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# (Re)Shaping the Socialization of Scientific Labs: Understanding Women’s Doctoral Experiences in STEM Lab Rotations

*Annie M. Wofford & Jennifer M. Blaney*

**Abstract:** Building on literature addressing doctoral student socialization and scientific research groups, we qualitatively explore the gendered nature of laboratory rotations for 54 women pursuing STEM doctorates. Using

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in-depth interviews and a feminist phenomenological approach, findings highlight how women (re)constructed strategies to select lab rotations, relying on social comparisons, social cues about labor practices, and support from principal investigators, peers, and departmental staff. This study documents how women were sometimes felt they had to choose between a prestigious lab aligning with their interests and a lab that would not be overtly sexist. We conclude with practical implications for enhancing equitable socialization structures in STEM.

*Keywords:* Graduate education; STEM; doctoral socialization; gender; student-advisor relationships

While women have made great strides toward parity in science, technology, engineering, and mathematics (STEM) fields in the United States, gender disparities persist. Even in fields like the biological sciences—where women make up over half of doctoral degree recipients—women remain underrepresented in more senior academic positions, holding just 31% of full and associate professor positions in biological, agricultural, and environmental life sciences in 2017 (NCES, 2018; NCSES, 2019). Women’s marginalization in STEM faculty roles is often a product of experiences and inequities in doctoral education (Hughes et al., 2017). For example, Mathur and colleagues (2018) found significant inequities in biomedical doctoral recipients’ vocational paths, such that women were more likely to pursue careers in healthcare or jobs where their main responsibility was teaching (e.g., adjunct or lecturer positions) while men were more likely to pursue research-related careers. Relatedly, gender disparities have been found across key doctoral student outcomes that are precursors for successfully obtaining faculty positions in biology, such as the number of scholarly publications (Feldon et al., 2017; Pezzoni et al., 2016).

It is especially vital to understand how gender shapes critical transitions in graduate school, such as the first year of doctoral training. Scholars have long discussed how the first year of graduate school impacts women’s participation and success in their chosen field (Golde, 1998; Sallee, 2011a). In biological and other laboratory (lab) sciences, researchers have documented how the first year of doctoral programs is characterized by lab rotations—a process in which students navigate short-term placements in several research labs while finding an appropriate match for their training (Hirshfield, 2015; Maher et al., 2019, 2020a). Despite lab rotations being viewed as a “signature pedagogy” that defines the first year of graduate training in many doctoral programs (Golde, 2007, p. 350), they are not well understood.

The present work seeks to understand women's<sup>1</sup> experiences during lab rotations within doctoral programs in the biological sciences. Using in-depth interviews and a feminist phenomenological approach, we qualitatively examine the gendered nature of lab rotations. By exploring how women (re)shape their socialization experiences during rotations in the biological sciences, this study points to ways that doctoral programs in lab sciences can more equitably support students through their rotations and lab selection. Discerning how components of the lab rotation process are gendered will help address pervading inequities that are sustained through doctoral programs and into women's scientific careers. Thus, we ask: How do women in Ph.D. programs experience lab rotations in the biological sciences?

### CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

This study explores the gendered nature of doctoral student socialization<sup>2</sup> in STEM and is situated within a socialization framework (Weidman, 2010). Socialization theory has been a predominant lens of inquiry for scholars examining doctoral training in the United States (e.g., Austin & McDaniels, 2006; Gardner, 2008). Doctoral student socialization describes the processes by which students internalize norms, social structures, and disciplinary values, typically through interactions with advisors, peers, and other individuals within the doctoral program (Austin & McDaniels, 2006; Burt, 2019; Gardner, 2008, 2010; Gilmore et al., 2016; Weidman, 2010; Weidman & DeAngelo, 2020; Weidman et al., 2001). Socialization experiences may be particularly complex during the first year of lab-based STEM doctoral programs, given that students form new social connections with each lab rotation. In addition, socialization theory has several limitations (summarized at the end of this section), and—as we discuss in our findings—women doctoral students in biology are finding ways to circumvent some dominant socializing forces of their programs. To examine this phenomenon, we rely on recent theoretical advancements to socialization and adopt a feminist perspective.

Our socialization lens draws heavily from Burt's (2019) theoretical model of engineering professorial intentions (TMEPI). The TMEPI is rooted in extant research about socializing relationships and practices that influence doctoral students' intentions to pursue a faculty career (e.g., Austin & Mc-

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<sup>1</sup>In this study, we use the term "women" to include any participants that self-identified as women when asked about their gender identity and in reference to other scholars' findings about gender. We use the terms "women" and "men" as both adjectives and nouns throughout this work.

<sup>2</sup>We use doctoral student socialization to frame the experiences of Ph.D. students, yet we acknowledge that doctoral education can include other trajectories such as professional degrees (e.g., M.D., J.D.).

Daniels, 2006; Gardner, 2008; Sallee, 2011a). Advancing this framing, Burt considered how sociocultural contexts and students' social identities underscore the doctoral socialization process. Specifically, Burt discussed how sociocultural contexts (e.g., institutional priorities for research productivity, economic factors) impact students' professorial intentions. Using a sample of participants with diverse social identities (e.g., gender, race/ethnicity, citizenship) and personal traits (e.g., marital status, occupation), Burt also found that students' social identities shaped their research group experiences, views of faculty life, and social comparisons. Providing additional context and complexity to this model, it is notable that the focus on research group experiences in the TMEPI builds on earlier studies of racial microaggressions, where Burt and colleagues (2016) highlighted the important role peer groups play in supporting Black doctoral students who encounter discrimination and microaggressions from advisors. However, peers and labmates in STEM graduate programs may simultaneously be a source of microaggressions (Burt et al., 2016).

With regard to the influence of gender in the TMEPI, several women in Burt's (2019) study discussed how their perceptions of faculty and familial roles conflicted. While Burt interpreted gender inequities to be a product of pressures from the broader science community and not research groups, we hypothesized that gender may be salient in how women choose research groups in a lab sciences context. In biology, the process of establishing a research group is often characterized by a sequence of lab rotations (each lasting 7 to 10 weeks) that lead to students' selection of a permanent research group. Thus, while Burt's theory focuses on longer-term outcomes for engineering doctoral students, we amended this model to focus on the early role of lab rotations as transitional and iterative research group experiences among doctoral students in the biological sciences.

### ***Identity and Doctoral Student Socialization***

Doctoral socialization processes are undoubtedly shaped by gender, and prior literature has provided insight into how women navigate a gendered process of doctoral socialization (Sallee, 2011a, 2011b). While research has historically depicted socialization as the way doctoral students learn and adapt to the norms and values that typify their discipline and program (Weidman et al., 2001), scholars have also challenged the passive foundations of socialization (i.e., where students are the recipient of "traditional" values) to account for students' agency. Countering this passive foundation has revealed inequities in doctoral socialization (e.g., Acker & Haque, 2015; Margolis & Romero, 2001; Portnoi et al., 2015) and led to the formal addition of agency in the newest socialization framework (see Weidman & DeAngelo, 2020). In the findings that follow, we highlight women's agentic role and offer insight into the ways in which women (re)shape socialization processes by circumventing hostile labs.

Discussing women's resistance to elements of doctoral socialization becomes increasingly complex when accounting for women's other identities such as race/ethnicity or first-generation status. Extant literature has documented how social identities and systems of oppression (e.g., racism, sexism) play an influential role in doctoral socialization and shape students' programmatic satisfaction and degree completion (González, 2006; Griffin et al., 2020; Turner & Thompson, 1993; Twale et al., 2016; Williams et al., 2018). Given our motivation to understand women's experiences in doctoral education, we focus the present work on gender while also considering other salient identities that may intersect and operate in tandem with gender for the women in our study.

### ***Gendered Doctoral Experiences for Women in STEM***

Although women are now numerically well represented among doctoral degree recipients in the life sciences, "assumptions and beliefs that women's growing access to education would result in gender equity in scientific careers have proven unfounded" (Fox, 2001, p. 657). Indeed, the hierarchical nature of gender in society is upheld in the stereotypes of who works in science (Fox, 2001; Joy et al., 2015). For example, Gazley and colleagues (2014) found a gendered hierarchy among women and men's post-Ph.D. STEM career aspirations even before matriculation, such that no women expressed a strong desire to become an academic scientist, whereas men frequently aspired to a career as a faculty member and principal investigator (PI). Prior research has also suggested that gender shapes how others perceive women as they move into leadership positions within lab contexts (Hirshfield, 2014).

