question 2: How are Career Preparation from PhD Programs and ECMT Associated with Attainment of Leadership Positions in Industry, by Gender?

To investigate the relationship between ECMT and attainment of leadership positions, we estimated the following Logit regression model:

$$\ln\left(\frac{p_i}{1-p_i}\right) = \boldsymbol{X_i\beta} + \boldsymbol{CT_i r} + Gender_i\delta + ECMT_i\mu + \varepsilon_i \tag{2}$$

In Eq. (2), we used p_i to denote the probability that individual i obtains a leadership position. The independent variables are identical to those described in Eq. (1), except that we have added the term $ECMT_i$. $ECMT_i$ is a binary variable that equals "1" if individual i participated in early career management training, and "0" otherwise. We analyzed the same sample used in research question 1, and the summary statistics are shown in Table 1 Column 1. Again, we conducted our analyses using the full sample (Table 3), and also disaggregated by gender (Table 4).

To test the robustness of our results, we also investigated whether the reasons provided for participating in ECMT (Table 2) are related to attainment of leadership positions. Again, the variable indicating the reasons for participating in ECMT is only available from one survey wave (1997). Overall, the reasons provided for ECMT, such as to increase career advancement opportunities or to facilitate occupation change, were not related to attainment of leadership positions. (Results available from authors by request.)

Research Question 3: Among STEM PhDs in Leadership Positions, Does ECMT Reduce the Time to the First Leadership Position, by Gender?

To estimate the effect of ECMT on career outcomes, we first present our approach to balance the characteristics of the group that participated in ECMT and the group that did not participate using a matching procedure. Participation in ECMT is not random, such that PhDs who intend to hold or who have a stronger desire for leadership positions may be more likely to participate in ECMT. Participation depends on factors, such as self-assessments on career preparation and relative skill levels. To address selection into ECMT, we used propensity score matching to balance our sample on observable factors associated with whether or not an individual participates in ECMT. We first created a subsample by limiting our analytical sample to individuals who are in leadership positions. The summary statistics for this sample are shown in the Table 1 Column 2. In terms of the propensity score matching procedure, we used Eq. (1), but with PhD completion year as a linear term, rather than the PhD completion year fixed effect, to predict the propensity of participating in ECMT. Then, with a one-to-one nearest neighbor matching with replacement framework, each individual in the "treated group" (individuals who participated in ECMT) is matched with an individual in the "control group" (individuals who did not participate in ECMT) based on the estimated propensity score to participate in ECMT. Our results are robust to other matching frameworks, such as nearest neighbor matching with replacement and a caliper.

Given that the focus of research question 3 is on ECMT and time to the first leadership position, we excluded from the control group: (1) individuals who received ECMT after holding a leadership position (239 PhDs); and (2) individuals who obtained leadership positions within 2 years after PhD completion (35 PhDs). Our resulting sample includes 322 PhDs who participated in ECMT and 322 PhDs matched individuals who did not participate in ECMT for a total of 644 PhDs in the sample. Our matching procedure balances the two groups based on the observable factors that are associated with participation in ECMT. Appendix Figure 2 shows the covariate balance before and after propensity score matching is applied. The balance of each variable is evaluated using the Standardized Mean Difference (SMD), which is defined as follows:

$$\hat{\beta} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{(s_1^2 + s_2^2)/2}} \tag{3}$$

In Eq. (3), $\overline{X}_1$ and $\overline{X}_2$ are a sample mean of the variables of interest for the treated and control groups, respectively (i.e., with and without ECMT). Meanwhile s_1^2 and s_2^2 are the sample variance of the variables of interest for the two groups, respectively. A larger absolute value of SMD indicates a larger imbalance between the treated and control groups, and an absolute SMD value of less than 0.2 is preferred (e.g., Rubin, 2001; Stuart, 2010). Previous studies have used cutoff values ranging from 0.1 to 0.25 to demonstrate covariate balance (e.g., Linden & Samuels, 2013; Normand et al., 2001; Rubin, 2001). Appendix Figure 2 shows that the absolute values of SMD for the covariates are below 0.15, indicating covariate balance after matching. This is also evidenced by Appendix Figure 3, which demonstrates that the kernel densities of the propensity scores from the treated subsample match those of the untreated subsample.

After the matching procedure, we used a linear regression model to estimate the effect of ECMT on the elapsed time to attainment of the first leadership position using the following equation:

$$y_i = \boldsymbol{X_i\beta} + \boldsymbol{CT_i r} + Gender_i\delta + ECMT_i\mu + \varepsilon_i \quad (4)$$

Equation (4) is similar to that of Eq. (2), except that y_i denotes the number of elapsed years between individual i's PhD completion and first post-PhD industry leadership position, and ε_i denotes the error term for the ordinary least squared regression.

Research Question 4: Among STEM PhDs in Leadership Positions, How is ECMT Associated with Salary, Size of Group Managed, and Job Satisfaction, by Gender?

