Who Is Publishing Journal Articles During Graduate School? Racial and Gender Inequalities in Biological Sciences Over Time

Article *in* Journal of Diversity in Higher Education · June 2021

DOI: 10.1037/dhe0000336

CITATIONS
0

READS
207

4 authors, including:

Josipa Roksa
University of Virginia
83 PUBLICATIONS **2,948** CITATIONS

SEE PROFILE

Yapeng Wang
University of Virginia
3 PUBLICATIONS **1** CITATION

SEE PROFILE

David Frank Feldon
Utah State University
91 PUBLICATIONS **2,274** CITATIONS

SEE PROFILE

Dear Author,

Thank you for using BluPencil, the online Proofing System.

While this PDF is auto-generated on the fly, the changes made here are saved as comments or annotations, and figures may be of low resolution. This version will not be as-is published online nor printed. Once the corrections are registered on BluPencil, the same will be validated against the journal-specific styles by our editors, updated, and then only the final typeset PDF will be generated for publication.

Thank you,
Team BluPencil

Journal of Diversity in Higher Education

ISSN: 1938-8926
https://doi.org/10.1037/dhe0000336

Who Is Publishing Journal Articles During Graduate School? Racial and Gender Inequalities in Biological Sciences Over Time

Josipa Roksa[1], Yapeng Wang[1], David Feldon[2], and Matthew Ericson[3]
[1] Department of Sociology, University of Virginia
[2] Department of Instructional Technology and Learning Sciences, Utah State University
[3] Curry School of Education, University of Virginia

Despite increased enrolment of women and students from underrepresented racial/ethnic groups in doctoral programs, notable inequalities in academic careers persist. We investigate one potential source of these inequalities: publication rates during graduate school. Results, based on a sample of doctoral students in biological sciences across 53 institutions, indicate that both white women and students from underrepresented racial/ethnic groups (African American and Latinx) have lower publication rates than white men. Notably, these gaps grow over time and are not explained by background factors, socialization experiences, or family obligations. The same patterns persist for first-author publications for African American and Latinx students, but not white women, suggesting potentially differential mechanisms of exclusion. Implications for research and practice are discussed.

Keywords: equity, STEM, gender, race, graduate education

In the past 10 years, women earned more than 50% of all doctoral degrees but held fewer associate and full professor positions and earned lower salaries than men at each rank (Johnson, 2017). Even at the assistant professor level, STEM fields hire fewer women than men (Nelson & Brammer, 2007; National Science Foundation [NSF], 2018). Similar disparities in academic careers exist for historically underrepresented racial/ethnic groups,[1] despite their increasing representation in PhD programs (Espinosa et al., 2019). While bias in academic hiring and compensation is well documented (e.g., Knobloch-Westerwick et al., 2013; Thomson et al., 2020), few studies examine how graduate training may contribute to inequitable representation in the academy.

Scholarly publication is a long-recognized "coin of the realm," which serves as a significant, though not sole, criterion in faculty hiring decisions (Cognard-Black, 2004; Ehrenberg et al., 2009; Way et al., 2019). Accordingly, differential publication rates between demographic groups during doctoral training may be one factor contributing to inequitable hiring patterns (e.g., Larivière et al., 2013). For example, Cognard-Black (2004) found that the number of publications produced during Ph.D. training predicted the likelihood of attaining a postdoctoral (physics) or faculty (English, sociology) position. Similarly, Way et al. (2019) reported that newly hired assistant professors in computer science had a higher level of scholarly productivity than candidates who were not hired, even after accounting for the prestige of their Ph.D.-granting institutions.

Relying on a national cohort of Ph.D. students in the biological sciences[2] across 53 institutions, we examine gender and racial/ethnic differences in research productivity (number of journal articles published and number of first-author journal articles published) over 5 years of doctoral study. The selection of a single field for this study prevents conflation of disciplinary publishing norms with differences between individuals or groups. Further, biological sciences as a specific disciplinary area was selected for several reasons. First, it reflects the largest number of doctorates awarded annually within STEM fields according to the Survey of Earned Doctorates (National Center for Science & Engineering Statistics [NCSES], 2019b), with the specific subfields included in this study representing the largest number of doctorates granted within biology more broadly. Second, the biological sciences award doctorates to the largest proportions of women and underrepresented racial/ethnic groups among STEM disciplines, which avoids "rarity" effects found in disciplines with very low proportions of women (Fox, 2006).

Josipa Roksa https://orcid.org/0000-0003-2757-5982
Yapeng Wang https://orcid.org/0000-0002-8085-9311
David Feldon https://orcid.org/0000-0003-3268-5764

We gratefully acknowledge the support of the National Science Foundation. This article is based upon work supported under awards 1431234, 1431290, and 1760894. The views in this article are those of the authors and do not necessarily represent the views of the funding agency. We also acknowledge support of Web of Science in verifying respondent publications. This paper benefited from feedback provided at the 2019 RC28 (Research Committee on Social Stratification and Mobility) annual meeting.

Correspondence concerning this article should be addressed to Josipa Roksa, Department of Sociology, University of Virginia, United States. Email: jroksa@virginia.edu

[1] Underrepresented racial/ethnic groups include racial/ethnic groups with disproportionately low representation in STEM fields (National Center for Science & Engineering Statistics [NCSES], 2019a).

[2] Specifically, the subfields included targeted "bench biology" domains: cellular and molecular biology, microbiology, genetics, and developmental biology. These areas were identified based on the similarity of laboratory structures, activities, and publishing norms in contrast to other biological sciences (e.g., ecology, zoology).

Publishing During Graduate School

It is increasingly expected that graduate students will publish before earning the Ph.D. (Nettles & Millett, 2006; Waaijer et al., 2016). However, there is a dearth of research on publication patterns, and especially inequality in publication patterns, among graduate students. In a recent study of graduate students at one Big Ten institution, Lubienski et al. (2018) reported that women published significantly fewer articles than men. Notably, the gap was largest in natural and biological sciences. Another study focusing on biological sciences found that in the first year of doctoral education, women were significantly less likely to be included as authors on published journal articles, even though they reported spending more time on research (Feldon et al., 2017). Further, they became progressively less likely to be offered authorship as their total time spent on research in the laboratory increased.

Studies examining racial differences in publication rates among graduate students are even more rare, but existing studies raise notable concerns. Mendoza-Denton et al. (2017) reported that publication gaps by race/ethnicity are even larger than those by gender. Based on data from the Berkeley Life in Science Survey (BLISS), focusing on mathematical, physical, and computer sciences, the authors reported that underrepresented racial/ethnic minority students were only about half as likely to submit a paper for publication than their peers. The gap between women and men was about half that size.

These studies reveal notable inequalities by both race and gender among graduate students. However, they do not consider how inequality in publications may evolve over students' time in graduate school. As Merton (1968) observed, early publications can lead to increased scholarly recognition and initiate a process of cumulative advantage (see also Conti & Visentin, 2015). Although not focusing on publications, Gopaul (2019) likewise described a pattern of cumulative advantage in graduate school by showing that students who won competitive scholarships were afforded additional opportunities to participate in prestige-boosting activities.

The benefits of early success matter beyond graduate school: publications generated during graduate school significantly predict productivity after degree completion across a variety of disciplines, amplifying inequality in early careers (Lindahl et al., 2020; Paglis et al., 2006; Way et al., 2019). In the biological sciences, for example, publishing earlier in one's doctoral training predicts greater overall career productivity 10 years post-Ph.D. (Laurance et al., 2013). Thus, early differences in publications may influence both who succeeds in securing a faculty position and the volume of their scholarly contributions to the field over time.