In light of persistent gender inequities, recent studies of women's doctoral experiences in STEM have highlighted the role of peer relationships. For one, Bostwick and Weinberg (2018) found that women who were part of doctoral cohorts with no same-gender peers were less likely than men to graduate within six years, concluding that "climate is the mechanism driving the observed gender peer effects" (Bostwick & Weinberg, 2018, p. 2). Another study discussed how women form same-gender mentoring relationships with advanced doctoral students, who serve as key socialization agents as women adjust to masculinized lab settings (Hirshfield, 2015). More broadly, researchers have consistently found that peers support women's persistence in STEM doctoral programs (Bhatia & Amati, 2010; Šaras et al., 2018). Given how peers are also often labmates in research, there remains a need to better understand the link between socialization experiences and how women (re) evaluate support from peers through lab rotations.

Additionally, gender plays a notable role in Ph.D. students' relationships with faculty advisors (Twale et al., 2016). Recent studies of STEM graduate programs have upheld the fact that advisors provide vital support to women (Miller, 2015; Tao & Gloria, 2019). Indeed, perceived advisor support fosters women doctoral students' sense of compatibility between their gender

identity and their scientific domain (Clark et al., 2016). Yet, STEM doctoral students' gender identities may also subject them to systemic disadvantages in faculty mentoring (Curtin et al., 2016; Noy & Ray, 2012). Some scholarship has also considered the effect of student-faculty gender congruence in doctoral education, and results suggest that women doctoral students fare better in terms of publishing and moving into academic careers when their advisor shares their gender identity (Gaule & Piacentini, 2018; Pezzoni et al., 2016).

### **Rotations as an Early Socialization Mechanism and Introduction to Labor Norms**

Lab rotations are a common aspect of many STEM Ph.D. programs (Conti & Liu, 2015; Holley, 2010; Maher et al., 2019). Specific to the biological sciences, Maher and colleagues (2019) found that the "student grapevine" shapes students' information networks in rotations, aligning with previous findings about the role of peer networks as a socialization mechanism (Gardner, 2007). Such a "grapevine" effect refers to the informal channels by which advanced students communicate advice to earlier-stage doctoral students. However, Maher et al. (2019) also recognized that these channels may open the "door to systemic inequity in information access" (p. 78). Indeed, a follow-up study revealed nuanced differences in how students' lab selection processes diverge depending on their gender, racial/ethnic, or first-generation identities (Maher et al., 2020a), which may have longer-term implications for key experiences like lab mentorship (Burt, 2017). Other literature in chemistry has also explored how women and men differentially experience lab rotations, with women encountering greater competition and work-life balance conflicts than men (Hirshfield, 2015). In our study, we aim to better understand such inequities by focusing on women's experiences in biological sciences lab rotations, highlighting how women make decisions about the lab norms and values with which they (mis)align. In doing so, this study adds necessary depth to our understanding of women's doctoral experiences in scientific labs.

Any dialogue about women's experiences during rotations should be prefaced with the understanding that graduate training and lab environments are shaped by larger academic labor practices and systems. In addition to adjusting to changing lab environments, students are expected to simultaneously navigate their roles as both doctoral students and workers within labs, which can complicate students' relationships with faculty advisors (Julius & Gumport, 2003). At the same time, academic capitalism influences the climate and policies of higher education (Mendoza, 2012). Conceptualized more than two decades ago, Slaughter and Leslie (1997) first discussed academic capitalism as market-like behaviors used by institutions to compete for scarce resources, such as research funds, faculty members, and students. Given how

scientific knowledge can be commodified for financial gain, and how graduate students can be viewed as inexpensive labor, the pressures of academic capitalism may have an especially strong influence on graduate school experiences in the sciences (Mendoza, 2007). In STEM doctoral programs, the effects of academic capitalism can create a culture of immense competition and may play an indirect role in how women adopt or circumvent certain socialization norms of rotating lab environments (see Stephan, 2012). Unjust labor practices may be why women in chemistry lab rotations describe being explicitly socialized to adopt masculinized norms like competition and the expectation to spend long hours in the lab (Hirshfield, 2015). As such, we view rotations as a key mechanism of socialization that shapes women's early understanding of academic labor norms, which, in turn, influences their later graduate school experiences.

### ***Navigating the Limitations of a Socialization Framework***

Socialization has endured as an important framework to study doctoral education. Yet, socialization has been disproportionately popular among U.S.-based researchers, which may limit the ways in which studies on American doctoral education can be discussed in international contexts (Acker & Haque, 2015). Acker and Haque (2015) argued that one reason socialization gained popularity in the United States is because American doctoral students navigate many benchmarks and extended interactions with faculty and peers. Several other shortcomings of socialization are ones that we directly critique in our analyses. First, scientific "norms" may be a reflection of larger systemic influences such as capitalism and sexism. In fact, a broad base of literature has interrogated how universities may abuse labor and treat knowledge as a commodity (e.g., Slaughter & Leslie, 1997; Stephan, 2012), as well as how norms within scientific fields have been shaped by sexism and stereotypically masculine ideals (Etzkowitz et al. 2000; Rosser, 2012). In light of these studies, one of the historical limitations of socialization theory is that it has operated under the assumption that students must assimilate into exclusionary and discriminatory spaces in order to be successful. However, recent research using a socialization lens has drawn attention to students' agentic roles in socialization and their abilities to challenge disciplinary norms (e.g., Gopaul, 2011; Portnoi et al., 2015; Weidman & DeAngelo, 2020). By exploring how women make meaning of their experiences, agency, and behaviors during rotations, our study provides new insight into socialization theory and how it can be applied critically to understand student experiences in lab environments.



## RESEARCH DESIGN

### *Methodological Approach*

This study used a feminist phenomenological approach to uncover how social reality, perceptions, and meaning making were influenced by gender (see Bartky, 1975; Garko, 1999). Phenomenology is appropriate for studies that seek to explain a phenomenon by focusing on participants' meaning making to get at the essence(s) of the phenomenon (van Manen, 2016). According to Goldberg and colleagues (2009), the "aim of *feminist* [emphasis added] phenomenology is to be inclusive of women's lived experiences, in a world primarily seen through the eyes of men" (p. 541). Given our goal to center women's voices in scientific labs, feminist phenomenology was foundational to our work. Specifically, we drew from existential approaches, as existential phenomenology is compatible with feminist values (Garko, 1999). This approach shaped our decision to focus on women's socialization experiences (as opposed to comparing women to men), and in doing so, we feature participants' voices in the essence of their everyday lived experiences during lab rotations (Garko, 1999; Heidegger, 1962/2008).

### *Institutional and Participant Sample*

This article used data from a larger, mixed-methods study investigating graduate students' experiences in biological sciences Ph.D. programs<sup>3</sup> over time. Initially, this project included 336 students across 53 universities who entered their Ph.D. programs in fall 2014. A primary goal of this project has been to examine inequities across graduate students' experiences and outcomes; thus, semistructured interviews were only conducted at the 27 (of 53) institutions where racially/ethnically minoritized doctoral students were participants (i.e., those who identified as Black or African American, Latina/o/x, American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, or another racial/ethnic group beyond white or Asian/Asian American).

In light of this study's focus on women's experiences as first-year doctoral students in lab rotations, we restricted the participant sample to reflect this scope. Participants must have (1) discussed rotations in their first-year interview, (2) completed both an interview at the end of their first year and during their second year, as we were interested in real-time and retrospective meaning making, and (3) self-identified as women. Employing these restrictions resulted in a sample of 54 women doctoral students who completed lab rotations during the 2014-2015 academic year across 24 institutions. See Table 1 in the Appendix for a profile of participants.

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<sup>3</sup>In particular, the larger study focused on "bench biology"—doctoral programs in microbiology, cellular and molecular biology, genetics, and developmental biology.

### ***Data Collection***

As part of the broader study, all participants completed a demographic survey at the beginning of their Ph.D. programs and in their second year (i.e., fall 2015). These data provided meaningful context in terms of participants' characteristics, such as gender, race/ethnicity, prior education, and post-Ph.D. career aspirations (see Table 1 in the Appendix). Students were interviewed annually (i.e., during each spring of their doctoral program). Interviews lasted between 30 and 60 minutes and were conducted via phone. All interviews were transcribed verbatim and deidentified.