We used linear regression models to examine the effect of ECMT on the following career outcomes: (1) salary, (2) size of group managed, and (3) job satisfaction among STEM PhDs in industry leadership positions. We evaluated these career outcomes based on the first survey wave in which the individual indicated holding a leadership position. In terms of the sample, we did not include PhDs who reported annual salaries of less than $10,000. We used the same propensity score matching procedure described above to generate the matched treated and control groups. We then used Eq. (4), except here y_{it} is (1) the natural log of annualized salary in 2013 dollars earned by individual i at year t; (2) the number of people supervised by individual i at year t; or (3) the job satisfaction of individual i at year t.

Results

Research Question 1: Career Preparation from PhD Programs and Participation in ECMT

Table 3 Column 1 shows the marginal effects at the mean on the likelihood of participating in ECMT. Although the coefficient is not statistically significant, women STEM PhDs are 2 percentage points more likely than men to participate in ECMT. Marital status and having young dependents do not appear to be associated with participation in ECMT. However, STEM PhDs who indicated a one standard deviation higher score in communication skills preparation during doctoral study are 1.8 percentage points more likely to participate in ECMT. Table 4 Column 1 shows the disaggregated regression results by gender. Among men, a one standard deviation higher score in management skills preparation during the PhD program is associated with a 2.6 percentage points higher likelihood of participating in ECMT. Among women, doctoral education preparation in technical, management, and communication skills are not associated with ECMT. Although the coefficients are not shown in Table 4, marital status and having young dependents are also not correlated with the likelihood of participating in ECMT.

Table 3 Marginal effects of factors associated with the attainment of ECMT and leadership positions among STEM PhDs

	ECMT		Leadership position	
	Coefficient	Std. Err	Coefficient	Std. Err
Doctoral education preparation				
Technical skills	0.011	0.008	− 0.006	0.009
Management skills	0.001	0.007	0.020*	0.008
Communication skills	0.018*	0.008	− 0.002	0.008
Post-PhD ECMT	–	–	0.085**	0.017
Individual characteristics				
Women	0.023	0.014	− 0.029	0.015
African American/Black	0.031	0.031	0.020	0.032
Asian	0.010	0.018	0.018	0.020
Hispanic/Latinx	− 0.024	0.024	0.001	0.027
Permanent resident	0.045	0.024	− 0.002	0.024
Temporary resident	0.012	0.023	− 0.032	0.022
Age at PhD	− 0.002	0.001	− 0.004*	0.001
Married	0.012	0.015	0.019	0.016
Dependents under age 6	0.002	0.015	− 0.014	0.016
N	4092			

Models are specified as Logit regressions. The baseline groups for race/ethnicity and citizenship are White and U.S. citizen, respectively. PhD field, PhD year, indicator for PhD reported having a disability, PhD program NRC ranking, and initial job sector are included in the models, but are not shown in the table

**/*Denote 0.01/0.05 significance levels, respectively

Table 4 Marginal effects of factors associated with the attainment of ECMT and leadership positions among STEM PhDs, by gender

	ECMT		Leadership position	
	Coefficient	Std. Err	Coefficient	Std. Err
Panel A: Women				
Doctoral education preparation				
Technical skills	0.003	0.014	0.004	0.014
Management skills	0.009	0.013	0.009	0.013
Communication skills	0.019	0.014	0.018	0.013
Post-PhD ECMT	–	–	0.106**	0.030
N	1371			
Panel B: Men				
Doctoral education preparation				
Technical skills	− 0.011	0.011	− 0.012	0.011
Management skills	0.026**	0.010	0.026**	0.010
Communication skills	− 0.008	0.010	− 0.010	0.010
Post-PhD ECMT	–	–	0.073**	0.021
N	2721			

Models are specified as Logit regressions. The same variables as Table 3 are included in the models, but not all are shown

**/*Denote significance levels 0.01/0.05, respectively

Research Question 2: Career Preparation from PhD Programs and ECMT on the Attainment of Leadership Positions

Table 3 Column 3 reports the marginal effects at the mean on the likelihood of attaining industry leadership positions. PhDs who participated in ECMT training are 8.5 percentage points more likely than PhDs who did not participate to attain a leadership position. Meanwhile, STEM PhDs who indicated a one standard deviation higher score on management skills preparation are 2 percentage points more likely to obtain leadership positions. Women are 2.9 percentage points less likely than men to hold a leadership position in industry, although the effect is not statistically significant at the 0.05 level. Marital status and having young dependents do not appear to be associated with attainment of leadership positions.

Table 4 Column 3 shows the disaggregated results by gender. Women who participated in ECMT are 10.6 percentage points more likely than women who did not participate in ECMT to obtain leadership positions. Among men, participation in ECMT is associated with a 7.3 percentage point increase in obtaining leadership positions. Moreover, men who reported a one standard deviation higher score on preparation in management skills from their PhD program are 2.6 percentage points more likely to obtain a leadership position.