Conceptual Framework

While a few recent studies have documented inequality in publication patterns over time, they have rarely investigated potential mechanisms that may underly those patterns (see Lubienski et al., 2018). To consider mechanisms that may produce inequality in publication rates, we rely on socialization theory, which is the primary framework for understanding graduate students' experiences (Gardner, 2009). Socialization is understood as "a process of internalizing the expectations, standards, and norms of a given society, which includes learning the relevant skills, knowledge, habits, attitudes, and values of the group that one is joining" (Austin & McDaniels, 2006, p. 400). This process of developing autonomous disciplinary researchers able to extend their discipline's knowledge base is fundamentally longitudinal (Weidman et al., 2001).

Within this framework, doctoral students are conceptualized to have several primary influences on their success: students' backgrounds and aptitudes that may impact their engagement with and access to socialization opportunities during their doctoral training; institutional culture and processes that shape students' knowledge acquisition, investment in their doctoral programs, and involvement in relevant scholarly activities; and students' sense of scholarly identity and commitment to a scholarly career (Weidman et al., 2001). Weidman and DeAngelo (2020) note that salient aspects of students' background include their academic preparation prior to entering doctoral study, as well as their aptitudes, motivations, and demographic identity characteristics such as race, gender, and socioeconomic status. Examples of such factors that are positively associated with entry into graduate study, sustained participation in research activities, and pursuit of a research career include prior experience with research and publication (e.g., Gilmore et al., 2015; Hathaway et al., 2002) and research self-efficacy (Adedokun et al., 2013; Carpi et al., 2017). Scientific reasoning is also commonly assumed to benefit graduate students' success, though research is limited (Sternberg & Sternberg, 2017). One prior study (Feldon et al., 2011) found that scientific reasoning correlated positively with increases in research skill assessed using samples of scholarly writing.

The mechanisms of doctoral training and institutional/departmental culture are intrinsically linked, because most research training—especially in STEM disciplines—takes place in the context of mentorship within a laboratory setting. Accordingly, direct instruction in research skills is rare, and support for learning often takes place informally through conversations with faculty, postdoctoral researchers, and senior peers. Given the critical role of relationships within laboratories, students' sense of belonging and inclusion in laboratory activities can have important consequences for the developmental trajectories of aspiring scientists, because their sense of belonging informs their comfort with engaging in laboratory conversations and opportunities (Maher et al., 2019; Posselt, 2018). In addition, previous studies suggest that students' laboratory experiences directly influence their identities as developing scholars (Lane et al., 2019; Malone & Barabino, 2009) and the nature and scope of their future professional endeavors through access to scholarly networks, projects, and data (Griffin et al., 2018; Ynalvez et al., 2017).

In its most recent iterations, socialization theory has more deliberately engaged issues of differential access, experiences, and outcomes associated with gender and race/ethnicity (e.g., Garcia et al., 2020; Sallee, 2011; Winkle-Wagner et al., 2020). For example, compared to their white male peers, women and students from underrepresented racial/ethnic groups report less positive socialization experiences and describe the existence of systemic inequities throughout their doctoral training (Felder et al., 2014; Gildersleeve et al., 2011; Ramirez, 2017). These socialization experiences extend to authorship and coauthorship opportunities, which are perceived to directly impact graduate students' visibility and future prospects within their disciplinary communities (Gilmore et al., 2016; Gopaul, 2019; Laudel & Gläser, 2008).

Several studies have described the importance of collaboration between faculty and graduate students in producing scientific

publications (Kamler, 2008; Paglis et al., 2006), developing students' research skills (Feldon et al., 2016) and facilitating students' socialization into their scholarly disciplines (Austin, 2002; Gardner, 2009). Particularly in the early years of doctoral training (and often beyond), coauthored article topics are usually dependent on faculty's areas of expertise and funding. Students are also dependent on faculty for learning the complex process of academic writing, which involves responding to both explicit and tacit knowledge of disciplinary norms and expectations (Aitchison et al., 2012; Kamler, 2008; Maher, 2014). Indeed, Feldon et al. (2016) found that graduate students who coauthored papers with their advisors demonstrated greater gains in their research skills over the course of an academic year than those who did not. In addition, one recent study reported that doctoral students in biological sciences who had high levels of interaction with both faculty and peers were 12 times as likely to be first authors on a paper as those classified as having high levels of interaction with peers only (Jeong et al., 2020).

This line of research would imply that socialization experiences may explain differential publication rates across sociodemographic groups. However, a few recent studies have questioned whether socialization experiences predict inequality in scholarly productivity (e.g., Lubienski et al., 2018; Roksa, Feldon, et al., 2018). These studies have relied only on cross-sectional analyses. We address this limitation by tracking students' scholarly productivity over 5 years of their doctoral study. More specifically, the purpose of this study is twofold. First, we examine whether publication patterns (total publications and first-author publications) may vary by gender and race/ethnicity as doctoral candidates progress through their studies. Second, we investigate the extent to which any observed inequalities in publication patterns are related to students' socialization experiences during graduate school, in addition to other factors.

Data and Method

Participants

This study includes 336 respondents who entered Ph.D. programs in biology in the fall of 2014. Participants were recruited in two ways. First, program directors and department chairs of the 100 largest biological sciences doctoral programs in the United States were contacted by email to describe the study and request that they inform incoming Ph.D. students about the research project. Following, to diversify the prospective pool of participants, all public flagship universities (research intensive), historically black colleges and universities (HBCUs), and Hispanic serving institutions (HSIs) offering Ph.D. programs in appropriate biology subfields were contacted.

Those who agreed forwarded recruitment information on behalf of the study to students, who then contacted the research team expressing interest in participation. In instances where programs' incoming cohorts consisted of six or more students, campus visits were arranged for a member of the research team to present information to eligible students and answer questions during program orientation or an introductory seminar meeting. Second, emails describing the study and eligibility criteria were forwarded to several listserves, including those of the American Society for Cell Biology and the Center for the Integration of Research, Teaching, and Learning (CIRTL) Network for broader dissemination. All students who responded to these emails already attended programs contacted in the first phase of recruitment, suggesting that recruitment efforts approached saturation at the institutional level.

The sample is distributed across 53 institutions (42 classified as Carnegie R1, accounting for 88% of individuals), which closely resembles the national estimate of 81% for first-year doctoral students in biological sciences (Council of Graduate Schools & Graduate Record Examination, 2017). Moreover, 60% of the current sample identifies as female, which is similar to the 52% of first-year doctoral students in biological sciences nationwide. CGS does not provide race/ethnicity of first-year doctoral students nationwide, leading us to rely on degree conferral data. According to NCSES (2019b), biological and biomedical sciences award 52% of Ph.D. degrees to women and 21% to individuals from underrepresented racial/ethnic groups. Fifteen percent of respondents in the study identify as underrepresented racial/ethnic groups, which is comparable to the national data. Thus, on key demographic measures, our sample does not notably deviate from the population.

Focusing on one discipline allows us to avoid conflating disciplinary differences in socialization practices with other sources of variation. A fundamental aspect of graduate education is socialization into a field or discipline, as students acquire the knowledge, skills, habits, and professional norms of their disciplines (Austin & McDaniels, 2006; Gardner, 2009). Disciplines vary in their structures (e.g., laboratory rotations in the sciences that are unusual in other fields; Maher et al., 2019) and publication practices (e.g., sole- vs. multiple-authored, journal articles vs. conference proceedings; Kamler, 2008). Focusing on one discipline prevents us from improperly interpreting differences across disciplines as individual or group differences.