Aligning with feminist phenomenology, the interview questions were designed to be open ended and allowed participants to lead the dialogue. In an effort to preserve participants' agency in guiding their stories, probing questions were used sparingly. At the onset of this study, the research team was unaware how pervasive rotations were within our study sites and how influential rotations would be in students' early experiences. Thus, the first protocol was not designed with rotations in mind, but rotations often emerged as a critical part of participants' discussions about their first-year experiences. As part of the second-year protocol, participants were directly asked to reflect on their rotation experiences. For this reason, we primarily relied on interview data collected in year one—when students were in the midst of rotations—and year two, when students had completed rotations and transitioned into a more permanent lab. In addition, for the 54 women in our study, we examined whether they were interviewed in year three or year four of their programs as part of the larger, mixed-methods project. When data were available, we incorporated women's longer-term reflections about lab rotations. By understanding women's real-time experiences and retrospective thoughts about lab rotations, we were able to establish unified stories for each participant's early doctoral experiences.

### ***Data Analysis and Trustworthiness***

We began analyses by merging each participant's annual transcript data into a single document per student, which allowed greater continuity in participants' stories and further insight into women's real-time and retrospective perceptions of lab rotations. Next, all transcripts were uploaded to Dedoose, an electronic qualitative coding platform. Both authors jointly identified five random students and independently reviewed these participants' transcripts. In this initial review, each author engaged in a process of horizontalization (i.e., identifying all quotes that corresponded to the research question) and analytic memo writing (Spinelli, 2005). This process allowed us to give equal consideration to all relevant participant quotes while also documenting how data (mis)aligned with our feminist approach and positionalities. Upon completing this first review, both authors met to develop and define initial

codes emerging from participants' quotes, and we continually collaborated through memos and dialogic engagement to support reflexivity and ongoing discussion (Ravitch & Carl, 2016).

The codebook was designed to be adaptable through our analyses and enabled us to code each transcript through an inductive process. We relied on axial coding (i.e., coding segments of text to identify patterns and relational concepts) and *in vivo* coding (i.e., verbatim descriptions from participants' actual language) in an effort to honor women's own words (Ravitch & Carl, 2016; Saldaña, 2015). To establish trustworthiness, the first author engaged in coding transcripts independently (after the initial codebook was collaboratively established) and kept analytic memos identifying relevant excerpts, questions, or clarifications to the themes established. In alignment with feminist approaches (Garko, 1999), the first author used these memos to personally engage with participants' stories. Then, the second author closely reviewed all transcripts and the first author's analytic memos, adding comments and interpretation to challenge and discuss the emerging findings. Both researchers met for peer debriefing sessions throughout the coding process, continuing to process through dialogic engagement (Creswell & Miller, 2000). While we allowed themes to emerge from the data through a process of horizontalization, our socialization framework was used to contextualize emergent themes. We integrated our feminist perspectives by identifying relevant literature to understand participants' experiences and by structuring the findings and discussion to be in conversation with each other.

### ***Role of the Researchers***

In applying existential and feminist phenomenological traditions, it is crucial to discuss how we, as researchers, were included in the analysis and how our positionalities were integral to the process of human science (Stanley & Wise, 1993). We embrace a multitude of roles and relationships that shape our questions, analytic approaches, and interpretation of findings. Professionally, both authors hold advanced degrees in higher education. As social scientists, both authors are disciplinary outsiders to STEM. The first author has worked in graduate school admissions, joined the larger research team during the second year of data collection, and conducted 20% ( $n = 11$ ) of the interviews used in the present analysis. The first author has also been immersed in these data via regular discussions with the researcher who led the data collection, a professor of higher education, who completed most of the other interviews. The second author joined the larger research team as a postdoctoral researcher after the interviews had been completed. While the second author did not conduct the interviews, her positionality shaped her analytical approach and interpretation of results. The second author has also had training and taught in gender studies and uses feminist methodologies in much of her work. The interviews were largely completed by other mem-

bers of the research team, but it is notable that all interviewers identified as women. We recognize that participants may have communicated some of their gendered experiences due to their shared gender identity with researchers. While interviewers' racial/ethnic identities varied, both authors identify as white women. Collectively, we recognize that we share some identities with participants (e.g., advanced degrees, gender) but remain outsiders to others (e.g., racial/ethnic identities, scientific training). In addition to the specific ways in which our identities informed our research decisions and processes, our positionalities also guided our original interest in this topic and may shape all aspects of the research in ways that we may be unaware.

## FINDINGS AND DISCUSSION

The purpose of this study was to understand how women doctoral students experience lab rotations in the biological sciences. Scholars have previously illuminated how students navigate lab rotations more generally (see Maher et al., 2019), and we expand upon this work by focusing on women's perspectives. The way women made meaning of their rotations (and the role of their identities) was largely influenced by participants' prior knowledge about the purpose of rotations and their expectations of lab climate, their perceptions of PI management styles and "fit," and the support they received from peers and departmental staff.

### *(Re)Interpreting the Purpose of Rotations to Gauge Sexism in Labs*

Based largely on their incoming knowledge and prior experiences, students entered each lab with set expectations, which were rarely met in their first rotation. More specifically, students had expectations for professional development, the lab environment, and, most strongly, their PI. Many participants used rotations as an opportunity to examine their expectations and make decisions about future labs, but inequities emerged in terms of how much information women had about the purpose of rotations. Although students rarely named sexism as part of the process, it became clear that women used rotations as an opportunity to "test out" each environment so that they could avoid selecting an overtly sexist or hostile lab for their training (though these efforts were not always successful). Importantly, not all students knew that sexism was something they should be considering during rotations. For example, after joining a permanent lab, Grace reflected on how she was unaware of the ways to navigate rotations strategically, saying:

I didn't know what I was supposed to get out of [rotations]...I did not get a good sense of what the lab was like...it seemed very bright and shiny, happy on the surface...but I've been made aware of a lot of personality conflicts that I wasn't aware of, and some favoritism on the part of my boss...He has said to people that he prefers women...I feel like it's a little tricky because I am a

girl, but sometimes I don't know if I'm more awkward, or more intense, or less sweet and giggly than the other girls. We don't always see eye to eye...and it's hard to communicate with him.

Even as a white, continuing-generation student, Grace described how she encountered sexism, which she partially attributed to not receiving advice on the purpose of rotations. Without a clear strategy for gaining insight into lab dynamics, she selected her lab based primarily on PI prestige. Additional data collection revealed that Grace later contemplated leaving her program but ultimately decided to switch labs before her third year instead. Grace also noted how support staff in her program were instrumental in helping her transition into a new lab instead of leaving the doctoral program altogether.

Similar to Grace's experience, Janelle, a white, first-generation college student, recalled wishing that she had been more strategic in terms of how she selected rotations, saying, "I wish I would have understood better what I would have benefited from as far as from a PI. I'm glad that I have a female mentor. I wish that I had rotated with more of them...I kind of limited myself with regard to the gender of the PIs that I rotated with." While she was not initially strategic in selecting lab rotations, Janelle ultimately joined a lab that she felt would be the most inclusive and supportive. For her, joining an inclusive lab meant working with a PI who was a woman, even if that PI's lab research did not suit her interests. Janelle's experience was largely representative of other participants who felt they had to choose between a lab that aligned with their interests and a lab that would be inclusive. The ways in which women described weighing lab decisions with PI roles, expectations of lab climate, and power dynamics in mind is reminiscent of recent work discussing equity in mentoring relationships (Griffin, 2020).

Had Janelle and others received earlier advice on how to strategically select rotations, perhaps they would have been able to find a lab that was both inclusive and closely aligned with their research interests. If labs were more consistently inclusive, women would be free to choose a lab based primarily on research interests. Absent that, the unspoken purpose of rotations (i.e., rotations as a tool for avoiding a sexist lab) should be made explicit, so that all students can make strategic decisions at the outset of rotations. To be clear, the idea that women ought to carry the burden of locating a lab that is not actively hostile is unacceptable and addressing these disturbing inequities should be a critical priority for institutions.

### ***Assessing Rotation Mentorship Through PI Management Style and "Fit"***

Women's rotation experiences were highly influenced by the mentorship style and availability of the PI, and students had strong opinions about what an ideal PI should be like. In general, participants described the ideal PI as a mentor who offers both support and independence. As Gloria, a continuing-generation woman of Asian descent, put it:

I feel like [the PI] should be able to help you when you need help and be around enough to kind of check up on you, but not to micromanage you. I think that person should definitely be around in the lab or in the office. . . . Some PIs travel or . . . you can't find them. I think that's something that's important to me, just having an advisor that is available that you can talk to, that responds to emails.

Gloria's comments largely reflected other women's preferences and are consistent with literature detailing how PI management style shapes research group experiences (Hirshfield, 2014).