Research Question 3: ECMT and Time to First Leadership Position

Table 5 reports the marginal effects of ECMT, as well as doctoral education preparation, on number of years to first leadership position from PhD completion. Participating in ECMT does not statistically significantly reduce the time to leadership position for either women or men. The time it takes to obtain their first leadership position is longer for women than men, all else held constant. Marital status and having young dependents do not appear to be associated with time to first leadership position. Moreover, career preparation from PhD programs do not appear to be associated with time to first leadership position.

We also examined the time to first leadership position separately for women and for men (Table 6). Among women, doctoral education preparation and ECMT are not statistically significant. However, the direction of the effects suggests that ECMT, as well as preparation in technical, management, and communication skills, have the potential to reduce time to the first leadership position for women. Future studies with larger sample sizes are needed to further examine these relationships. Meanwhile, among men, higher scores in management skills preparation are associated with reduced time to the first leadership position. ECMT, however, does not appear to be related to time to first leadership position.

Research Question 4: ECMT and Salary, Size of Group Managed, and Job Satisfaction Among STEM PhDs in Industry Leadership Positions

The results on the association between participation in ECMT and each of the three outcomes—salary, group size managed, and job satisfaction—are shown in Table 7. Table 8 presents the disaggregated results by gender. The results on the first career outcome of interest, salary, are presented in Table 7 Column 1. Consistent with previous literature, there is a salary gap of 10.1 percentage points between women and men. This salary gap between women and men leaders are on par with evidence from the literature; for example, Bell (2005) reported the gender salary gap was 8 to 25 percentage points between men and women executives. ECMT and career preparation during doctoral study, as well as marital status and having young dependents, are not associated with salary. Focusing on

Table 5 Marginal effects of early career management training (ECMT) on the time to first post-PhD leadership position in industry

	Coefficient	Std. Err
Doctoral education preparation		
Technical skills	0.418	0.229
Management skills	− 0.483*	0.199
Communication skills	− 0.081	0.197
Post-PhD ECMT	− 0.091	0.331
Individual characteristics		
Women	1.595**	0.383
African American/Black	− 2.555**	0.803
Asian	0.626	0.452
Hispanic/Latinx	0.883	0.683
Permanent resident	1.898	1.737
Temporary resident	1.355*	0.545
Age at PhD	0.451	0.618
Married	0.014	0.042
Dependents under age of 6	0.145	0.410
PhD program NRC ranking		
Second quartile	0.896*	0.437
Third quartile	0.695	0.509
Fourth quartile	0.738	0.682
Not ranked	− 0.004	0.605
Initial job sector/position		
Academia	0.572	0.733
Government	− 0.272	0.679
Postdoctoral research associate	0.806	0.492
N	644	

The baseline groups of race/ethnicity, citizenship, PhD program NRC ranking, initial job sector are White, U.S. citizen, first quartile, and industry, respectively. Major, PhD year, and indicator for PhD reported having a disability are included in the models, but are not shown in the table

**/*Denote significance levels 0.01/0.05, respectively

the results on women, the association between ECMT and salary is not statistically significant (Table 8 Panel A Column 1). However, the direction of the effect suggests that among women, ECMT is associated with an 8.5% higher salary (or $9,841 more) on average, in 2013 dollars. Among men, higher scores on communication skills during doctoral study is associated with lower salaries in leadership positions (Table 8 Panel B Column 1).

The results for group size managed are presented in Table 7 Column 2. Women supervise 1.5 fewer individuals, or 26% smaller groups, on average, relative to men. Neither doctoral education preparation nor ECMT appear to be associated with group sized managed. However, among women, those who report a one standard deviation higher score in management skills supervise smaller groups with 0.9 fewer individuals (Table 8 Panel A Column 2). Among men, doctoral education preparation and ECMT are not associated with group size managed (Table 8 Panel B Column 2).

Table 7 Column 3 includes the results on the relationship between ECMT and job satisfaction. We do not find a statistically significant difference in job satisfaction between men

Table 6 Marginal effects of early career management training (ECMT) on the time to achieving first leadership position, by gender

	Coefficient	Std. Err
Panel A: Women		
Doctoral education preparation		
Technical skills	0.792	0.439
Management skills	− 0.095	0.360
Communication skills	− 0.105	0.392
Post-PhD ECMT	− 0.421	0.577
N	196	
Panel B: Men		
Doctoral education preparation		
Technical skills	0.325	0.277
Management skills	− 0.678**	0.232
Communication skills	− 0.116	0.224
Post-PhD ECMT	0.138	0.390
N	448	

The same variables as Table 5 are included in the models, but not all are shown

**/*Denote significance levels 0.01/0.05, respectively

and women. However, STEM PhDs who participated in ECMT are 8.5 percentage points less likely to indicate that they are very satisfied with their jobs, while STEM PhDs with a one standard deviation higher score in management skills are 5.2 percentage points more likely to indicate that they are very satisfied with their jobs. STEM PhDs who indicated being married are also less likely than those who are not to report higher job satisfaction. Among women and among men, neither doctoral education preparation nor ECMT are associated with job satisfaction (Table 8 Column 3).

