BRIEFS

Sex Differences in Doctoral Student Publication Rates

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Women in the sciences who earn PhDs are less likely than their male counterparts to pursue tenure-track positions at research universities. Moreover, among those who become STEM researchers, men have been found to publish more than women. These patterns raise questions about when sex differences in publication begin. Using data from a survey of doctoral students at one large institution, this study finds that men submitted and published more scholarly works than women across many fields, with differences largest in natural/biological sciences and engineering. Potential contributing factors are considered, including sex differences in faculty support, assistantships, family responsibilities, and career goals.

Keywords: career development; doctoral students; equity; faculty development; gender studies; graduate education; higher education; publications; regression analyses; research; secondary data analysis; sex; STEM; survey research; women's issues

A recent study of bibliometric data from across the globe found 1.9 times as many articles published by men than women (Larivière, Ni, Gingras, Cronin, & Sugimoto, 2013). This pattern may be largely due to the fact that more men are established, full-time scholars in many fields. For example, within the top 100 U.S. universities, women comprise only 9% to 16% of tenure-track faculty in many math-intensive fields (Ceci & Williams, 2001).

Larivière et al. (2013) also noted that publication gaps by sex are particularly large in fields requiring large research expenditures and suggested that inequitable funding practices may be a factor in these publication gaps. Ceci and Williams (2011) reviewed data from several prior studies and found little evidence of biased grant and article review processes, but they did note that men in academia have more resources, including time for conducting research, as women are more often in part-time and teaching-intensive positions and disproportionately affected by family responsibilities.

General analyses of bibliometric databases, such as that conducted by Larivière et al. (2013), can offer useful, birds-eye estimates of the *numbers* of publications authored by men and women. However, such analyses cannot directly compare *rates* of publication by sex[1] as they do not identify the full population of all potential authors.[2] In a rare comparison of publication rates, Milesi, Brown, Hawkley, Dropkin, and Schneider (2014) found that in a national sample of STEM researchers, men published over 25% more journal articles than women (with the difference slightly less among those with National Science Foundation funding). However, the national sample consisted of only 29% women, raising the questions of whether this difference holds in fields with gender parity and when such differences begin. In one recent study focused on biology, which now has over 50% female PhD graduates, male first-year PhD students spent fewer hours on research yet published 15% more journal articles than their female peers for every 100 hours invested (Feldon, Peugh, Maher, Roksa, & Tofel-Grehl, 2017).

It is unclear how men and women's career paths begin and diverge and whether differences at the starting gate, such as those found by Feldon et al. (2017) in biology, occur across all academic fields. We do know that across fields, women are less likely than men to attend the most prestigious doctoral programs (Weeden, Thébaud, & Gelbgiser, 2017), and so this may account for some differences in publication and career trajectories. However, we do not know whether male and female researchers in the same academic stage, field, and institution publish at similar rates or whether differences appear even at the earliest career stage—graduate school. If so, these differences might relate to a later divergence in career paths, including fewer female PhD

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graduates in the sciences pursuing tenure-track positions than their male counterparts (Canizares, 2009).

This study addresses the following questions:

Research Question 1: Among doctoral students within the same institution, do the number of scholarly works submitted for publication, first-authored, and published differ between women and men?

Research Question 2: How do such differences vary by field?

Method

This study uses 1,285 responses from a survey given to recent PhD graduates from one Big Ten institution. The survey assessed satisfaction with many program components (e.g., advising, coursework, financial support, etc.) and also asked about the number of "research articles, chapters, and other scholarly works" submitted during doctoral study. Follow-up questions asked about the number of first- or solo-authored submissions as well as the number of submissions that were accepted or published. In this study, five additional program satisfaction and support items were examined that might shed light on reasons for the publication disparities, along with seven questions pertaining to program supports and obstacles that were administered to only a subset of students (with *n*s ranging from 546 to 734). A question about career goals, administered to only 523 of the 1,285 students, was also considered.