While participants in the present study clearly knew what they wanted from their PI, the ideal balance between autonomy and direct guidance was elusive. Given how difficult it was for women to find this balance of PI support, rotations were a crucial part of successfully identifying a more permanent lab placement. During the rotation process, PI management styles and "fit" in the lab became two prominent ways that women discussed their attempts to find faculty support.

#### *Selecting Labs Based on PI Management Style*

PI management style emerged as one aspect of rotations that could be a tipping point for students' decisions about which lab to ultimately join. For example, Penelope, a continuing-generation woman of Asian descent broadly interested in neuroscience research, related:

The general topic was what drew me to certain rotations, and then from there, what made me choose my PI is based on just how she runs the lab and how the people in the lab felt with her leadership. Everyone seemed very happy. They seemed like they wanted to be there, which definitely helps propel the science.

For women who had a more difficult time finding a management style that suited them, PI management styles were often characterized using extremes that depicted faculty as either too "hands-off" or as "micro-managers." Isabella, a white, continuing-generation student, demonstrated this characterization by saying that one of her rotational PIs was "absent the entire time," and "her communication over email was spotty." At the same time, other women saw PIs as "micro-managers." For example, Chelsea, a first-generation college student of Asian descent, explained how "the PI that I'm working with now, she's kind of micromanaging. . . . I want to be a little bit more independent." Still others described PIs who were both too hands-off and micro-managers. As Camila, a white, continuing-generation college student, put it,

[My PI] is a micro-manager where she shouldn't necessarily be. I think it's because she's so hands-off, that her finger isn't exactly on the pulse of what's going on. She'll ask for details that aren't really related to things that we're working on at that point, and she wants it yesterday.

The ways in which students prioritized PI management styles is somewhat unsurprising, given that faculty advisors play a particularly substantive role in labs, serving as both advisor *and* manager/supervisor (i.e., PI) for graduate student workers. It is worth noting that the harshest comments about micro-managing were typically reserved for PIs who were women, which aligns with prior work on how gender shapes the way doctoral students perceive faculty in the lab, with women in PI roles often facing harsher criticism than men (Hirshfield, 2014; Rosser, 2012).

### *Tradeoffs of Selecting Labs with PI “Fit”*

In addition to management styles, students often relied on perceptions of fit to determine whether they would succeed in a lab. While women sometimes used the term “fit” ambiguously, when pressed, it became clear that fit was used to describe the absence of discrimination. Thus, women seemingly used the term “fit” to rationalize their resistance to problematic socialization norms and avoidance of discriminatory environments. The logic of assessing fit speaks to prior literature about the characteristics (i.e., being white and a man) that faculty may see as being “needed” for success in science and the agentic role that women can play to circumvent these norms and values (e.g., Johnson, 2007; Ko et al., 2014). Despite faculty advisors (and rotational PIs) serving as primary socialization agents (Weidman, 2010), students were often unable to find a lab with a PI who fulfilled this expected mentorship role in practice. The problems with identifying lab and PI fit may lead to later stratification, as students who are not able to select the most prestigious lab or the lab that most closely aligned with their interests may face later disadvantages on the academic job market.

While many women valued finding a supportive lab, sometimes at the cost of research alignment (discussed above), having a supportive lab may have been even more critical for women with multiple marginalized identities. That is, while participants rarely mentioned their identities explicitly, the desire to prioritize finding a supportive and inclusive lab was likely due to the fact that such environments were not guaranteed, especially for women who were also racially/ethnically minoritized and/or the first in their family to attend college. As Elaine, a first-generation Woman of Color (who identified as Black and white) put it, “the interest came secondary to having a really supportive environment...it’s more important to have a supportive environment.”

It is also important to note that, even when students selected labs based on the PI’s characteristics, women sometimes felt misled when their PI’s mentorship style changed after they joined the lab in a longer-term capacity, suggesting that faculty sometimes misled students in an attempt to recruit them to work in their labs. The misleading nature of such support is consistent with existing literature (e.g., Slay et al., 2019) and may reflect larger trends in academic labor, which will be discussed further below.



### *Support from Labmates and Peers*

Participants stressed the important role that peers (especially cohort-mates) and labmates (particularly senior graduate students and research staff) played in shaping the quality of their rotations. As Mila, a Latina, continuing-generation student in neuroscience, explained, “I’ve been turning to other grad students in my program and other—a postdoc that also works in my lab. Someone with more experience with the advisor herself and with the program requirements and navigating the whole rotation situation.” Students also emphasized the unique role that labmates played, relative to their peers and cohort-mates. Below, we discuss how participants described these different sources of support.

#### *Labmate Support During Rotations*

Changing lab environments during rotations often came with a steep learning curve, and more advanced students (as well as other lab members) provided day-to-day support—support that was particularly noteworthy given the fact that many PIs were not regularly present in the lab. As Grace explained, “The other grad students in my lab are extremely helpful in terms of just needing to know what to do or if I say, ‘Hey, does anyone know where this is? How do I order this? Where can I find the label maker?’” In addition to the daily support Grace described, women also explained that labmates played a vital role in navigating their permanent lab selection by providing “more accurate” information on lab dynamics, which is crucial considering that PIs sometimes misled students during the rotation/recruitment process (discussed above). Collectively, these findings are similar to Golde et al.’s (2009) idea of “cascading mentorship”—or, the notion of scaffolded mentoring from postdocs to advanced graduate students to junior graduate students—which research has also highlighted by pointing to the pivotal support that postdocs provide in the lab (Blaney et al., 2020; Feldon et al., 2019).

#### *Cohort Support During Rotations*

While labmates offered significant support to students, women’s ability to form a peer support system in their lab was inhibited by constantly changing research groups. In light of these frequent lab changes, many participants emphasized that cohort-mates were a constant source of support that helped them navigate rotations. As Bella, a white, continuing-generation student, explained,

The grad students in my year, since we’re going through the same thing at the same time, it’s helpful just, like, for support, to be able to go and vent, or, you know, ask them what they’re doing just to make sure we’re on the right path and everything like that.



Tiana, a Black, first-generation college student interested in an industry career, elaborated by explaining how she chiefly sought support from her cohort-mates, saying:

...I feel like we're going through this together. There [are] a few people—not a few people. More than a few people actually...Sometimes [we] just go out for social gatherings just to sort of get our minds clear. Let's say if we just had a big exam, we'll go out to celebrate that.

While cohort-mates provided social and academic support through rotations, these relationships were often clouded by competition, as students vied for limited lab positions, which is consistent with prior literature on how women, in particular, experience competition through the lab selection process (Hirshfield, 2015). Some women also described how their interactions were inhibited by their racial or ethnic identity. For example, Tiana went on to explain,

Because I'm one of the few minority students at my institution, I also sometimes feel it's different as well. But, that's more of a personal thing, I don't think it has anything to do with graduate school per se, maybe. I think it's just sort of being...Having to deal with little microaggressions and things like that, that some of my other peers may not necessarily have to deal with.

The notion that peer interactions are constrained by race is well documented. Even though Tiana found support from her peers, she also felt isolated by what she referred to as “little microaggressions” from peers that contributed to a less than inclusive climate. This finding speaks to Burt and colleagues' (2016) prior work on racial microaggressions and STEM doctoral research group experiences, highlighting the ways that peer groups can support students facing microaggressions from advisors but may also be a source of microaggressions and anti-Black discrimination. Although the racialized experiences of women were not the primary focus of this study, the comments that Women of Color uniquely shared about their interactions adds a layer of complexity to the gendered nature of lab rotations.

#### *Departmental Support During Rotations*

Similar to the support that women received from their cohort, the larger departmental context often served as a constant throughout rotations. Departmental staff sometimes acted as a stabilizing force, which was critical for students who had negative rotation experiences. Wen, a continuing-generation woman of Asian descent in molecular biology, discussed how departmental staff supported her through rotations, saying, “I think without our program director, a lot of people would be burned out or be very stressed out or unhappy. Our program director is kind of like our mom here, which is nice.” Wen's comment also provides insight into the gendered nature of

how some students viewed support, characterizing the program director as a “mom” due to her personal support. Gendered familial language emerged in relation to the lab “home,” as well.

Yet, departments did not always serve as a stabilizing force. For Camila, who described the competition she felt in her cohort, the hostile department complicated her rotations:

I’m really happy in the lab I ended up in, but the path to get there was really unpleasant. I think a lot of it comes down to the culture within the department... there’s a lot of unpleasantness between people. There’s a lot of really weird silence. It’s just a really cold environment. It’s a really bizarre environment. I’d say that for the most part, my experience has been largely unpleasant, but it’s certainly getting better. I ended up in a lab that studies something entirely different than anything I’ve ever worked on simply because the people were so much better than my other labs.