Discussion

Informed by Eagly and Carli's (2007) leadership labyrinth, we examined how human capital as described by Becker (1964) and work-home conflict are related to attainment of leadership positions. By examining the career paths of individuals with the highest level of educational attainment—PhDs—we partially account for arguments related to differences in human capital or educational achievement in explaining gaps in access to leadership positions between men and women. Our research findings reveal that post-PhD early career management training is associated with a higher likelihood of attaining leadership roles for women STEM PhDs and for men STEM PhDs. Moreover, doctoral education preparation in management skills can help with the attainment of leadership positions, as well as reduce the time to attainment of the first leadership position. These findings suggest that professional development in management may help increase participants' internalization of leadership roles, potentially mitigate gender bias in the workplace (Ely et al., 2011; Ibarra et al., 2013), and/or provide more opportunities for increasing social networks and access to mentors (Blake-Beard, 2001). Employers that offer ECMT are potentially providing increased access to top-level positions. Increased access to leadership positions have

Table 7 Marginal effects of early career management training (ECMT) on log salary, size of group managed, and job satisfaction

	Log salary	Size of group Managed	Job satisfaction
Doctoral education preparation			
Technical skills	0.034	− 0.009	− 0.040
	(0.023)	(0.348)	(0.027)
Management skills	0.013	0.350	0.052*
	(0.020)	(0.303)	(0.023)
Communication skills	− 0.037	− 0.144	0.003
	(0.020)	(0.300)	(0.023)
Post-PhD ECMT	0.016	0.592	− 0.085*
	(0.033)	(0.504)	(0.038)
Individual characteristics			
Women	− 0.101**	− 1.543**	− 0.033
	(0.039)	(0.583)	(0.045)
African American/Black	− 0.031	0.987	0.073
	(0.081)	(1.225)	(0.093)
Asian	0.000	1.309	− 0.009
	(0.045)	(0.689)	(0.053)
Hispanic/Latinx	0.105	− 0.264	0.060
	(0.069)	(1.042)	(0.079)
Permanent resident	0.077	10.919**	0.335
	(0.055)	(2.649)	(0.202)
Temporary resident	0.037	0.560	− 0.032
	(0.062)	(0.832)	(0.063)
Age at PhD	− 0.016**	− 1.390	− 0.076
	(0.004)	(0.942)	(0.072)
Married	0.052	− 0.100	− 0.013**
	(0.041)	(0.064)	(0.005)
Dependents under age 6	0.037	0.786	0.004
	(0.041)	(0.625)	(0.048)
PhD program NRC ranking			
Second quartile	0.024	− 0.019	− 0.039
	(0.044)	(0.667)	(0.051)
Third quartile	0.054	0.827	− 0.012
	(0.051)	(0.776)	(0.059)
Fourth quartile	0.052	− 0.643	− 0.168*
	(0.069)	(1.040)	(0.079)
Not ranked	0.036	1.434	0.188**
	(0.060)	(0.923)	(0.070)
Initial job sector/position			
Academia	− 0.062	− 0.793	0.151
	(0.075)	(1.118)	(0.085)
Government	− 0.068	0.370	0.237**
	(0.068)	(1.035)	(0.079)
Postdoctoral research associate	− 0.099*	− 0.607	0.038
	(0.050)	(0.751)	(0.057)
N	626	644	644

Standard errors of the coefficients are in parentheses. Each column represents a separate model. Models are specified as linear regressions. The baseline groups for race/ethnicity, U.S. citizenship, NRC ranking, and initial job sector are White, U.S. citizen, first quartile, and industry, respectively. PhD field, PhD year, and indicator for PhD reported having a disability are included, but are not shown in the table

**/*Denote significance levels 0.01/0.05, respectively

Table 8 Estimated effects of early career management training (ECMT) on log salary, size of group managed, and job satisfaction, by gender

	Log salary	Size of group managed	Job satisfaction
Panel A: Women			
Doctoral education preparation			
Technical skills	0.038	0.937	− 0.049
	(0.046)	(0.515)	(0.056)
Management skills	− 0.044	− 0.907*	0.067
	(0.039)	(0.423)	(0.046)
Communication skills	− 0.004	0.167	0.055
	(0.041)	(0.461)	(0.050)
Post-PhD ECMT	0.085	0.300	− 0.144
	(0.061)	(0.678)	(0.074)
N	192	196	196
Panel B: Men			
Doctoral education preparation			
Technical skills	0.053	− 0.319	− 0.051
	(0.029)	(0.463)	(0.031)
Management skills	0.020	0.752	0.042
	(0.024)	(0.388)	(0.026)
Communication skills	− 0.052*	− 0.481	− 0.022
	(0.023)	(0.375)	(0.025)
Post-PhD ECMT	− 0.027	0.103	− 0.057
	(0.040)	(0.653)	(0.044)
N	434	448	448

Standard errors of the coefficients are in parentheses. Each column represents a separate model. Models are specified as linear regressions. The models include the same variables as Table 7, but not all are shown in the table

**/*Denote significance levels 0.01/0.05, respectively

implications for enhancing innovation and leadership diversity, potentially contributing to counteracting structural and systemic barriers.