The university assigned its 90 doctoral programs into five broad groups for assessment purposes.[3] To test for significant sex differences in publications within the five program groups, multilevel Poisson regression models were used (appropriate for outcomes consisting of counts). Additionally, *t* tests were used to examine differences in men and women's responses to the 12 survey questions regarding program satisfaction, supports, and obstacles (with adjustments made for multiple comparisons). Poisson regression models were then used to examine whether the 12 survey variables predicted the number of publication submissions. In keeping with *Educational Researcher*'s "Brief" format, details of survey and analysis methods are included in the online Appendix (available on the journal website), including mean differences of potential explanatory variables by sex and program group (Tables A2–A4), Poisson regression results (Tables A5–A7), and correlations among the survey variables (Tables A8–A9).

Results

Publication Rates by Sex

As shown in Table 1, men submitted an average of 5.9 manuscripts for publication (3.7 as first or solo author), in contrast with women's report of 3.7 publications submitted (2.2 as first or solo author). The number of submissions that were published or accepted also differed significantly, with an average of 4.9 for men and 2.9 for women.

Differences were larger in some fields than others. In the engineering and physical sciences, men submitted an average of 7.2 publications, compared with 5.5 among women (d = 0.40), and in the natural and biological sciences, men submitted an average of 5.3 publications in comparison with 3.8 among women (d = 0.49). Differences in humanities/arts and applied health/social sciences were also significant and followed a similar but less marked pattern favoring men. (See Figure 1 for distributions by sex and program group.)

However, there were no significant sex differences in publications in the education and professional programs. These results are encouraging in comparison with earlier *Educational Researcher* articles that reported a severe underrepresentation of female authors of education research (Lipman-Blumen, Stivers, Tickamyer, & Brainard, 1975; Lockheed & Stein, 1980). This shift may reflect changes in the composition and publishing expectations of education researchers over the past several decades.

Additional Survey Data by Sex

Several other variables from the doctoral survey could shed light on reasons for these patterns in publication rates. First, overall, men tended to have slightly higher satisfaction with key components of their doctoral experience than did women, including their relationship with their advisor (d = .19) and career preparation (d = .28) (Table A2, available on the journal website). These differences were slightly larger in at least some STEM fields and were significant predictors of publication submissions in the regression analysis (Table A5, Model 3, available on the journal website). Men were also slightly more satisfied than women with program collegiality (d = .14), but this difference was only significant within education and professional programs, and collegiality was not a significant predictor of publication submissions in the regression models (and was thus removed).

An examination of assistantships by sex (Table A2, available on the journal website) revealed that overall, men (85%) were slightly more likely than women (80%) to report being a research assistant (RA) at some point in their program. However, this difference was inconsistent across program groups and not significant within any of the five groups after Bonferroni correction. Similarly, women (82%) were more likely than men (76%) to serve as a teaching assistant (TA) and report that teaching responsibilities were an obstacle to program progress (d = .26), but sex differences within program groups were not significant. The regression analysis revealed that RAships were a strong positive predictor of publication submissions (with RAs submitting 70% more manuscripts than non-RAs), while TAs and those who reported that teaching responsibilities were an obstacle to program progress submitted about 10% fewer publications than did other students.

Supplemental questions asked a subsample of students about faculty support for their research and chosen career paths (Table A3, available on the journal website). Overall, men were more likely than women to report that faculty encouraged their publication of scholarly work (d = .37), but women were as likely as men to report that their advisor supported them in their chosen career path. Additionally, women were more likely than men to report that family obligations (d = .16), work/financial commitments (d = .32), and faculty availability (d = .26) hindered their progress, although these patterns were not consistent across program groups or significant within any group after Bonferroni correction. Women were also more likely than men to say that a biased program climate was an obstacle for them (d = .47), although this was less of an obstacle for women than other