While departments had varying influences on students’ rotations and lab selection, both Wen and Camila described how departmental support affected their experiences and retention.

### ***Meaning Making Through Social Comparisons***

When making meaning of their rotations, participants also looked to their peers to draw comparisons before determining the extent to which they were satisfied with their own rotation experiences. The ways in which participants compared themselves to their peers mirrors prior literature detailing the importance of social comparisons for making meaning of one’s own experience (Schwalbe & Staples, 1991). In this study, social comparisons helped women reconcile dissatisfaction when their expectations were unmet. However, other times, women used comparisons to assess whether or not they were “productive enough.” As Abigail aptly stated, “you’re able to compare that [culture of productivity] to each lab [rotation] and kind of understand what yours looks like compared to everybody else’s.” Such peer comparisons during rotations directly speak to the pressure of research productivity that shapes students’ socialization experiences (Burt, 2019)—productivity which stems from labor practices within their rotational lab environments and larger forces of academic capitalism.

While social comparisons were useful in helping students develop potentially more realistic expectations, they sometimes led to feelings of competition or inadequacy. Morgan, a Black, continuing-generation student—who initially wanted a tenure track career but later noted being largely deterred from academia—recounted that, after a few rocky rotations, she felt distressed because she “had to do another rotation while many of my other [peers] have already chosen their permanent labs.” Similarly, Camila described the rotation process as “grueling.” She explained how feelings of competition were prevalent within her cohort as students competed for positions in elite labs:

I think a lot of the competitive feelings within a cohort are intrinsic to the cohort. Everybody [was] competing with each other, and nobody wants to admit they're having a hard time. Asking for help would be a bad thing, a sign of weakness.

As another problematic symptom of social comparisons, competition also led students to adopt unrealistic work expectations and feel pressure to stay in the lab into the evenings and on the weekends. Overworking in the lab could be viewed as a norm of doctoral socialization, and the realities of such detrimental values were often felt in the later years of the Ph.D. program. For example, in a later interview (during year four of the program), Camila reflected on her rotations, saying, "Everybody expects 100% of your time, and it's being split between several different bosses, so there's just a lot of demands during that year, so a lot of stress."

While social comparisons, competition, and a lack of work-life balance may characterize the doctoral training process more generally, these forces were especially salient because of the rapid and ever-changing nature of rotations, which is somewhat consistent with findings related to women's rotation experiences in other STEM disciplines (Hirshfield, 2015). As Amanda, a white, continuing-generation student, put it, "rotations are really rushed because of the acclimation, and then the second rotation is kind of hectic, because we're juggling the more difficult course load." In short, the stress that students felt as a result of social comparisons was amplified given the unique and intense nature of lab rotations.

## SUMMARY OF KEY FINDINGS

### *Synthesizing and Contextualizing Findings*

In this study, we set out to understand how women experience lab rotations in biological sciences doctoral programs. Guided by recent research on doctoral student socialization and a feminist perspective, our findings suggest that applications of socialization theory must account for (1) the ways that individuals' social identities and agency underscore many aspects of their experiences and (2) larger power structures affecting higher education (e.g., academic labor practices).

Literature from feminist science studies and sociology of science is particularly useful in contextualizing our findings related to how women selected labs after their rotations, given that such research emphasizes the need to question traditional norms about knowledge production and what it means to "do science" (Harding, 1991, 2004). Our findings prompt further questioning about the purpose of rotations during the first year of doctoral training. While formal information about rotations may suggest

that the purpose of rotations is to find a permanent lab that closely aligns with one's research interests, this was far from the case for women in our study. Rather, participants typically selected their first lab rotation based on research alignment, only to find that the environment in that lab was not tenable and concluding that the personal characteristics of the PI were more important than the actual research.

While selecting labs based on mentoring style may provide opportunities for women to exercise agency in shaping their training and socialization experiences—consistent with newer adaptations of socialization theory (Weidman & DeAngelo, 2020)—this does very little to change larger systems of inequity. Margolis and Romero (2001) argued that “mentoring has specific reproduction functions” and that it “offers no meaningful way to change the system” (p. 93-94). In our study, the ways that women rotated through hostile labs to sometimes locate a relatively inclusive permanent lab are reminiscent of Margolis and Romero's critique in multiple ways. First, women were able to navigate this process with varying degrees of ease and success, largely based on their prior knowledge about rotations. Second, while women often used their agency to leave labs that were hostile, those labs may have continued to operate in line with the status quo and with discriminatory practices largely unnoticed by others at the institution. Third, though it is difficult to discern from our study, it is possible that women may face consequences on the job market by foregoing more prestigious lab placements in favor of a more supportive PI (thus giving up some amount of social capital in prestigious connections). By documenting the process by which women navigate their rotations, this study illuminates how academic spaces in science perpetuate inequity in nuanced ways.

### ***Understanding Lab Rotations in the Context of Academic Labor Practices***

To fully interpret the findings above, we must also acknowledge the larger context of academic labor practices, recognizing that students serve as workers and knowledge producers within labs. During the past two decades, researchers have increasingly interrogated labor practices in graduate training, providing relevant context for our findings—particularly those related to students' experiences of feeling misled by PIs during rotations. Slaughter and Leslie (1997) used the term “academic capitalism” to refer to university labor trends which treat research products as a commodity. Since then, others have expanded upon this work by documenting changes in research productivity expectations and demands, the unique nature of lab funding from external agencies, and the ways labs represent the “shop floor” in the knowledge economy (Cantwell, 2015; Owen-Smith, 2001; Stephan, 2012). The experiences that women shared in the present work reveal that they felt similar demands during rotations.

Increased research demands on PIs may help explain our findings related to how students felt misled by faculty during rotations. Some women were led to believe that PIs were supportive and collaborative, only to find (after joining the lab) that PIs provided little support and/or had unrealistic expectations. These findings resonate with the “bait and switch” concept noted by Slay and colleagues (2019), who discussed how faculty mislead prospective graduate students from marginalized groups to believe a program is more diverse and equitable than it is in reality. In relation to lab rotations and selection, Maher et al. (2020b) posited that “when competition between laboratories to recruit students is high, so too is the likely need for the laboratory to offer a ‘friendly façade’ to their rotating student guests. Once the recruitment deal is sealed, a focus on productivity over student learning needs or project preferences may emerge” (p. 15). Our findings confirm this view of rotations as an extended recruitment process. Increased research demands may lead faculty to abuse student labor, which only becomes visible when PIs are no longer trying to recruit students (see Maher et al., 2020b; Stephan, 2012).

### **Summary**

The present findings provide insight into how women doctoral students experience lab rotations in the biological sciences. We introduced the significance of women’s prior knowledge about rotations and their expectations of lab climate, the important role that PI management and mentoring styles played in rotations (which sometimes resulted in women foregoing a lab that aligned well with their research), and how peers, labmates, and departmental staff provided key support as students navigated new environments. Further, we discussed how peer relationships contributed to a meaning-making process rooted in social comparisons, a process that both helped and hindered students in rotations. Finally, our results point to several ways in which the rotation experience was complicated by students’ social identities intersecting with their gender.

These findings both confirm and build upon existing literature on the gendered nature of doctoral education (Burt, 2019; Gardner, 2008; Sallee, 2011a, 2011b), focusing specifically on early lab experiences. Women, and particularly Women of Color, may feel that their identities constrain their ability to locate a lab where they “fit with the PI” during lab rotations. In this study, women emphasized that rotations present a valuable opportunity to find an inclusive lab where overt discrimination would not permeate their daily work environments or where systemic disadvantage would not be laced within the structures of mentorship (see Noy and Ray, 2012). While women often chose their first rotation based on research interest, they used their agency throughout rotations and learned to place higher value on relationship-oriented factors. Collectively, the experiences shared by women in our study inform critical implications for theory, practice, and future research.

### IMPLICATIONS FOR THEORY

Considering how scholars have recently highlighted the role of research groups in STEM doctoral student socialization (Burt, 2019), we expected that rotations may impact women's identity development as biological scientists. Participants in our study seemed to (re)define their lab expectations with each rotation, which extends Burt's notions of research group experiences and social comparisons by drawing attention to how rotations are an iterative early socialization mechanism. In addition, we found that social comparisons resemble a two-sided coin. Some women used peer comparisons to adjust their expectations of PIs in rotations, and negative rotations were more damaging if women felt isolated in their experiences. Other times, peer comparisons enforced competition and were an unhelpful measure of productivity. We conclude that social comparisons to cohort-mates and labmates characterize women's first-year research group experiences through lab rotations, which aligns with the types of competition described by women in lab environments more generally (Rosser, 2012).