We focused on human capital factors and gender differences of the leadership labyrinth metaphor to help examine women's leadership attainment. Consistent with previous literature, our results show that there is a salary gap between men and women in leadership positions. We also found suggestive evidence that early career management training can potentially reduce the time to the first leadership position and also boost salary for women. While these results are not statistically significant, future studies with larger sample sizes could further examine the role of ECMT on women's career leadership attainment and earnings. Nevertheless, our findings highlight the importance of continued professional development opportunities for women and men in their trajectories toward leadership positions.

Our data, however, do not permit us to test the mechanisms for how doctoral preparation or post-PhD management training contribute to a higher likelihood of obtaining leadership roles. The NSF SDR does not provide information regarding the nature or the contents of the leadership training, such that we are unable to address how heterogeneity in training influences employment outcomes. Our findings suggest that these professional

development opportunities are important to the long-term career paths of STEM PhDs and that further research is needed to investigate how dosage/duration and contents of the training program contribute to the attainment of leadership positions.

Although the leadership labyrinth has informed our study, there are other factors that contribute to differences in women's and men's attainment of leadership positions. These include: (1) differences in style, self-promotion, negotiation, and traits, and (2) prejudice and biased perceptions and evaluations, stereotypes, and cross-pressures as described by Northouse (2016). These other factors are important in explaining gender differences in employment outcomes. By focusing on human capital factors and work-home conflict, our study does not address issues from the demand side, such that we are unable to address why and how employers determine who to hire and how structural barriers constrain women's career paths. The attainment of leadership positions is not limited to increasing human capital, but is also dependent on organizational and cultural structures regarding power and how it is distributed. Our findings speak to the importance of PhD training and employer-provided leadership training (ECMT) in changing attitudes, culture, and aspirations for leadership positions, and how changes at the organizational level can help promote greater diversity in leadership attainment.

Limitations

While the NSF SDR is a comprehensive data set, our study has several limitations. First, the levels of preparedness in communication, management, and technical trainings are based on self-assessment and are self-reported, and therefore may not be accurate or fully reflect the level of preparation the doctoral program offered. It is possible that PhDs in management roles may reflect more positively on the level of preparation provided by their PhD programs in management skills. However, this concern is mitigated by the different time points in which the doctoral education preparation and career outcomes are measured. That is, the PhD respondents provided information regarding their doctoral education preparation years prior to obtaining a leadership position.

Furthermore, we consider our results to be correlational, rather than causal. There are many unobservable factors that are related to participation in ECMT and in the attainment of leadership roles. We addressed some of the potential selection bias through the use of propensity score matching for research questions 3 and 4. Although we used propensity score matching to partially address the nonrandomness of participation in ECMT, it may not have fully resolved the selection bias issue. We conducted a robustness check to determine whether the motivation/reason for participating in ECMT influences career outcomes and found that differences in reasons do not appear to influence the likelihood of attaining a leadership position.

Since the NSF SDR data that we analyzed were not originally intended as a longitudinal study, we used repeated measures of the same PhD respondent for individual-time observations, but there may be occasions when PhDs are either not sampled or did not respond to a given survey wave. Our results therefore address a subsample of PhDs who responded to multiple survey waves.

Conclusion and Implications

Changes in doctoral education preparation in management skills and increases in ECMT opportunities among employers have the potential to increase the participation of STEM PhDs in leadership roles in industry. Participation in ECMT has a positive relationship with attainment of leadership positions for both men and women. Women who participate in ECMT are more likely than women who do not participate in ECMT to obtain leadership positions. Moreover, among PhDs in leadership positions, women who participate in ECMT have relatively higher salaries than women who do not participate in ECMT, although this estimate is not statistically significant (likely due to small sample size). Although these findings suggest that increases in the accumulation of human capital in terms of education and professional development can help promote leadership trajectories, our research findings also highlight the importance of changes at the organization level. That is, employers creating more opportunities for ECMT may help facilitate women's pathways toward leadership and help promote cultural changes in how women leaders are perceived and supported within the organization.

We also provide evidence that doctoral programs with relatively greater focus on developing management skills are contributing to preparing their PhDs for leadership roles. Doctoral programs are proficient in preparing PhD students in technical skills, such as computer, problem-solving, and quantitative skills, and our findings suggest that increased attention to management skills can potentially lead more PhDs to consider and pursue leadership positions post-graduation. STEM PhDs who report feeling better prepared in management skills are more likely to attain leadership positions. PhD programs that promote development of management skills may contribute to helping their students aspire for potential careers in leadership and to reach those positions more quickly. Investments in PhD students' preparation in management skills therefore have the potential for long-term impact on career pathways to leadership and in helping address cultural issues associated with who is encouraged to envision and pursue leadership.