Table 1
Doctoral Student Publications by Sex and Program Group

Program Group		Total Publications Submitted		Publications Submitted as First Author		Publications Accepted or Published	
		Men	Women	Men	Women	Men	Women
Social sciences and applied health[a]	Mean	4.45	3.68	2.72	1.90	3.45	2.95
	SE	0.44	0.28	0.29	0.17	0.39	0.24
	n	109	99	109	99	109	99
	Effect size (*d*)	0.20**		0.33***		0.15	
Natural and biological sciences[a]	Mean	5.32	3.78	3.23	2.47	4.29	3.01
	SE	0.30	0.34	0.21	0.30	0.30	0.28
	n	106	87	106	87	106	87
	Effect size (*d*)	0.49***		0.31**		0.45***	
Engineering and physical sciences[a]	Mean	7.21	5.47	4.51	3.27	6.16	4.46
	SE	0.21	0.36	0.16	0.24	0.19	0.33
	n	469	112	469	112	469	112
	Effect size (*d*)	0.40***		0.37***		0.42***	
Education and professional programs[a]	Mean	2.83	3.03	1.70	1.67	2.03	2.30
	SE	0.46	0.33	0.35	0.23	0.38	0.27
	n	66	100	66	100	66	100
	Effect size (*d*)	–0.06		0.01		–0.09	
Humanities and creative arts[a]	Mean	2.98	1.72	2.37	1.53	2.27	1.36
	SE	0.55	0.25	0.53	0.23	0.40	0.23
	n	62	75	62	75	62	75
	Effect size (*d*)	0.38***		0.26***		0.35***	
Total[b]	Mean	5.92	3.67	3.71	2.22	4.92	2.93
	SE	0.16	0.16	0.12	0.11	0.15	0.13
	n	812	473	812	473	812	473
	Effect size (*d*)	0.54***		0.48***		0.53***	

[a]Significance levels by program group refer to post hoc chi-square tests on the coefficients of Poisson regressions containing Sex × Program interactions (but no additional explanatory variables). These Poisson regression results are found in Tables A5 (Model 2 only) and A6 ($df = 1$; H_0: Male + Male × ProgramGroup = 0) available on the journal website. *p* values were corrected using a Benjamini-Hochberg correction for multiple comparisons (15 comparisons).
[b]Overall significance levels refer to *t*-test results comparing male and female means.
$^{**}p < .01$. $^{***}p < .001$.

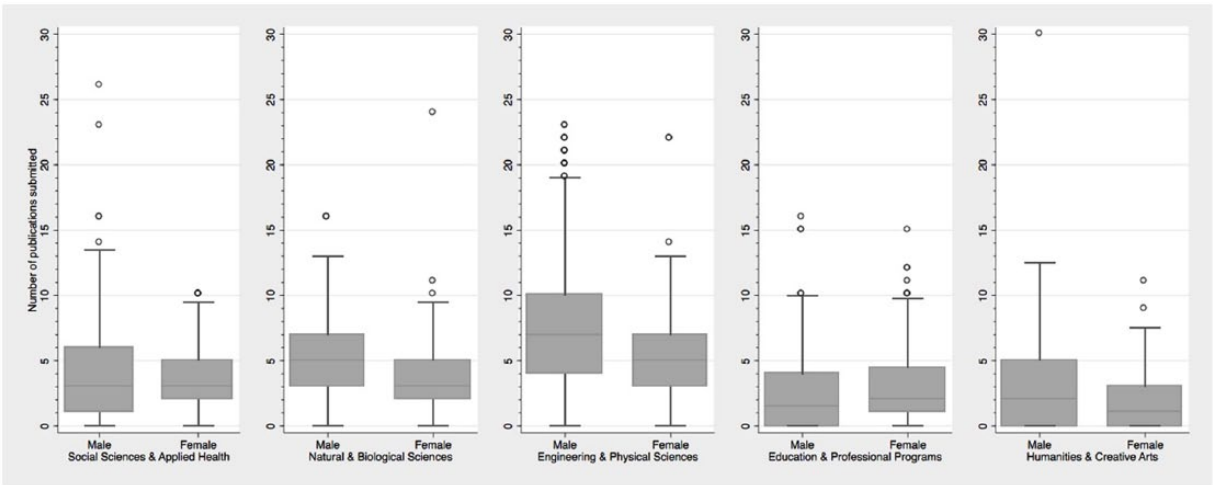

FIGURE 1. *Distribution of total publications submitted by sex and program group*

factors, with only 6% of women (vs. 2% of men) saying this was a "major obstacle." In comparison, 14% of women cited family obligations (8% of men), 20% cited work/financial commitments (10% of men), 15% cited teaching responsibilities (8% of men), and 11% (6% of men) cited faculty availability as major obstacles to program progress. In the regression analyses conducted with the subsample who answered all of these survey questions (n = 495), faculty encouragement of publication was a significant positive predictor of submissions for publication, while family obligations and lack of faculty availability was a negative predictor (Table A7, available on the journal website). Student reports of work/financial obligations or program climate hindering their progress did not significantly relate to their publication submissions.