Measure

Each year students completed surveys asking a range of questions regarding their graduate school experiences, as well as information on any journal articles published. In addition, in the first year, a series of questions were asked regarding their experiences before graduate school. Extensive survey measures allow us to consider a wide range of factors as potential mechanisms for explaining gender and racial/ethnic differences in publication rates.

We examine two different outcomes: (a) cumulative number of journal articles and (b) cumulative number of first-authored journal articles. Both of those capture the total number of articles published up to the year of observation. Although originally self-reported, journal publications were independently verified by researchers using *Web of Science* and G*oogle Scholar*. Any duplicates or nonpeer reviewed pieces were removed.

The key predictor variables are gender and race/ethnicity. With respect to race/ethnicity, we focus on comparing white and underrepresented racial/ethnic groups, removing other respondents from the sample.[3] Racial/ethnic groups underrepresented in STEM

[3] Respondents who were missing data on race ($N = 5$), self-reported "other" as a racial/ethnic category ($N = 9$), or were Asian ($N = 71$) were excluded from analysis. Although Asian students are often combined with whites, our earlier work indicated that publication patterns of Asian students differed notably from white students and varied by international student status, which is the majority of Asian students in the sample (Roksa, Jeong, et al., 2018).

include African Americans, Latinx, and American Indians or Alaska Natives (NCSES, 2019a). None of the respondents in our sample identified as American Indians or Alaska Natives, and thus our study includes two underrepresented racial/ethnic groups: African American and Latinx. Due to limitations of sample size, analyses consider three groups: students from underrepresented racial/ethnic groups (African American and Latinx students across genders, $N = 50$), white women ($N = 116$), and white men ($N = 85$). This categorization is warranted given prior literature, indicating that both women and students from underrepresented racial/ethnic groups face challenges in STEM fields.

Additional predictor variables are divided into three categories: background measures that precede entry into graduate school, graduate school socialization experiences, and family-related measures. In terms of pregraduate school factors, we include first-generation status (a dummy variable representing students whose parents did not complete a 4-year college degree),[4] whether students had any publications before Ph.D. entry (divided into three categories: none, low (1–3 publications), or high (more than 3 publications), number of months of research experience before the Ph.D., and scientific reasoning at doctoral entry assessed using the 24-item Lawson's Test of Scientific Reasoning (Lawson, 1978).

Students' graduate school experiences are represented by a number of different indicators, all of which vary over time. We begin by commonly used socialization measures, including participation in scholarly activities and interaction with faculty and peers (Weidman & Stein, 2003).[5] Weidman and Stein's measures are checklists, asking students whether they have participated in various activities such as "asked a fellow student to critique your work" and "called or written to a scholar at another institution to exchange views on scholarly work." The summary indicator represents the proportion of the checked items among the available choices. In addition, given our interest in racial/ethnic and gender differences, we consider two measures: (a) departmental collegiality, which includes items such as "the faculty sees me as a serious scholar" (Weidman & Stein, 2003), and (b) students' sense of belonging including items such as "I feel a sense of belonging to my lab/research group" (Bollen & Hoyle, 1990). These measures are Likert agree−disagree items and represent the average of the items for each scale. Both scales are highly reliable. Cronbach's α for departmental collegiality is 0.77 for Y1, 0.78 for Y2, 0.80 for Y3, 0.82 for Y4, and 0.73 for Y5. Cronbach's α for students' sense of belonging is 0.96 for Y1, 0.95 for Y2, 0.96 for Y3, 0.96 for Y4, and 0.95 for Y5.

We also consider two additional factors that may be related to the likelihood of publications: (a) career expectations and (b) research self-efficacy. Career expectations are represented by a dummy variable for respondents who expected to pursue a tenure-track faculty career after Ph.D. In years 2–5 of data collection, respondents were asked what was their first choice career goal upon completing the program. In year 3, we also asked them to reflect on what they expected when they started their doctoral program. We use that information to fill in data for the first year. Research self-efficacy scale asks respondents to rate their abilities in different research-related tasks, from understanding concepts in the field and identifying a research question, to designing experiments and analyzing and interpreting data (Kardash, 2000). Each item is rated on a 5-point Likert scale ranging from *not at all* to *a great deal*. Cronbach's α for research self-efficacy is 0.90 for Y1, 0.91 for Y2, 0.90 for Y3, 0.92 for Y4, and 0.91 for Y5.

Finally, we consider several family-related measures that may impact individuals' research productivity, including marital status (a categorial variable indicating three statuses: single/divorced/widowed, married or cohabiting, serious romantic relationship) and presence of children (dummy variable representing whether respondents have children). While it may be valuable to consider number of children, only between 3% and 5% of respondents in the sample have children at any point in time during the study. We also include a measure of students' perceptions of the extent to which personal life impacts their work. The original question was: "To what extent do you feel your personal life impacts the amount of time you invested in your graduate work?," measured on a 7-point Likert scale ranging from *not at all* to *extensively*.

Table 1 shows descriptive statistics for each of these measures for the full sample as well as for the three groups examined in this study.

Procedure

We estimate HLM growth curve models using Stata (version 16.1), with observations for each year nested within students. While students are also nested within institutions, the amount of variance explained at that level was small (4% for total journal publications and less than 1% for total first-authored journal publications). Likelihood ratio tests also show that three-level models do not fit data better than two-level models, leading us to opt for a more parsimonious two-level model. In the growth curve models, we include a square term for time as it is statistically significant in both models, and fit statistics indicate a better fit than a simple linear term ($p < .001$ for both outcomes). Both intercepts and slopes are allowed to vary randomly across all models.

Level 1 equation can be represented as follows (1).

$$NumPub_{ti} = \pi_{0i} + \pi_{1i} Year_{ti} + \pi_{2i} Year_{ti}^2 + \sum_k \pi_{ki} GradSchExps_{kti} + \sum_p \pi_{pi} Family_{pti} + e_{ti}, \quad (1)$$

where $NumPub_{ti}$ is the total number of publications (or total number of first-author publications) for student i measured at graduate school year t, π_{0i} is the intercept that can vary by student i, $Year_{ti}$ is the time variable that indicates the graduate school years, $Year_{ti}^2$ is the time variable squared, $GradSchExps_{kti}$ is a set of time-varying covariates indicating graduate school experiences for student i measured at graduate school year t, $Family_{pti}$ is a set of time-varying covariates indicating family-related measures for student i measured at graduate school year t, and e_{ti} is the Level-1 residual.

Level-2 equations can be represented as follows, (2) and (3).

$$\pi_{0i} = \beta_{00} + \beta_{01} WhiteWomen_i + \beta_{02} AfricanAmerican/Latinx_i + \sum_m \beta_{0m} PreGrad_{mi} + u_{0i}, \quad (2)$$

[4] While there are multiple definitions of first-generation status, the one used in this study is most commonly used at both undergraduate (Whitley et al., 2018) and doctoral (National Science Foundation [NSF], 2015) levels.

[5] The original scale included several additional items, which directly referred to authoring or coauthoring papers for publication and are thus excluded, given that one of our outcomes is publication.