Advancing women's career equality will certainly need to incorporate larger-scale structural and cultural changes. Our research findings extend the literature on how early career professional development opportunities and PhD training in management skills contribute to STEM PhDs' likelihood of obtaining leadership roles in the industry sector using the Leadership Labyrinth framework (Eagly & Carli, 2007). Our study provides doctoral programs and industry stakeholders with actionable information for potentially enhancing training to align with workforce demands and student preferences and needs. Furthermore, it provides evidence that changes to organizations in terms of how leadership careers are promoted and conceptualized at the PhD program level and at the employer level have potential impact on individual-level decisions and pathways. Importantly, research findings provide current PhD students and PhDs with evidence that strengthening management skills during the PhD and participating in management training during their early careers may contribute to enhancing their employment outcomes. Increasing the participation of women at the highest level of organizations can lead to wide-ranging changes in technological innovations and to inspiring students to pursue leadership in STEM fields.

Appendix

Table 9 and Figs. 2 and 3.

Table 9 Factor analysis of doctoral education career preparation skills

	Technical	Management	Communication
Oral communication			0.892
Computer	0.463		
Establishing contacts		0.518	
Research integrity/ethics	0.300		
Problem-solving	0.529		
Subject matter knowledge	0.420		
Management/administrative		0.671	
Quantitative	0.691		
Teaching			0.303
Collaboration/teamwork		0.458	
Writing			0.256

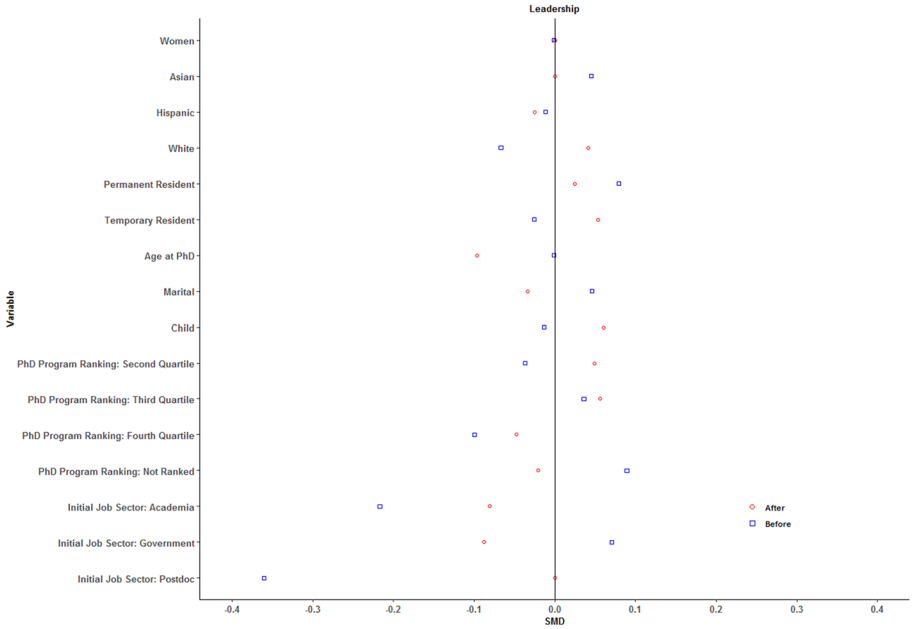

Fig. 2 Love plot of covariate balance before and after matching

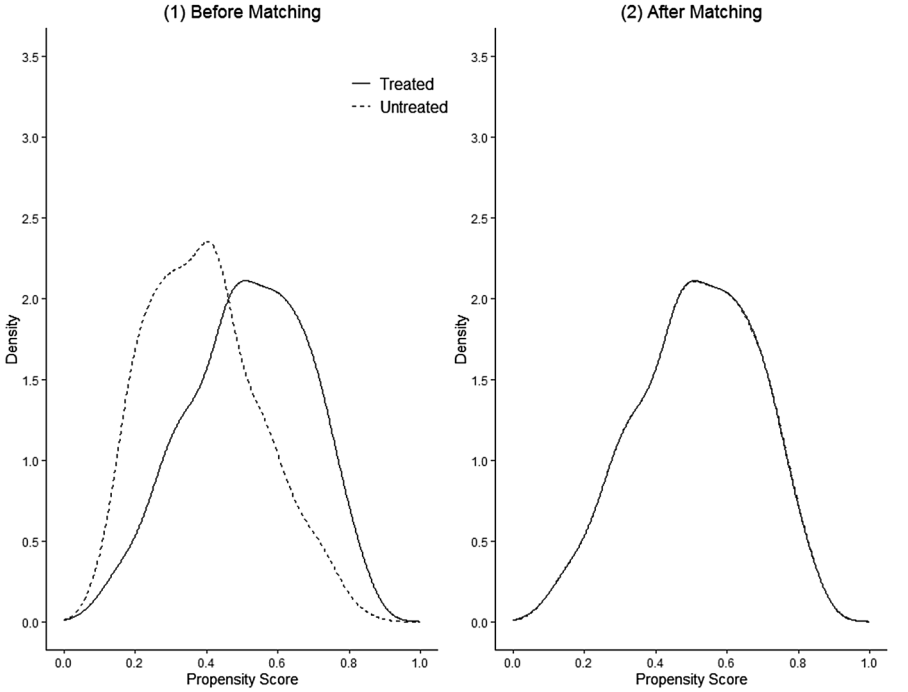

Fig. 3 Kernel densities of probability of participating in ECMT before and after matching

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References

Andrews, J., & Higson, H. (2008). Graduate employability, "professional skills" versus "hard" business knowledge: A European study. *Higher Education in Europe, 33*(4), 411–422.