Taken together, our results provide insight into how research on doctoral student experiences might apply socialization theory moving forward. Here, engaging academic capitalism helps explain the sociocultural context (i.e., pressure for research productivity) that centrally affects STEM doctoral students' trajectories (Burt, 2019). Indeed, rotations appear to be a disciplinary-specific mechanism of academic capitalism, characterized by competition among students and pressure to be seen as productive, as faculty PIs aim to select and recruit student workers. Focusing on women's experiences elicited vastly different narratives of student agency than prior work on lab rotations (Maher et al., 2020b), which substantiates recent adaptations to socialization (see Weidman & DeAngelo, 2020) that center students' identities and agency.

### IMPLICATIONS FOR PRACTICE

Some of the most compelling findings in the present work relate to the way participants prioritized "fit," PI mentoring style, and other interpersonal factors in their lab selection. In light of our findings, we contend that finding a nondiscriminatory lab is critical to women's doctoral success, and women should not have to forego prestige and research alignment for inclusion. Ideally, women in STEM Ph.D. programs should be able to choose a lab with the underlying expectation that discrimination would not be a potential threat. PIs must not assume that students leave labs for "fit" reasons. Institutions should interrogate nebulous concepts like "fit" to help faculty identify discriminatory environments. Without organizational acknowledgement of hostile lab settings, it may prove difficult to hold faculty accountable for unrecognized, problematic dynamics, as also suggested a decade ago by

Rosser and Taylor (2009) and discussed recently within the field of education (Davis, 2019). Further, considering the integral relationships that many participants formed with departmental staff, institutions should consider investing in specific support staff for students rotating in labs. Rotations are a uniquely stressful and exciting process that has long-term implications for students' doctoral training experiences and outcomes, and it is imperative that students—particularly students from groups that have been historically subjected to sexist or racist interactions in graduate education—can rely on departmental support.

Finally, although larger trends in academic labor go beyond individual control, faculty PIs need to be better trained in how to support and mentor students, recognizing their role as managers and supervisors in addition to their role of faculty advisor. While graduate faculty across disciplines may experience similar role conflicts, professional development and training may be especially important in STEM disciplines that practice rotations, as PIs are responsible for managing a revolving door of laboratory staff. Managing rotating first-year doctoral students as staff within labs requires careful attention to personnel needs. In particular, faculty should be educated in inclusive and socially just management and mentoring practices to support women in their programs, particularly those who hold other minoritized identities (e.g., Black women who described experiencing microaggressions in their rotations). This recommendation aligns with earlier research on microaggressions between PIs and students in STEM Ph.D. programs, highlighting how “faculty advisors need to become more culturally competent in the ways they behave and interact with students from underrepresented groups” (Burt et al., 2016, p. 11). It is also important to realize that professional development alone will not address underlying inequities due to changing academic labor practices.

### **LIMITATIONS AND FUTURE DIRECTIONS**

While this study provides new insight into women's first-year doctoral experiences in lab rotations, it is important to discuss several limitations and opportunities for future research. First, students were recruited from Ph.D. programs at research-intensive institutions in the United States. Therefore, findings may not represent doctoral students at other institution types in the U.S. or internationally. Second, all rotations took place in lab-based programs in the biological sciences; thus, research in other disciplinary contexts—even those with rotations—may lead to different conclusions than those found in this study. Moreover, while students identified discriminatory experiences during rotations, our focus on students' meaning making may not represent larger structural inequities. Relatedly, research may benefit from examining



inequities in rotations in the context of changing academic labor practices. For example, we posit that increased pressures for productivity may have led faculty to adopt unethical labor practices, which shaped participants' rotations; however, more research is needed to determine the extent to which this might be the case. Similarly, scholars could use critical organizational frameworks to understand how toxic lab spaces may persist under a guise of "fit" as suggested by this study.

### CONCLUSION

Using interview data from 54 women enrolled in Ph.D. programs in the biological sciences, the present study explores how women experience lab rotations. Findings provide insight into the unique experience of lab rotations—a process characterizing the first year of doctoral training. Within an expanded framework of socialization that focuses on gendered experiences in research groups, we found that women's expectations for lab climate, perceptions of PI management styles, and support from peers and departments underscored their meaning-making processes during rotations and the ways in which they used the term "fit" ambiguously. Ultimately, women were often forced to choose between a prestigious lab aligning with their research interests *or* a lab where they may have a better "fit" with the PI, a concept that we problematize. As rotations remain a common practice in multiple STEM disciplines, it is imperative to better understand how doctoral students make meaning of their experiences with an equity-minded lens. Without such, even the STEM disciplines that have seemingly made the most progress in equity and representation (e.g., biological sciences) may not fully recognize prevailing disparities in doctoral students' experiences and trajectories.



## APPENDIX

TABLE 1.  
DESCRIPTION OF PARTICIPANTS (N=54)

<i>Pseudonym</i>	<i>Race/ethnicity<sup>a</sup></i>	<i>First-generation to attend college</i>	<i>Highest prior degree</i>	<i>Postgraduate career intention</i>
Aliyah	Latina	Yes	Bachelor's	Did not provide
Abigail	White	No	Bachelor's	Industry or NPO
Amanda	White	No	Bachelor's	Industry
Ana	Latina and white	No	Bachelor's	Academia
Anastasia	Black and white	Yes	Bachelor's	Academia
Angelica	White	No	Bachelor's	Did not provide
Annabelle	White	No	Bachelor's	Academia
Antonia	Latina and white	No	Bachelor's	Industry
Aria	Asian/American and white	No	Bachelor's	Academia or NPO
Arlene	White	No	Bachelor's	Academia
Ava	American Indian or Alaska Native and white	Yes	Bachelor's	Industry or NPO
Avery	White	No	Bachelor's	Academia, Industry, or NPO
Bella	White	No	Bachelor's	Industry
Brielle	White	Yes	Bachelor's	Academia
Camila	White	No	Master of Arts	Academia, Industry, or NPO
Cassandra	Asian/American and Latina	Yes	Master of Public Health	Academia or NPO
Charlotte	White	No	Bachelor's	Industry
Chelsea	Asian/American	Yes	Master of Science	Industry
Claire	White	No	Bachelor's	Academia, Industry, or NPO
Cyra	Other	No	Bachelor's	Academia
Deanna	White	No	Bachelor's	Academia
Elaine	Black and white	Yes	Bachelor's	Academia
Erica	White	No	Bachelor's	Academia or Industry
Gabriella	Black	Yes	Bachelor's	Industry
Gloria	Asian/American	No	Bachelor's	Academia
Grace	White	No	Bachelor's	Academia

Hanh	Asian/Asian American	Yes	Bachelor's	Did not provide
Harper	White	No	Bachelor's	Industry
Hazel	White	No	Bachelor's	Academia or Industry
Isabella	White	No	Bachelor's	Academia
Jane	Black	No	Bachelor's	Academia
Janelle	White	Yes	Bachelor's	Academia
Jenna	Black	No	Bachelor's	Academia, Industry, or NPO
Joan	White	No	Master of Science	Academia or Industry
Leah	White	Yes	Bachelor's	Academia, Industry, or NPO
Leslie	Asian/Asian American	Yes	Bachelor's	Industry
Lucy	White	No	Master of Science in Medicine	Industry
Madison	White	No	Bachelor's	Industry or NPO
Marie	White	No	Bachelor's	Industry
Marina	White	Yes	Master of Science	Academia, Industry, or NPO
Marissa	Black	No	Bachelor's	Industry
Melanie	White	Yes	Bachelor's	Academia
Mila	Latina and white	No	Bachelor's	Academia or Industry
Morgan	Black	No	Bachelor's	Academia or Industry
Nora	White	No	Bachelor's	Academia or Industry
Paisley	White	No	Bachelor's	Academia
Penelope	Asian/Asian American	No	Bachelor's	Industry or NPO
Sadie	White	No	Bachelor's	Did not provide
Samantha	White	No	Bachelor's	Academia or NPO
Savannah	Black	No	Bachelor's	Academia
Scarlet	White	Yes	Bachelor's	NPO
Tiana	Black	No	Bachelor's	Academia, Industry, or NPO
Violeta	Latina	Yes	Bachelor's	Academia
Wen	Asian/Asian American	No	Master of Science	Did not provide
		No	Bachelor's	Academia

Note. Postgraduate career intention during year 1 was measured retrospectively by asking participants about their level of interest (1 = "not at all" to 3 = "definitely") in a range of fields when they began their doctoral program. NPO is used as an abbreviation for nonprofit organization.