Table 1
Descriptive Statistics for Independent Variables

	Full sample	African American and Latinx	White women	White men
Pregraduate school factors				
First-generation student (%)	27.71	48.98*	18.10	28.57
Prior research experience (months)	21.59 (14.92)	24.62** (15.65)	23.22** (15.14)	17.55 (13.41)
Prior publications (%)				
None	21.54	16.33	22.81	22.89
Low (1–3)	51.63	44.90	50.88	56.63
High (more than 3)	26.83	38.78*	26.32	20.48
Scientific reasoning	19.86 (3.70)	17.29*** (5.14)	19.99** (3.19)	21.18 (2.43)
Graduate school experiences				
Scholarly activities	0.44 (0.22)	0.42 (0.20)	0.44 (0.22)	0.45 (0.23)
Faculty interaction	0.71 (0.27)	0.75 (0.28)	0.70 (0.27)	0.71 (0.27)
Peer interaction	0.93 (0.17)	0.90 (0.20)	0.95 (0.15)	0.92 (0.17)
Collegiality	3.90 (0.62)	3.75* (0.67)	3.91 (0.65)	3.98 (0.55)
Belonging	8.34 (1.92)	8.22 (2.04)	8.37 (2.12)	8.37 (1.53)
Research self-efficacy	3.43 (0.60)	3.46 (0.73)	3.39 (0.57)	3.47 (0.56)
Expect tenure-track faculty (%)	42.93	39.53	41.67	46.97
Family-related measures				
Impact of personal life	4.22 (1.38)	4.55* (1.30)	4.24 (1.46)	4.00 (1.30)
Have children (%)	3.07	4.44	0.94	5.19
Marital status (%)				
Married/cohabiting		15.22	28.28	28.99
Serious romantic relationship		26.09	23.23	28.99
Single/divorced/widowed		58.70	48.48	42.03

Note. Table reports proportions for categorical measures and means and standard deviations (in parentheses) for continuous measures. For time-varying variables, only year 1 statistics are reported. Statistical significance based on *t*-tests comparing African American and Latinx respondents with white men (column 2) and white women with white men (column 3).
* $p < .05$. ** $p < .01$. *** $p < .001$.

$$\pi_{1i} = \beta_{10} + \beta_{11} WhiteWomen_i + \beta_{12} AfricanAmerican/Latinx_i + \sum_n \beta_{1n} PreGrad_{ni} + u_{1i}, \quad (3)$$

Where $WhiteWomen_i$ indicates white female students, $AfricanAmerican\ /\ Latinx_i$ indicates African American and Latinx students, $PreGrad_i$ indicates time-invariant pregraduate school factors, β_{00} or β_{10} indicates intercepts, and u_{0i} or u_{1i} indicates Level-2 (random) residuals.

After restricting the sample to white, African American, and Latinx respondents, the study begins with 251 respondents. By the summer of the first year, 7 had left their Ph.D. programs or the study; thus, our starting sample size in year 1 is 244 students (or 97% of the original sample). Attrition from the study over the subsequent years remains low: by the end of the second year, 92% of the sample was retained ($N = 230$), by the end of the third year, 86% ($N = 216$), by the end of the fourth year, 82% ($N = 206$), and by the end of the fifth year, 76% ($N = 191$).[6] Some attrition arises because students left their programs and some because they left the study.

Missing data for independent variables are dealt with using multiple imputation. The multiple imputation is conducted in the software Blimp (version 2.2) using the Fully Bayesian Model-Based Imputation (MBI) approach with 20 imputations (Enders et al., 2019). We do not impute missing data for the dependent variables. Prior work using this sample to examine publication rates found that using attrition weights (i.e., the inverse of the probability of having valid publication data) does not alter the results (Roksa, Feldon, et al., 2018).

Results

Publication Patterns Over Time

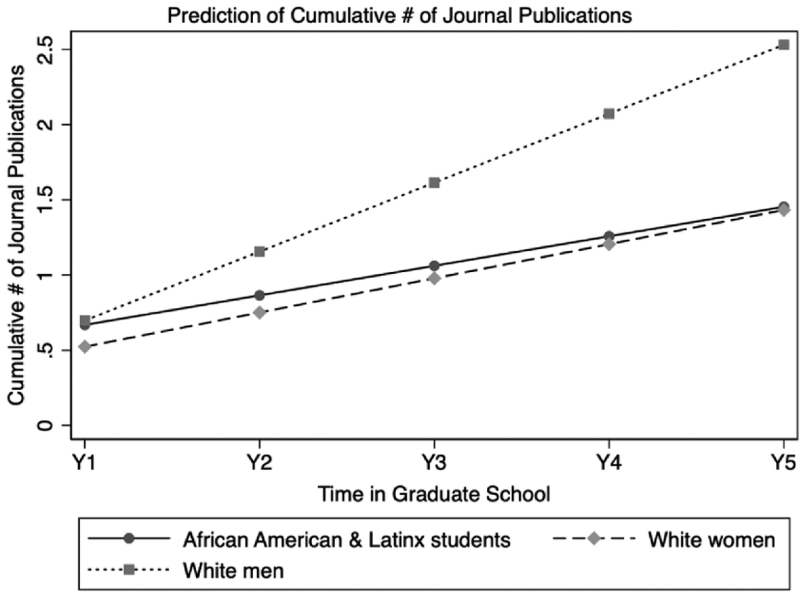
Figure 1 shows average marginal effects for the number of journal articles published over time (based on Model 1, Table 2). In the first year, all groups start with a similar number of published journal articles. However, notable inequalities in publication patterns emerge over time. White women and white men grow further apart as they progress through graduate school ($b = -0.231$, $p = .005$). By the 5th year of graduate study, white women are predicted to publish on average about 1 fewer article than white men. African American and Latinx students follow patterns similar to white women—their growth in publication rates over time is lower than that for white men, and the coefficient is of similar magnitude ($b = -0.262$, $p = .010$). By the 5th year of graduate study, the gaps between white women and students from underrepresented racial/ethnic groups on the one hand and white men on the other are much more pronounced than they were in the 1st year, showing growing inequality over time.

Figure 2 shows results for first-authored articles (Model 1, Table 3). Similar to the patterns for overall publications, African American and Latinx students publish journal articles at a lower rate over time ($b = -0.141$, $p = .019$), which creates growing inequality between them and white men as they progress through graduate school. By the 5th year, African American and Latinx students are

[6] Attrition is calculated based on the number of students who were no longer in the sample (because they left the study or their graduate programs) by the end of a given academic year, which is when the publication survey was administered.

Figure 1

Predicted Cumulative Number of Journal Articles Over Time



Note. Estimates based on Model 1 in Table 2.

predicted to publish on average 0.5 first-authored articles fewer than white men. Although the rate of publication over time for white women is slightly lower, it is statistically indistinguishable from that of white men ($b = -0.074$, $p = .125$). The slope coefficient for white women is also half of the magnitude of that for African American and Latinx students.

Understanding Inequality in Publication Patterns

To consider factors that may contribute to this disparity in publication patterns over time, we add a different set of variables sequentially to the baseline models. The results for journal publications presented in Table 2 indicate that adding pregraduate school factors (Model 2), graduate school experiences (Model 3), family-related measures (Model 4), or all predictors together (Model 5) does not alter the disadvantage experienced by white women and students from underrepresented racial/ethnic groups over time. The slope coefficients for both groups remain statistically significant and of the same magnitude across models. Thus, these factors, either separately or collectively, do not account for differential publication rates over time.

This remarkable stability in coefficients may seem surprising. It emerges from a few sources and is consistent with several prior studies that controlled for at least some of these factors (Lubienski et al., 2018; Roksa, Feldon, et al., 2018). First, white women and students from underrepresented racial/ethnic groups differ on very few characteristics from white men (see t-tests in Table 1). Moreover, differences that exist are in opposite directions or are not consequential for predicting publication patterns over time. For example, white women and students from underrepresented racial/ethnic groups report more months of research experience before entering graduate school (perhaps reflecting the perception that these groups need to have more experience to be competitive for graduate school entry) but have slightly lower scientific reasoning scores. In addition to pointing in opposite directions, neither of those measures predicts publication patterns either in the first year (intercept) or over time (slope) in the full model (Model 5, Table 2).