Still, overall, the main regression analysis, which included program satisfaction and RA/TA variables for the full analytic sample (n = 1,285), left the majority of the sex difference in publication submissions unexplained (as described further in Table A5, Note 3, available on the journal website). The same was true with the supplementary regression analysis containing additional data on program supports and obstacles collected from a subsample of the analytic sample (n = 495; see Table A7, available on the journal website).

Survey data on students' "primary career goal" were also collected from a subsample of students (Table A4, available on the journal website). Significantly more men than women hoped to obtain a research-intensive faculty position (34% vs. 25%) or a private sector position (27% vs. 12%). Hence, perhaps men in this study pursued more publication opportunities because they prioritized jobs that require a strong research record. On the other hand, given that career goals were reported after doctoral program completion, men's stronger publication records might have contributed to sex differences in reported career goals.

Discussion

The men in this study submitted and published substantially more scholarly works than their female peers. It is noteworthy that this pattern occurred in both the heavily male-dominated engineering and physical sciences group as well as other program groups not dominated by men, including the natural and biological sciences, humanities and creative arts, and social sciences and applied health. A dozen additional survey items were used to explore why these patterns may have occurred, including whether men felt more supported in their programs than women.

Men rated their relationship with advisor, career preparation, and faculty support for research higher than did their female peers, and satisfaction on these items predicted publication submissions in the regression models. The sex differences in these variables align with previous studies suggesting that male doctoral students may receive more research mentoring from their advisors in science (Fox, 2001; Nolan, Buckner, Marzabdi, & Kuck, 2008) and other fields (Seagram, Gould, & Pyke, 1998). Although sex differences in assistantships were not consistent across programs, research assistantships were a strong predictor of publication submissions.

Few students in this study reported that a biased program climate was a major obstacle to their progress, but more women than men—particularly in engineering and social sciences/applied health—reported that a biased climate was at least a minor obstacle. This seems to fit with disparities in faculty encouragement noted previously as well as recent news and blog reports suggesting that women may be more likely than men to be relegated to managerial tasks in the lab and viewed in sexual instead of professional terms (Greenberg, 2015; Jarreau, 2016). However, student reports of a hindering program climate did not relate to publication submissions in the supplementary regression analysis, yet the subsample available for that particular analysis was relatively small, and so this null finding should be interpreted with caution. Further research is needed to explore if and how the climate in STEM graduate programs contributes to publication disparities between women and men.

Ceci and Williams (2011) note that child care issues affect women more than men. In this study, family responsibilities were reported to be more of a hindrance for women than men. Still, this difference was not large or consistent across program groups.

Overall, both the full sample and subsample regression analyses that included all potential explanatory survey variables available in this study left the majority of the sex disparities in publication submissions within each program group unexplained. It could be that more sensitive variables are needed to detect the most relevant forms of doctoral program bias against women, and perhaps more focused examinations of specific programs would yield more clear results in terms of explaining publication disparities. However, it could also be that factors that go beyond faculty bias and traditional program supports should be considered, particularly given that publication disparities were substantial even in fields with gender parity.

For example, it is possible that even when women and men have similar opportunities to engage with research, male doctoral students may be more assertive when negotiating authorship. Additionally, as Martin (2015) argues, men may be more confident in their abilities and therefore more willing to submit their work for evaluation. This hypothesis is consistent with earlier findings by Sonnert and Holton (1995) suggesting that women who are STEM researchers may be more thorough and cautious in publishing their work than men. In fact, Sonnert and Holton wondered if this more cautious approach should be preferred over the push for larger numbers of publications. Still, if this were a driving force in these results, we might expect to see sex differences in first-authored submissions to be particularly large and for the gap in submissions to be larger than the gap in accepted work. However, that is not the case, according to the data in Table 1.

Scholars have also found gender differences in career preferences and values (Ceci & Williams, 2011; Eccles & Wang, 2016). Although career preferences might seem unlikely to explain the patterns noted here (given that sex disparities in publishing persisted within fields and not just between them), men might more aggressively pursue publication during graduate school because they more often prioritize high occupational status and pay in comparison with women's preference for working

with and helping others (Eccles & Wang, 2016). It is striking that in this study, although women reported less faculty support for publication, they reported similar satisfaction as men with support for their chosen career path. Moreover, the men were more likely than women to report that a research-intensive faculty position was their primary career goal. Hence, the women in this study may have viewed publications as less essential for their future careers than the men.