\*Students had the option to identify as "Black or African American"; given that these data did not reveal specific ethnic identities of the African diaspora, we use the term Black in the present work.

## REFERENCES

- Acker, S., & Haque, E. (2015). The struggle to make sense of doctoral study. *Higher Education Research & Development*, 34(2), 229–241.
- Austin, A. E., & McDaniels, M. (2006). Preparing the professoriate of the future: Graduate student socialization for faculty roles. In J. C. Smart (Ed.), *Higher education: Handbook of theory and research*, Vol. XXI (pp. 397–456). Springer.
- Bartky, S. L. (1975). Toward a phenomenology of feminist consciousness. *Social Theory and Practice*, 3(4), 425–439.
- Bhatia, S., & Amati, J. P. (2010). “If these women can do it, I can do it, too”: Building women engineering leaders through graduate peer mentoring. *Leadership and Management in Engineering*, 10(4), 174–184. [https://doi.org/10.1061/\(ASCE\)LM.1943-5630.0000081](https://doi.org/10.1061/(ASCE)LM.1943-5630.0000081)
- Blaney, J. M., Kang, J., Wofford, A. M., & Feldon, D. F. (2020). Mentoring relationships between doctoral students and postdocs in the lab sciences. *Studies in Graduate and Postdoctoral Education*. Advance online publication. <https://doi.org/10.1108/SGPE-08-2019-0071>
- Bostwick, V. K., & Weinberg, B. (2018). *Nevertheless she persisted? Gender peer effects in doctoral STEM programs* (No. w25028). <https://doi.org/10.3386/w25028>
- Burt, B. A. (2017). Learning competencies through engineering research group experiences. *Studies in Graduate and Postdoctoral Education*, 8(1), 48–64.
- Burt, B. A. (2019). Toward a theory of engineering professorial intentions: The role of research group experiences. *American Educational Research Journal*, 56(2), 289–332.
- Burt, B. A., McKen, A. S., Burkhart, J. A., Hormell, J., & Knight, A. J. (2016, June 26). Racial microaggressions within the advisor-advisee relationship: Implications for engineering research, policy, and practice. *Proceedings of the 123<sup>rd</sup> Annual ASEE Conference & Exposition*, 1–14. <https://doi.org/10.18260/p.26029>
- Cantwell, B. (2015). Laboratory management, academic production, and the building blocks of academic capitalism. *Higher Education*, 70(3), 487–502.
- Clark, S. L., Dyar, C., Maung, N., & London, B. (2016). Psychosocial pathways to STEM engagement among graduate students in the life sciences. *CBE—Life Sciences Education*, 15(3), Article 45. <https://doi.org/10.1187/cbe.16-01-0036>
- Conti, A., & Liu, C. C. (2015). Bringing the lab back in: Personnel composition and scientific output at the MIT Department of Biology. *Research Policy*, 44(9), 1633–1644.
- Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into Practice*, 39(3), 124–130.
- Curtin, N., Malley, J., & Stewart, A. J. (2016). Mentoring the next generation of faculty: Supporting academic career aspirations among doctoral students. *Research in Higher Education*, 57(6), 714–738. <https://doi.org/10.1007/s11162-015-9403-x>
- Davis, K. (2019, September 17). The silence is deafening. *Inside Higher Ed*. <https://www.insidehighered.com/views/2019/09/17/institutions-shouldnt-remain-silent-face-professors-questionable-behavior-toward>
- Etzkowitz, H., Kemelgor, C., & Uzzi, B. (2000). *Athena unbound: The advancement of women in science and technology*. Cambridge University Press.

- Feldon, D. F., Litson, K., Jeong, S., Blaney, J. M., Kang, J., Miller, C., Griffin, K., & Roksa, J. (2019). Postdocs' lab engagement predicts trajectories of Ph.D. students' skill development. *Proceedings of the National Academy of Sciences*, 1–7.
- Feldon, D. F., Peugh, J., Maher, M. A., Roksa, J., & Tofel-Grehl, C. (2017). Time-to-credit gender inequities of first-year PhD students in the biological sciences. *CBE—Life Sciences Education*, 16(1), Article 4.
- Fox, M. F. (2001). Women, science, and academia: Graduate education and careers. *Gender & Society*, 15(5), 654–666.
- Gardner, S. K. (2007). “I heard it through the grapevine”: Doctoral student socialization in chemistry and history. *Higher Education*, 54(5), 723–740.
- Gardner, S. K. (2008). Fitting the mold of graduate school: A qualitative study of socialization in doctoral education. *Innovative Higher Education*, 33(2), 125–138.
- Gardner, S. K. (2010). Keeping up with the Joneses: Socialization and culture in doctoral education at one striving institution. *The Journal of Higher Education*, 81(6), 658–679.
- Garko, M. G. (1999). Existential phenomenology and feminist research: The exploration and exposition of women's lived experiences. *Psychology of Women Quarterly*, 23(1), 167–175. <https://doi.org/10.1111/j.1471-6402.1999.tb00349.x>
- Gaule, P., & Piacentini, M. (2018). An advisor like me? Advisor gender and post-graduate careers in science. *Research Policy*, 47(4), 805–813.
- Gazley, J. L., Remich, R., Naffziger-Hirsch, M. E., Keller, J., Campbell, P. B., & McGee, R. (2014). Beyond preparation: Identity, cultural capital, and readiness for graduate school in the biomedical sciences. *Journal of Research in Science Teaching*, 51(8), 1021–1048.
- Gilmore, J. A., Wofford, A. M., & Maher, M. A. (2016). The flip side of the attrition coin: Faculty perceptions of factors supporting graduate student success. *International Journal of Doctoral Studies*, 11, 419–439.
- Goldberg, L., Ryan, A., & Sawchyn, J. (2009). Feminist and queer phenomenology: A framework for perinatal nursing practice, research, and education for advancing lesbian health. *Health Care for Women International*, 30(6), 536–549.
- Golde, C. M. (1998). Beginning graduate school: Explaining first-year doctoral attrition. *New Directions for Higher Education*, 1998(101), 55–64. <https://doi.org/10.1002/he.10105>
- Golde, C. M. (2007). Signature pedagogies in doctoral education: Are they adaptable for the preparation of education researchers? *Educational Researcher*, 36(6), 344–351.
- Golde, C. M., Bueschel, A. C., Jones, L., & Walker, G. E. (2009). Advocating apprenticeship and intellectual community: Lessons from the Carnegie Initiative on the Doctorate. In R. G. Ehrenberg & C. V. Kuh (Eds.), *Doctoral education and the faculty of the future* (pp. 53–64). Cornell University Press.
- González, J. C. (2006). Academic socialization experiences of Latina doctoral students: A qualitative understanding of support systems that aid and challenges that hinder the process. *Journal of Hispanic Higher Education*, 5(4), 347–365.
- Gopaul, B. (2011). Distinction in doctoral education: Using Bourdieu's tools to assess the socialization of doctoral students. *Equity & Excellence in Education*, 44(1), 10–21.