Graduate school experiences show even less variability across groups and have virtually no relationship to publication patterns. In addition to descriptive data for year 1 presented in Table 1, we ran mixed-effects models for each graduate school experience, controlling for pregraduate school factors. These supplemental analyses (available upon request from the authors) indicate essentially no differences in graduate school experiences, either in the first year or over time, between white women and students from underrepresented racial/ethnic groups relative to white men. Moreover, as Table 2 shows, none of the graduate school experiences predict publication patterns, except for career expectations: students who expect to pursue tenure-track faculty jobs publish slightly more ($b = 0.135$, $p = .024$, Model 2), although the coefficient drops below the .05 significance level in the full model (Model 5). Supplemental mixed-effects models show that expectation to pursue a tenure-track faculty position does not vary across groups either in the first year or over time.

Selected results in Table 3 present the same set of models for first-authored journal articles, revealing the same patterns. There is minimal change in coefficients across models, and most variables examined do not predict publication patterns either in the first year or over time. Thus, even net of all of the controls, African American and Latinx students continue to have a lower rate of publishing first-authored articles over time ($b = -0.153$, $p = .020$).

Limitations

While this study is unique in following a sample of students across many institutions for 5 years, it has limitations. First, the

Table 2
HLM Growth Curve Models Predicting Cumulative Number of Journal Articles

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept					
Key predictors (ref: White men)					
White women	−0.174 (0.091)	−0.178* (0.090)	−0.159 (0.091)	−0.178* (0.091)	−0.179* (0.090)
African American and Latinx students	−0.029 (0.115)	0.001 (0.121)	−0.005 (0.116)	−0.006 (0.115)	0.017 (0.121)
Pregraduate school factors					
First-generation student		−0.094 (0.092)			−0.056 (0.098)
Prior research experience (months)		0.002 (0.003)			0.003 (0.003)
Prior publications (ref: none)					
Low (1–3)		0.146 (0.101)			0.151 (0.101)
High (more than 3)		0.459*** (0.121)			0.438*** (0.121)
Scientific reasoning		0.024* (0.012)			0.019 (0.012)
Slope					
Key predictors (ref: White men)					
White women	−0.231** (0.081)	−0.235** (0.084)	−0.225** (0.081)	−0.227** (0.082)	−0.222** (0.084)
African American and Latinx students	−0.262** (0.101)	−0.268* (0.111)	−0.259** (0.100)	−0.259* (0.102)	−0.265* (0.111)
Pregraduate school factors					
First-generation student		−0.010 (0.088)			0.004 (0.088)
Prior research experience (months)		0.000 (0.003)			0.000 (0.003)
Prior publications (ref: none)					
Low (1–3)		−0.049 (0.093)			−0.044 (0.092)
High (more than 3)		0.073 (0.111)			0.083 (0.110)
Scientific reasoning		0.004 (0.011)			0.004 (0.011)
Graduate school experiences					
Scholarly activities			0.037 (0.122)		0.009 (0.122)
Faculty interaction			−0.160 (0.104)		−0.150 (0.104)
Peer interaction			−0.039 (0.159)		−0.038 (0.158)
Collegiality			0.013 (0.045)		0.037 (0.044)
Belonging			0.005 (0.015)		0.002 (0.015)
Research self-efficacy			0.062 (0.045)		0.031 (0.045)
Expect tenure-track faculty			0.135* (0.060)		0.112 (0.060)
Family-related measures					
Impact of personal life				−0.002 (0.018)	−0.008 (0.018)
Have children				−0.182 (0.182)	−0.202 (0.173)
Marital status: (ref: single/divorced/widowed)					
Married/cohabiting				0.172* (0.079)	0.162* (0.078)
Serious romantic relationship				0.075 (0.062)	0.054 (0.063)
Year	0.458*** (0.073)	0.388 (0.259)	0.453*** (0.075)	0.445*** (0.073)	0.362 (0.260)
Year squared	0.075*** (0.010)	0.075*** (0.010)	0.075*** (0.011)	0.076*** (0.010)	0.075*** (0.011)
Constant	0.312*** (0.071)	−0.375 (0.279)	0.073 (0.260)	0.260* (0.103)	−0.515 (0.385)

Note. $N = 966$. Standard errors in parentheses.
* $p < .05$. ** $p < .01$. *** $p < .001$.

sample size prevents us from conducting more nuanced analyses, by for example, conducting separate analyses for African American and Latinx students or exploring differences between women and men among students from different racial/ethnic groups. Combining African American and Latinx students conflates race and ethnicity and thus ignores variation in students' experiences and outcomes. In addition, prior research indicates that women from underrepresented racial/ethnic groups face "double disadvantage" in academia (Malcom et al., 1976; see also Armstrong & Jovanovic, 2015), which warrants examination in future research.

Our study is also restricted to lab-based biological sciences. Although that strengthens the validity of the findings, avoiding confounds from disciplinary differences in publishing and collaboration patterns, it is unclear whether the patterns observed herein hold for other fields—especially those that do not rely on a lab structure. Future research is needed to explore inequalities in publication patterns over time across a wider range of disciplines.

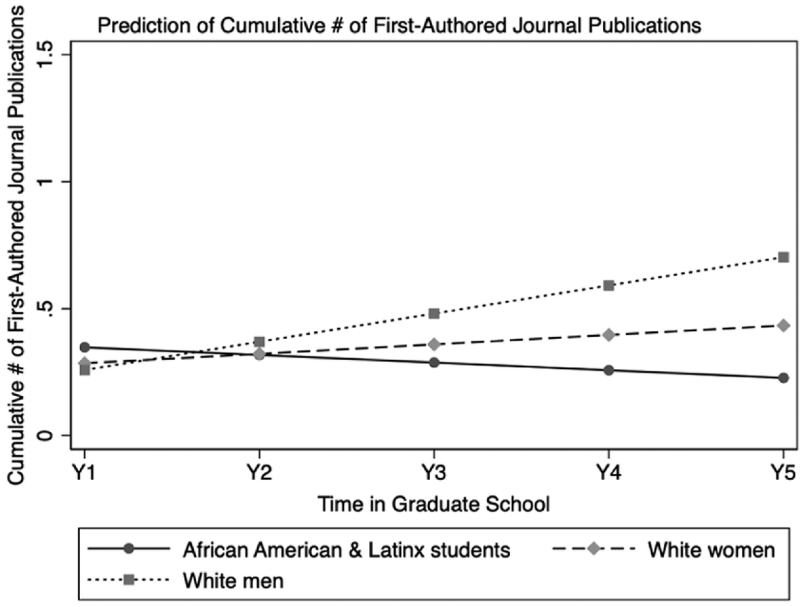
Moreover, our study focuses on the number of publications and does not capture their quality. Future studies are needed to consider not only the number of publications but also the relative prestige of journals as well as article impact (e.g., citations). Finally, analyses presented in this study reveal patterns during graduate education and do not examine an association between publication during graduate school and subsequent outcomes (such as job placement). While prior studies have reported a relationship between publication during graduate education and labor market outcomes (Cognard-Black, 2004; Ehrenberg et al., 2009; Way et al., 2019), additional research is warranted in this area, especially with respect to gender and racial/ethnic inequalities.