Austin, A. E. (2002). Preparing the next generation of faculty: Graduate school as socialization to the academic career. *Journal of Higher Education, 73*(1), 94–122.

Balcar, J. (2014). Professional skills and their wage returns: Overview of empirical literature. *Review of Economic Perspectives, 14*(1), 3–15.

Bass, B., & Stogdill, R. (1990). *Bass & Stogdill's handbook of leadership: Theory, research, and managerial applications* (3rd ed.). Free Press; Collier Macmillan.

Becker, G. (1964). *Human capital: A theoretical and empirical analysis*. Columbia University Press.

Bell, L. A. (2005). Women-led firms and the gender gap in top executive jobs. Institute for the Study of Labor Discussion Paper 168.

Biddle, J., & Roberts, K. (1994). Private sector scientists and engineers and the transition to management. *Journal of Human Resources, 29*(1), 82–107.

Blake-Beard, S. D. (2001). Taking a hard look at formal mentoring programs. *The Journal of Management Development, 20*(4), 331–345.

Boaden, R. J. (2006). Leadership development: Does it make a difference? *Leadership & Organization Development Journal, 27*(1), 5–27.

Borghans, L., Weel, B., & Weinberg, B. (2014). People skills and the labor-market outcomes of underrepresented groups. *ILR Review, 67*(2), 287–334.

Brungardt, C. (1997). The making of leaders: A review of the research in leadership development and education. *Journal of Leadership Studies, 3*(3), 81–95.
Catalyst. (2020, September 14). Women in S&P 500 companies. https://www.catalyst.org/research/women-ceos-of-the-sp-500/
Chanland, D. E., & Murphy, W. M. (2018). Propelling diverse leaders to the top: A developmental network approach. *Human Resource Management, 57*(1), 111–126.
Cook, A., & Glass, C. (2014). Women and top leadership positions: Towards an institutional analysis. *Gender, Work, and Organization, 21*(1), 91–103.
Correll, S. J., Benard, S., & Paik, I. (2007). Getting a job: Is there a motherhood penalty? *The American Journal of Sociology, 112*(5), 1297–1339.
Day, D. V., & Harrison, M. M. (2007). A multilevel, identity-based approach to leadership development. *Human Resource Management Review, 17*(4), 360–373.
Deming, D. J. (2017). The growing importance of social skills in the labor market. *Quarterly Journal of Economics, 132*(4), 1593–1640.
DeRue, D. S., & Ashford, S. J. (2010). Who will lead and who will follow? A social process of leadership identity construction in organizations. *Academy of Management Review, 35*(4), 627–647.
Eagly, A., & Carli, L. (2007). *Through the labyrinth: The truth about how women become leaders (Leadership for the common good)*. Harvard Business School Press.
Ely, R. J., Ibarra, H., & Kolb, D. M. (2011). Taking gender into account: Theory and design for women's leadership development programs. *Academy of Management Learning & Education, 10*(3), 474–493.
Fortune. (2020). Women in S&P 500 companies. https://fortune.com/fortune500/
Fritz, C., & Van Knippenberg, D. (2018). Gender and leadership aspiration: The impact of work-life initiatives. *Human Resource Management, 57*(4), 855–868.
Gipson, A. N., Pfaff, D. L., Mendelsohn, D. B., Catenacci, L. T., & Burke, W. W. (2017). Women and leadership: Selection, development, leadership style, and performance. *The Journal of Applied Behavioral Science, 53*(1), 32–65.
Gould, J. A., Kulik, C. T., & Sardeshmukh, S. R. (2018). Trickle-down effect: The impact of female board members on executive gender diversity. *Human Resource Management, 57*(4), 931–945.
Hancock, S., & Walsh, E. (2016). Beyond knowledge and skills: Rethinking the development of professional identity during the STEM doctorate. *Studies in Higher Education, 41*(1), 37–50.
Heckman, J. J., & Kautz, T. (2012). Hard evidence on professional skills. *Labour Economics, 19*(4), 451–464.
Hochschild, A., & Machung, A. (1990). The second shift: Working parents and the revolution at home. *The American Journal of Sociology, 96*(3), 776–778.
Hoobler, J. M., Lemmon, G., & Wayne, S. J. (2014). Women's managerial aspirations: An organizational development perspective. *Journal of Management, 40*(3), 703–730.
Hoobler, J. M., Wayne, S. J., & Lemmon, G. (2009). Bosses' perceptions of family-work conflict and women's promotability: Glass ceiling effects. *Academy of Management Journal, 52*(5), 939–957.
Hotho, S., & Dowling, M. (2010). Revisiting leadership development: The participant perspective. *Leadership & Organization Development Journal, 31*(7), 609–629.
Ibarra, H., Ely, R., & Kolb, D. (2013). Women rising: The unseen barriers. *Harvard Business Review, 91*(9), 60–66.
Joshi, A. (2014). By whom and when is women's expertise recognized? The interactive effects of gender and education in science and engineering teams. *Administrative Science Quarterly, 59*(2), 202–239.
Judge, T. A., Cable, D. M., Boudreau, J. W., & Bretz, R. D. (1995). An empirical investigation of the predictors of executive career success. *Personnel Psychology, 48*(3), 485.
Klimoski, R., & Amos, B. (2012). Practicing evidence-based education in leadership development. *Academy of Management Learning & Education, 11*(4), 685–702.
Kossek, E. E., & Buzzanell, P. M. (2018). Women's career equality and leadership in organizations: Creating an evidence-based positive change. *Human Resource Management, 57*(4), 813–822.
Kossek, E., Su, R., & Wu, L. (2017). "Opting out" or "pushed out"? Integrating perspectives on women's career equality for gender inclusion and interventions. *Journal of Management, 43*(1), 228–254.
Kuhn, P., & Weinberger, C. (2005). Leadership skills and wages. *Journal of Labor Economics, 23*(3), 395–436.
Laker, D. R., & Powell, J. L. (2011). The differences between hard and professional skills and their relative impact on training transfer. *Human Resource Development Quarterly, 22*(1), 111–122.
Lee, H. F., Miozzo, M., & Laredo, P. (2010). Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university. *Research Policy, 39*(7), 869–881.
Linden, A., & Samuels, S. J. (2013). Using balance statistics to determine the optimal number of controls in matching studies. *Journal of Evaluation in Clinical Practice, 19*(5), 968–975.