- Griffin, K. A. (2020). Rethinking mentoring: Integrating equity-minded practice in promoting access to and outcomes of developmental relationships. In A. Kezar and J. Posselt (Eds.), *Higher education administration for social justice and equity: Critical perspectives for leadership* (pp. 93–110). Routledge.
- Griffin, K. A., Baker, V. L., & O'Meara, K. (2020). Doing, caring, and being: "Good" mentoring and its role in the socialization of graduate students of color in STEM. In J. C. Weidman & L. DeAngelo (Eds.), *Socialization in higher education and the early career: Theory, research and application* (pp. 223–239). Springer International Publishing.
- Harding, S. (1991). *Whose science? Whose knowledge?: Thinking from women's lives*. Cornell University Press.
- Harding, S. (2004). A socially relevant philosophy of science? Resources from standpoint theory's controversiality. *Hypatia*, 19(1), 25–47.
- Heidegger, M. (1962/2008). *Being and time* (J. Stambaugh, Trans.). State University of New York Press.
- Hirshfield, L. E. (2014). "She's not good with crying": The effect of gender expectations on graduate students' assessments of their principal investigators. *Gender and Education*, 26(6), 601–617.
- Hirshfield, L. E. (2015). "I just did everything physically possible to get in there": How men and women chemists enact masculinity differently. *Social Currents*, 2(4), 324–340.
- Holley, K. A. (2010). Doctoral student socialization in interdisciplinary fields. In S. K. Gardner & P. Mendoza (Eds.), *On becoming a scholar: Socialization and development in doctoral education* (pp. 97–112). Stylus Publishing.
- Hughes, C. C., Schilt, K., Gorman, B. K., & Bratter, J. L. (2017). Framing the faculty gender gap: A view from STEM doctoral students. *Gender, Work & Organization*, 24(4), 398–416. <https://doi.org/10.1111/gwao.12174>
- Johnson, A. C. (2007). Unintended consequences: How science professors discourage women of color. *Science Education*, 91(5), 805–821. <https://doi.org/10.1002/sce.20208>
- Joy, S., Liang, X., Bilimoria, D., & Perry, S. (2015). Doctoral advisor-advisee pairing in STEM fields: Selection criteria and impact of faculty, student and departmental factors. *International Journal of Doctoral Studies*, 10, 343–363. <https://doi.org/10.28945/2302>
- Julius, D. J., & Gumpert, P. J. (2003). Graduate student unionization: Catalysts and consequences. *The Review of Higher Education*, 26(2), 187–216.
- Ko, L. T., Kachchaf, R. R., Hodari, A. K., & Ong, M. (2014). Agency of women of color in physics and astronomy: Strategies for persistence and success. *Journal of Women and Minorities in Science and Engineering*, 20(2), 171–195.
- Maher, M. A., Wofford, A. M., Roksa, J., & Feldon, D. F. (2019). Doctoral student experiences in biological sciences laboratory rotations. *Studies in Graduate and Postdoctoral Education*, 10(1), 69–82.
- Maher, M. A., Wofford, A. M., Roksa, J., & Feldon, D. F. (2020a). Finding a fit: Biological science doctoral students' selection of a principal investigator and research laboratory. *CBE—Life Sciences Education*, 19(3), Article 31. <https://doi.org/10.1187/cbe.19-05-0105>

- Maher, M. A., Wofford, A. M., Roksa, J., & Feldon, D. F. (2020b). Exploring early exits: Doctoral attrition in the biomedical sciences. *Journal of College Student Retention: Research, Theory & Practice*, 22(2), 205–226.
- Margolis, E., & Romero, M. (2001). “In the image and likeness...”: How mentoring functions in the hidden curriculum. In E. Margolis (Ed.), *The hidden curriculum in higher education* (pp. 79–96). Routledge.
- Mathur, A., Cano, A., Kohl, M., Muthunayake, N. S., Vaidyanathan, P., Wood, M. E., & Ziyad, M. (2018). Visualization of gender, race, citizenship and academic performance in association with career outcomes of 15-year biomedical doctoral alumni at a public research university. *PLoS ONE*, 13(5), Article e0197473.
- Mendoza, P. (2007). Academic capitalism and doctoral student socialization: A case study. *The Journal of Higher Education*, 78(1), 71–96.
- Mendoza, P. (2012). The role of context in academic capitalism: The industry-friendly department case. *The Journal of Higher Education*, 83(1), 26–48.
- Miller, E. (2015). Examining factors associated with the success of women in mathematics doctoral programs. *Journal of Women and Minorities in Science and Engineering*, 21(1), 47–85. <https://doi.org/10.1615/JWomenMinorScienEng.2015010814>
- National Center for Education Statistics. (2018). Table 318.30: Bachelor’s, master’s, and doctor’s degrees conferred by postsecondary institutions, by sex of student and discipline division: 2016–17. In U.S. Department of Education, National Center for Education Statistics (Ed.), *Digest of Education Statistics* (2018 ed.). [https://nces.ed.gov/programs/digest/d18/tables/dt18\\_318.30.asp?current=yes](https://nces.ed.gov/programs/digest/d18/tables/dt18_318.30.asp?current=yes)
- National Center for Science and Engineering Statistics. (2019). Table 17: U.S. residing employed doctoral scientists and engineers in 4-year educational institutions, by field of doctorate, sex, and faculty rank: 2017. *Survey of Doctorate Recipients* (2017 ed.). [https://ncesdata.nsf.gov/doctoratework/2017/html/sdr2017\\_dst\\_17.html](https://ncesdata.nsf.gov/doctoratework/2017/html/sdr2017_dst_17.html)
- Noy, S., & Ray, R. (2012). Graduate students’ perceptions of their advisors: Is there systematic disadvantage in mentorship? *The Journal of Higher Education*, 83(6), 876–914.
- Owen-Smith, J. (2001). Managing laboratory work through skepticism: Processes of evaluation and control. *American Sociological Review*, 66(3), 427–452.
- Pezzoni, M., Mairesse, J., Stephan, P., & Lane, J. (2016). Gender and the publication output of graduate students: A case study. *PLoS ONE*, 11(1), 1–12.
- Portnoi, L. M., Chlopecki, A. L. A., & Peregrina-Kretz, D. (2015). Expanding the doctoral student socialization framework: The central role of student agency. *The Journal of Faculty Development*, 29(3), 5–16.
- Ravitch, S. M., & Carl, N. M. (2016). *Qualitative research: Bridging the conceptual, theoretical, and methodological*. SAGE Publications.
- Rosser, S. V. (2012). *Breaking into the lab: Engineering progress for women in science*. NYU Press.
- Rosser, S. V., & Taylor, M. Z. (2009). Why are we still worried about women in science? *Academe*, 95(3), 7–10.
- Saldaña, J. (2015). *The coding manual for qualitative researchers* (3<sup>rd</sup> ed). SAGE Publications.

- Sallee, M. W. (2011a). Performing masculinity: Considering gender in doctoral student socialization. *The Journal of Higher Education*, 82(2), 187–216.
- Sallee, M. W. (2011b). Toward a theory of gendered socialization. *NASPA Journal about Women in Higher Education*, 4(2), 170–192.
- Šaras, E. D., Perez-Felkner, L., & Nix, S. (2018). Warming the chill: Insights for institutions and researchers to keep women in STEM. *New Directions for Institutional Research*, 2018(179), 115–137. <https://doi.org/10.1002/ir.20278>
- Schwalbe, M. L., & Staples, C. L. (1991). Gender differences in sources of self-esteem. *Social Psychology Quarterly*, 54(2), 158–168.
- Slaughter, S., & Leslie, L. L. (1997). *Academic capitalism: Politics, policies, and the entrepreneurial university*. Johns Hopkins University Press.
- Slay, K. E., Reyes, K. A., & Posselt, J. R. (2019). Bait and switch: Representation, climate, and tensions of diversity work in graduate education. *The Review of Higher Education*, 42(5), 255–286.
- Spinelli, E. (2005). *The interpreted world: An introduction to phenomenological psychology*. SAGE Publications.
- Stanley, L., & Wise, S. (1993). *Breaking out again: Feminist epistemology and ontology*. Routledge.
- Stephan, P. (2012). *How economics shapes science*. Harvard University Press.
- Tao, K. W., & Gloria, A. M. (2019). Should I stay or should I go? The role of impostorism in STEM persistence. *Psychology of Women Quarterly*, 43(2), 151–164.
- Turner, C. S. V., & Thompson, J. R. (1993). Socializing women doctoral students: Minority and majority experiences. *The Review of Higher Education*, 16(3), 355–370.
- Twale, D. J., Weidman, J. C., & Bethea, K. (2016). Conceptualizing socialization of graduate students of color: Revisiting the Weidman-Twale-Stein framework. *Western Journal of Black Studies*, 40(2), 80–94.
- van Manen, M. (2016). *Phenomenology of practice: Meaning-giving methods in phenomenological research and writing*. Routledge.
- Weidman, J. C. (2010). Doctoral student socialization for research. In S. K. Gardner & P. Mendoza (Eds.), *On becoming a scholar: Socialization and development in doctoral education* (pp. 45–55). Stylus Publishing.
- Weidman, J. C., & DeAngelo, L. (Eds.). (2020). *Socialization in higher education and the early career: Theory, research and application* (Vol. 7). Springer International Publishing. <https://doi.org/10.1007/978-3-030-33350-8>
- Weidman, J. C., Twale, D. J., & Stein, E. L. (2001). Socialization of graduate and professional students in higher education: A perilous passage? *ASHE-ERIC Higher Education Report*, 28(3), 1–136.
- Williams, M. S., Brown Burnett, T. J., Carroll, T. K., & Harris, C. J. (2018). Mentoring, managing, and helping: A critical race analysis of socialization in doctoral education. *Journal of College Student Retention: Research, Theory & Practice*, 20(2), 253–278.