Discussion

This study provides a unique account of publication patterns during graduate school by examining data over time and considering both race/ethnicity and gender. The findings highlight that inequality is a cumulative process and grows over time. White women and students from underrepresented racial/ethnic groups accumulate fewer articles as they progress through graduate school relative

Figure 2

Predicted Cumulative Number of First-Authored Journal Articles Over Time



Note. Estimates based on Model 1 in Table 3.

to white men. These growing gaps over time raise concerns about the prospect of increasing gender and racial/ethnic equity among tenure-track faculty. If journal articles are one of the key criteria for obtaining faculty jobs (and competitive postdoctoral research positions that lead to faculty jobs), white women and students from underrepresented racial/ethnic groups seem to be getting further away from those jobs during their time in graduate school, relative to white men.

Notably, we find that graduate school socialization experiences are not related to the likelihood of publications or to the inequality in publication patterns (see also Lubienski et al., 2018; Roksa, Feldon, et al., 2018). This implies the need to examine the adequacy of socialization as an explanatory mechanism (Feldon, 2020). More specifically, the premise of socialization, which is that students need to assimilate into the culture of the discipline and institution (Austin & McDaniels, 2006), can keep inequality invisible or normalize it and has been increasingly questioned. A number of scholars have argued for the need to reconceptualize socialization by recognizing the bidirectionality of socialization and considering the role of students' agency (Garcia et al., 2020; Winkle-Wagner et al., 2020). The way socialization is conceptualized and subsequently operationalized thus warrants reexamination, particularly when examining experiences of women and students from underrepresented racial/ethnic groups.

While the factors examined herein cannot explain gaps in publication rates, a growing number of studies have noted that women and students from underrepresented racial/ethnic groups have less positive socialization experiences (e.g., Felder et al., 2014; Gildersleeve et al., 2011; Ramirez, 2017; Sal[illegible] 2011). More specifically, a number of studies have reported th[illegible]udents from underrepresented

Table 3

Selected Results From the HLM Growth Curve Models Predicting Cumulative Number of First-Authored Journal Articles

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept					
Key predictors (ref: White men)					
White women	0.026 (0.041)	0.025 (0.041)	0.035 (0.041)	0.024 (0.041)	0.029 (0.041)
African American and Latinx students	0.089 (0.052)	0.094 (0.054)	0.090 (0.052)	0.083 (0.052)	0.086 (0.055)
Slope					
Key predictors (ref: White men)					
White women	−0.074 (0.048)	−0.078 (0.050)	−0.071 (0.048)	−0.074 (0.048)	−0.075 (0.050)
African American and Latinx students	−0.141* (0.060)	−0.157* (0.066)	−0.137* (0.060)	−0.142* (0.060)	−0.153* (0.066)
Variables included					
Pregraduate school factors		X			X
Graduate school experiences			X		X
Family-related measures				X	X

Note. $N = 966$. Standard errors in parentheses.
* $p < .05$. ** $p < .01$. *** $p < .001$.

racial/ethnic groups as well as women have less supportive relationships with advisors (e.g., Dinsmore & Roksa, 2020; Noy & Ray, 2012). Given the centrality of advisors in facilitating early publications, this may contribute to our finding that both African American and Latinx doctoral students and white women have lower rates of publishing than white men. In addition, several prior studies have indicated that women are less likely to be included in collaborations (Feldon et al., 2017; Miller & Roksa, 2020; Wagner, 2016), which may contribute to our finding that white women's research productivity parallels that of men with respect to doing their own work (i.e., work leading to first-author publications) but not with respect to total publications (i.e., which includes publications resulting from collaboration on projects led by others). A range of socialization experiences, from relationships with faculty and peers, to subtle mechanisms that allocate opportunities for research and collaboration, may contribute to observed inequities and require careful attention in future research.

These findings have important implications for both graduate school experiences and early career transitions. If publications remain the "coin of the realm" for obtaining jobs (Ehrenberg et al., 2009), women, African American, and Latinx students will be systematically disadvantaged until graduate education practices are altered to facilitate success of *all* students. Faculty mentors play a crucial role in disrupting the observed patterns. In addition to general training to improve quality of mentoring (e.g., Pfund et al., 2014), targeted professional development for faculty mentors may heighten their awareness of potential inequities that can manifest through benign neglect or assumptions of a "colorblind" approach to mentoring and offer strategies to proactively support students from underrepresented racial/ethnic groups (Butz et al., 2019; Byars-Winston et al., 2020). Students traditionally excluded from STEM may especially benefit from research-based communities of practice and a sense of care in their advising relationships that promotes deeper personal connections (Griffin et al., 2020).

In addition, challenging and altering assumptions and structures of graduate education away from assimilation and toward empowering students from different backgrounds is crucial for more equitable experiences in STEM. This includes recognizing unique strengths that traditionally excluded groups bring to higher education (Yosso, 2005) and building stronger connections to diverse communities through activities such as bridge programs and hiring more diverse faculty (Winkle-Wagner et al., 2020). In addition, making "hidden curriculum" visible by integrating disciplinary norms and expectations into program structures may reduce inequalities. For example, a highly structured program that includes systematic involvement in research and clear expectations for publishing is credited with facilitating parity in the number of articles submitted for publication across race and gender at UC Berkeley's College of Chemistry (Mendoza-Denton et al., 2017).

Understanding the ways in which inequities manifest along the pathway from graduate training to independent scholar is essential to informing the efforts to diversify the professoriate. The findings reported in this study demonstrate that even in fields reporting gender equity and greater proportions of African American and Latinx students in Ph.D. attainment than other STEM disciplines, underlying mechanisms of inequality exist with measurable and impactful consequences. Finding gender inequality in publication rates in this context is especially noteworthy because it cannot be explained away by a relative scarcity of women in the field generally. Future research to uncover and document differences across different groups that affect the professional trajectories of early career scholars can provide crucial insights to inform sustained efforts toward equity.

References

Adedokun, O., Bessenbacher, A., Parker, L., Kirkham, L., & Burgess, W. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science Teaching*, *50*, 940–951. https://doi.org/10.1002/tea.21102

Aitchison, C., Catterall, J., Ross, P., & Burgin, S. (2012). Tough love and tears: Learning doctoral writing in the sciences. *Higher Education Research & Development*, *31*, 435–447. https://doi.org/10.1080/07294360.2011.559195

Armstrong, M. A., & Jovanovic, J. (2015). Starting at the crossroads: Intersectional approaches to institutionally supporting minority women STEM faculty. *Journal of Women and Minorities in Science and Engineering*, *21*(2), 141–157. https://doi.org/10.1615/JWomenMinorScienEng.2015011275

Austin, A. (2002). Preparing the next generation of faculty: Graduate school as socialization to the academic career. *The Journal of Higher Education*, *73*(1), 94–122. https://doi.org/10.1080/00221546.2002.11777132

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. 21, pp. 397–456). Springer. https://doi.org/10.1007/1-4020-4512-3_8

Bollen, K. A., & Hoyle, R. H. (1990). Perceived cohesion: A conceptual and empirical examination. *Social Forces*, *69*(2), 479–504. https://doi.org/10.2307/2579670

Butz, A. R., Spencer, K., Thayer-Hart, N., Cabrera, I. E., & Byars-Winston, A. (2019). Mentors' motivation to address race/ethnicity in research mentoring relationships. *Journal of Diversity in Higher Education*, *12*(3), 242–254. https://doi.org/10.1037/dhe0000096

Byars-Winston, A., Leverett, P., Benbow, R. J., Pfund, C., Thayer-Hart, N., & Branchaw, J. (2020). Race and ethnicity in biology research mentoring relationships. *Journal of Diversity in Higher Education*, *13*, 240–253. https://doi.org/10.1037/dhe0000106

Carpi, A., Ronan, D., Falconer, H., & Lents, N. (2017). Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM. *Journal of Research in Science Teaching*, *54*, 169–194. https://doi.org/10.1002/tea.21341

Cognard-Black, A. (2004). *Nice work if you can get it: Determinants of academic employment and other workplace rewards among new doctorate recipients* (Unpublished dissertation). The Ohio State University.