Linehan, M., & Walsh, J. S. (2000). Work–family conflict and the senior female international manager. *British Journal of Management, 11*, S49–S58.

Manathunga, C., Pitt, R., & Critchley, C. (2009). Graduate attribute development and employment outcomes: Tracking PhD graduates. *Assessment & Evaluation in Higher Education, 34*(1), 91–103.

Miller, D., Xu, X., & Mehrotra, V. (2015). When is human capital a valuable resource? The performance effects of Ivy league selection among celebrated CEOs. *Strategic Management Journal, 36*(6), 930–944.

Normand, S. L. T., Landrum, M. B., Guadagnoli, E., Ayanian, J. Z., Ryan, T. J., Cleary, P. D., & McNeil, B. J. (2001). Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: A matched analysis using propensity scores. *Journal of Clinical Epidemiology, 54*(4), 387–398.

Northouse, P. G. (2016). *Leadership theory and practice* (7th ed.). Sage Publishing.

Oakley, J. G. (2000). Gender-based barriers to senior management positions: Understanding the scarcity of female CEOs. *Journal of Business Ethics, 27*(4), 321–334.

O'Meara, K., Jaeger, A., Eliason, J., Grantham, A., Cowdery, K., Mitchall, A., & Zhang, K. (2014). By design: How departments influence graduate student agency in career advancement. *International Journal of Doctoral Studies, 9*(1), 155–179.

Platow, M. J. (2012). PhD experience and subsequent outcomes: A look at self-perceptions of acquired graduate attributes and supervisor support. *Studies in Higher Education, 37*(1), 103–118.

Proudfoot, S. (2014). *Survey of doctorate recipients, 2013*. National Science Foundation.

Roberts, K., & Biddle, J. (1994). The transition into management by scientists and engineers: A misallocation or efficient use of human resources? *Human Resource Management, 33*(4), 561–579.

Rubin, D. B. (2001). Using propensity scores to help design observational studies: Application to the tobacco litigation. *Health Services and Outcomes Research Methodology, 2*(3–4), 169–188.

Selfa, L., and Proudfoot, S. (2014). *Unemployment among doctoral scientists and engineers remained below the national average in 2013* (NSF 14-317). National Science Foundation, National Center for Science and Engineering Statistics.

Singh, R., Zhang, Y., Wan, M. M., & Fouad, N. A. (2018). Why do women engineers leave the engineering profession? The roles of work-family conflict, occupational commitment, and perceived organizational support. *Human Resource Management, 57*(4), 901–914.

Stuart, E. A. (2010). Matching methods for causal inference: A review and a look forward. *Statistical Science, 25*(1), 1–21.

Virick, M., & Greer, C. R. (2012). Gender diversity in leadership succession: Preparing for the future. *Human Resource Management, 51*(4), 575–600.

Weinberger, C. J. (2014). The increasing complementarity between cognitive and social skills. *Review of Economics and Statistics, 96*(4), 849–861.