Regardless of the cause, concerns remain about long-term disadvantages women face if they publish less than their male peers. Given that some potential factors explored here differed by sex in some disciplines but not others and the various factors together left much of the sex gap in publications unexplained in the regression analyses, more focused studies within disciplines and across institutions are needed to further understand the mechanisms at work.

Limitations

One limitation of this study involves the relatively small sample sizes within some program groups as well as for the supplemental questions asked. Small sample sizes can lead to erroneous null findings (e.g., within the humanities and creative arts). To lessen this concern, marginally significant findings—namely, those that became insignificant after Bonferroni correction—are noted (Tables A2–A3, available on the journal website). Additionally, the percentages of men and women and the gendered publication patterns were similar in the various samples used in this study, lessening concerns about selection bias within the various subsamples (details in Footnote A2, available on the journal website).

Another limitation is that analyses of program groups might mask important differences between programs within the same program group, including differences in gender parity, publication norms, time to degree, and other factors that could influence publication submissions.[4] Further studies of gendered patterns within specific programs would complement the broader patterns reported here.

Perhaps the most important limitation of this study is its reliance on data from a single university. Although some might wonder if this university's programs are simply highly biased against women, this seems unlikely as the survey data showed small or no sex differences in many areas of program satisfaction, including program collegiality and support for their chosen career path. Additionally, across the university's STEM departments, there are several thriving graduate organizations (e.g., GradSWE—a graduate student affiliate of Society for Women in Engineering) and supports (fellowships, conferences, retreats) targeting women in STEM. Although further research is needed to determine whether results are consistent at other research universities, it seems unlikely that the publication patterns favoring men in departments and colleges across this university are unique to this institution.

Implications

These findings from a fairly typical, large R1 university point to a potentially important difference between men and women in doctoral programs—namely, authorship of publications. If the findings in this study hold up at other institutions, this would suggest that from the starting line, women—especially those in the natural/biological and engineering/physical sciences—may be given fewer opportunities to publish during graduate school or perhaps are less well positioned or inclined to pursue such opportunities. Such patterns could lay the groundwork for divergent career trajectories and might help explain why women in the sciences are less likely than men to seek tenure-track positions even after receiving their PhD (Canizares, 2009).

Larger scale studies are needed to determine the generalizability of these findings as well as qualitative studies to further illuminate reasons behind these patterns, assuming they do persist. Such studies could inform the strategic targeting of interventions to ensure women benefit from doctoral study as much as men. These interventions could take various forms, including reducing women's TA responsibilities, increasing the availability of RA positions for women, assisting with family obligations, providing better training for faculty in mentoring of doctoral students (enhancing lab culture, encouraging women to submit their work, and modeling authorship negotiation skills), or increasing opportunities for women to experience scientific research as an inclusive, helpful endeavor worth pursuing.

NOTES

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[1]Given the binary nature of the comparisons in this study, we use the term *sex* instead of *gender* when comparing men and women, but we use *gender* when discussing broader issues.

[2]Additionally, as Larivière, Ni, Gingras, Cronin, and Sugimoto (2013) note, large-scale, bibliometric analyses are prone to some error when relying on authors' names to determine the sex of the author.

[3]Table A1 (available on the journal website) contains enrollments by sex in each program and group. Although the group names may not seem mutually exclusive and the clusters may appear to defy conventions in some ways, these categories were created to reflect the structure of the university (e.g., where physics and computer science reside in the College of Engineering) and allow for the programs considered most similar within the university to be clustered together for review purposes. Given this study's focus on gender, it is helpful that physics, mathematics, engineering, and computer science are grouped together as these tend to be the most male-dominated STEM fields (Schneider, Milesi, Perez-Felkner, Brown, & Gutin, 2015). Hence, this study uses the original groupings created by the university.

[4]For example, the humanities/arts includes both philosophy (which is male dominated) and art history (which is female dominated). Given sample limitations, this study does not delve into differences between such fields or explore other field-specific issues, such as how the association of "brilliance" with many male-dominated fields (Meyer, Cimpian, & Leslie, 2015) might relate to field publication norms and the type of student attracted to such fields. Such work could be fruitful in future studies of sex differences in publication and career paths.

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