Conti, A., & Visentin, F. (2015). Science and engineering Ph.D. students' career outcomes, by gender. *PLOS ONE*, *10*(8), Article e0133177. https://doi.org/10.1371/journal.pone.0133177

Council of Graduate Schools and Graduate Record Examination. (2017). *CGS Survey of Graduate Enrollment & Degrees (Fall 2014)* [User-requested table generated by CGS]. Council of Graduate Schools.

Dinsmore, B., & Roksa, J. (2020). *Race, gender and relationships with advisors: Inequalities in becoming a scholar*. Paper presented at the American Sociological Association Meeting.

Ehrenberg, R., Zuckerman, H., Groen, J., & Brucker, S. (2009). Changing the education of scholars. In R. G. Ehrenberg & C. V. Kuh (Eds.), *Doctoral education and the faculty of the future* (pp. 15–34). Cornell University Press.

Enders, C. K., Du, H., & Keller, B. T. (2019). A model-based imputation procedure for multilevel regression models with random coefficients, interaction effects, and other nonlinear terms. *Psychological Methods*. Advance online publication. https://doi.org/10.1037/met0000228

Espinosa, L. L., Turk, J. M., Taylor, M., & Chessman, H. M. (2019). *Race and ethnicity in higher education: A status report*. American Council on Education.

Felder, P. P., Stevenson, H. C., & Gasman, M. (2014). Understanding race in doctoral student socialization. *International Journal of Doctoral Studies*, *9*, 21–42. https://doi.org/10.28945/1947

Feldon, D. F. (2020). Implications of measurement issues for advancing the socialization framework. In L. DeAngelo & J. C. Weidman (Eds.), *Socialization in higher education and the early career: Theory, research and application* (pp. 287–310). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-33350-8_16

Feldon, D. F., Peugh, J., Maher, M. A., Roksa, J., & Tofel-Grehl, C. (2017). Time-to-credit gender inequities of first-year Ph.D. students in the biological sciences. *CBE Life Sciences Education*, *16*(1), 4. https://doi.org/10.1187/cbe.16-08-0237

Feldon, D. F., Shukla, K. D., & Maher, M. A. (2016). Faculty–student coauthorship as a means to enhance STEM graduate students' research skills. *International Journal for Researcher Development*, *7*(2), 178–191. https://doi.org/10.1108/IJRD-10-2015-0027

Feldon, D. F., Peugh, J., Timmerman, B. E., Maher, M. A., Hurst, M., Strickland, D., … Stiegelmeyer, C. (2011). Graduate students' teaching experiences improve their methodological research skills. *Science*, *333*(6045), 1037–1039. https://doi.org/10.1126/science.1204109

Fox, M. F. (2006). Gender, hierarchy, and science. In J. S. Chafetz (Ed.), *Handbook of the sociology of gender* (pp. 441–457). Springer. https://doi.org/10.1007/0-387-36218-5_20

Garcia, G. A., Ramirez, J. J., & Patrón, O. E. (2020). Rethinking Weidman's models of socialization for Latinxs along the postsecondary educational pipeline. In L. DeAngelo & J. C. Weidman (Eds.), *Socialization in higher education and the early career: Theory, research and application* (pp. 55–72). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-33350-8_4

Gardner, S. K. (2009). Conceptualizing success in doctoral education: Perspectives of faculty in seven disciplines. *The Review of Higher Education*, *32*(3), 383–406. https://doi.org/10.1353/rhe.0.0075

Gildersleeve, R. E., Croom, N. N., & Vasquez, P. L. (2011). "Am I going crazy?!": A critical race analysis of doctoral education. *Equity & Excellence in Education*, *44*(1), 93–114. https://doi.org/10.1080/10665684.2011.539472

Gilmore, J. A., Vieyra, M., Timmerman, B. E., Feldon, D. F., & Maher, M. A. (2015). The relationship between undergraduate research participation and subsequent research performance of early career STEM graduate students. *The Journal of Higher Education*, *86*, 834–863. https://doi.org/10.1353/jhe.2015.0031

Gilmore, J., Wofford, A., & Maher, M. (2016). The flip side of the attrition coin: Faculty perceptions of supporting graduate student success. *International Journal of Doctoral Studies*, *11*, 419–439. https://doi.org/10.28945/3618

Gopaul, B. (2019). "Nothing succeeds like success": Doctoral education and cumulative advantage. *The Review of Higher Education*, *42*(4), 1431–1457. https://doi.org/10.1353/rhe.2019.0071

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 L. DeAngelo & J. C. Weidman (Eds.), *Socialization in higher education and the early career: Theory, research and application* (pp. 223–239). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-33350-8_13

Griffin, K. A., Baker, V., O'Meara, K., Nyunt, G., Robinson, T., & Staples, C. L. (2018). Supporting scientists from underrepresented minority backgrounds: Mapping developmental networks. *Studies in Graduate and Postdoctoral Education*, *9*, 19–37. https://doi.org/10.1108/SGPE-D-17-00032

Hathaway, R., Nagda, B., & Gregerman, S. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: An empirical study. *Journal of College Student Development*, *43*(5), 1–18.

Jeong, S., Litson, K., Blaney, J., & Feldon, D. F. (2020). Shifting gears: Characteristics and consequences of latent class transitions in doctoral socialization. *Research in Higher Education*, *61*, 1027–1053. https://doi.org/10.1007/s11162-019-09583-7

Johnson, H. L. (2017). *Pipelines, pathways, and institutional leadership: An update on the status of women in higher education*. American Council on Education.

Kardash, C. M. (2000). Evaluation of undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology*, *92*(1), 191–201. https://doi.org/10.1037/0022-0663.92.1.191

Kamler, B. (2008). Rethinking doctoral publication practices: Writing from and beyond the thesis. *Studies in Higher Education*, *33*(3), 284–294.

Knobloch-Westerwick, S., Glynn, C. J., & Huge, M. (2013). The Matilda effect in science communication: An experiment on gender bias in publication quality perceptions and collaboration interest. *Science Communication*, *35*, 603–625. https://doi.org/10.1177/1075547012472684

Lane, A. K., Hardison, C., Simon, A., & Andrews, T. C. (2019). A model of the factors influencing teaching identity among life sciences doctoral students. *Journal of Research in Science Teaching*, *56*, 141–162. https://doi.org/10.1002/tea.21473

Larivière, V., Ni, C., Gingras, Y., Cronin, B., & Sugimoto, C. R. (2013). Bibliometrics: Global gender disparities in science. *Nature*, *504*, 211–213. https://doi.org/10.1038/504211a

Laurance, W., Useche, D. C., Laurance, S., & Bradshaw, C. (2013). Predicting publication success for biologists. *Bioscience*, *63*, 817–823. https://doi.org/10.1525/bio.2013.63.10.9

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, *15*(1), 11–24. https://doi.org/10.1002/tea.3660150103

Laudel, G., & Gläser, J. (2008). From apprentice to colleague: The metamorphosis of early career researchers. *Higher Education*, *55*(3), 387–406. https://doi.org/10.1007/s10734-007-9063-7

Lindahl, J., Colliander, C., & Danell, R. (2020). Early career performance and its correlation with gender and publication output during doctoral education. *Scientometrics*, *122*, 309–330. https://doi.org/10.1007/s11192-019-03262-1

Lubienski, S. T., Miller, E. K., & Saclarides, E. S. (2018). Sex differences in doctoral student publication rates. *Educational Researcher*, *47*(1), 76–81. https://doi.org/10.3102/0013189X17738746

Maher, M. A. (2014). Transparent transactions: When doctoral students and their supervisors write together. In C. Aitchison & C. Guerin (Eds.), *Writing groups for doctoral education and beyond: Theory and practice* (pp. 82–93). Routledge.

Maher, M., Wofford, A., Roksa, J., & Feldon, D. F. (2019). Doctoral student experiences in biological sciences laboratory rotations. *Studies in Graduate and Postdoctoral Education*, *10*, 69–82. https://doi.org/10.1108/SGPE-02-2019-050

Malcom, S. M., Hall, P. Q., & Brown, J. W. (1976). *The double bind: The price of being a minority woman in science*. American Association for the Advancement of Science.

Malone, K. R., & Barabino, G. (2009). Narrations of race in STEM research settings: Identity formation and its discontents. *Science Education*, *93*(3), 485–510. https://doi.org/10.1002/sce.20307

Mendoza-Denton, R., Patt, C., Fisher, A., Eppig, A., Young, I., Smith, A., & Richards, M. A. (2017). Differences in STEM doctoral publication by ethnicity, gender and academic field at a large public research university. *PLOS ONE*, *12*(4), Aticle e0174296. https://doi.org/10.1371/journal.pone.0174296

Merton, R. K. (1968). The Matthew effect in science. The reward and communication systems of science are considered. *Science*, *159*(3810), 56–63. https://doi.org/10.1126/science.159.3810.56

Miller, C., & Roksa, J. (2020). Balancing research and service in academia: Gender, race, and laboratory tasks. *Gender & Society*, *34*(1), 131–152. https://doi.org/10.1177/0891243219867917

National Center for Science and Engineering Statistics (NCSES). (2019a). *Women, minorities, and persons with disabilities in science and engineering*. National Science Foundation (NSF). https://ncses.nsf.gov/pubs/nsf19304/digest

National Center for Science and Engineering Statistics (NCSES). (2019b). *Survey of earned doctorates: 2019*. National Science Foundation. https://ncses.nsf.gov/pubs/nsf21308/data-tables

National Science Foundation (NSF). (2015). *Doctorate recipients from U.S. universities*. Author.

National Science Foundation (NSF). (2018). *Doctoral scientists and engineers in Academia*. National Science Foundation. https://www.nsf.gov/statistics/2018/nsb20181/report/sections/academic-research-and-development/doctoral-scientists-and-engineers-in-academia

Nelson, D., & Brammer, C. (2007). *A national analysis of minorities in science and engineering faculties at research universities*. University of Oklahoma Press.

Nettles, M., & Millett, C. (2006). *Three magic letters: Getting to Ph.D*. The Johns Hopkins University Press.

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. https://doi.org/10.1353/jhe.2012.0036

Paglis, L. L., Green, S. G., & Bauer, T. N. (2006). Does adviser mentoring add value? A longitudinal study of mentoring and doctoral student outcomes. *Research in Higher Education*, *47*(4), 451–476. https://doi.org/10.1007/s11162-005-9003-2

Pfund, C., House, S. C., Asquith, P., Fleming, M. F., Buhr, K. A., Burnham, E. L., … Sorkness, C. A. (2014). Training mentors of clinical and translational research scholars: A randomized controlled trial. *Academic Medicine*, *89*, 774–782. https://doi.org/10.1097/ACM.0000000000000218

Posselt, J. R. (2018). Rigor and support in racialized learning environments: The case of graduate education. *New Directions for Higher Education*, *2018*(181), 59–70. https://doi.org/10.1002/he.20271

Ramirez, E. (2017). Unequal socialization: Interrogating the Chicano/Latino(a) doctoral education experience. *Journal of Diversity in Higher Education*, *10*(1), 25–38. https://doi.org/10.1037/dhe0000028

Roksa, J., Feldon, F., & Maher, M. (2018). First-generation students in pursuit of the Ph.D.: Comparing socialization experiences and outcomes to continuing-generation peers. *The Journal of Higher Education*, *89*, 728–752. https://doi.org/10.1080/00221546.2018.1435134

Roksa, J., Jeong, S., Feldon, D., & Maher, M. (2018). Socialization experiences and research productivity of Asians and Pacific Islanders: 'Model minority' stereotype and domestic vs. international comparison. *Research in Sociology of Education*, *20*, 155–179. https://doi.org/10.1108/S1479-353920180000020007

Sallee, M. W. (2011). Performing masculinity: Considering gender in doctoral student socialization. *The Journal of Higher Education*, *82*(2), 187–216. https://doi.org/10.1353/jhe.2011.0007

Sternberg, R. J., & Sternberg, K. (2017). Measuring scientific reasoning for graduate admissions in psychology and related disciplines. *Journal of Intelligence*, *5*, 29. https://doi.org/10.3390/jintelligence5030029

Thomson, R., Jr., Sánchez Salazar, E., & Ecklund, E. (2020). The very ivory tower: Pathways reproducing racial-ethnic stratification in US academic science. *Ethnic and Racial Studies*. Advance online publication. https://doi.org/10.1080/01419870.2020.1786144

Waaijer, C. J., Macaluso, B., Sugimoto, C. R., & Larivière, V. (2016). Stability and longevity in the publication careers of US doctorate recipients. *PLOS ONE*, *11*(4), Article e0154741. https://doi.org/10.1371/journal.pone.0154741

Wagner, C. (2016). Rosalind's ghost: Biology, collaboration, and the female. *PLOS Biology*, *14*(11), Article e2001003. https://doi.org/10.1371/journal.pbio.2001003

Way, S. F., Morgan, A. C., Larremore, D. B., & Clauset, A. (2019). Productivity, prominence, and the effects of academic environment. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(22), 10729–10733. https://doi.org/10.1073/pnas.1817431116

Weidman, J. C., & DeAngelo, L. (2020). Toward a 21st century socialization model of higher education's impact on students. In J. C. Weidman & L. DeAngelo (Eds.), *Socialization in higher education and the early career: Theory, research, and application* (pp. 311–323). Springer. https://doi.org/10.1007/978-3-030-33350-8_17

Weidman, J. C., & Stein, E. L. (2003). Socialization of doctoral students to academic norms. *Research in Higher Education*, *44*(6), 641–656. https://doi.org/10.1023/A:1026123508335

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, Vol. 28, No. 3). Jossey-Bass.

Whitley, S. E., Benson, G., & Wesaw, A. (2018). *First-generation student success: A landscape analysis of programs and services at four-year institutions*. Center for First-generation Student Success, NASPA–Student Affairs Administrators in Higher Education, and Entangled Solutions.

Winkle-Wagner, R., McCoy, D. L., & Lee-Johnson, J. (2020). Creating porous ivory towers: Two-way socialization processes that embrace Black students' identities in academia. In L. DeAngelo & J. C. Weidman (Eds.), *Socialization in higher education and the early career: Theory, research and application* (pp. 73–89). Springer International Publishing AG. https://doi.org/10.1007/978-3-030-33350-8_5

Ynalvez, M. A., Ynalvez, R. A., & Ramírez, E. (2017). Mentor-mentee interaction and laboratory social environment: Do they matter in doctoral students' publication productivity? *Biochemistry and Molecular Biology Education*, *45*, 130–144. https://doi.org/10.1002/bmb.21001

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race, Ethnicity and Education*, *8*, 69–91. https://doi.org/10.1080/1361332052000341006

Received February 10, 2021
Revision received May 19, 2021
Accepted June 9, 2021 ■