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Unpacking the monolith

Intersecting gender and citizenship status in STEM graduate education

Michael A. Miner
Department of Sociology, University of Wisconsin–Milwaukee, Milwaukee, Wisconsin, USA

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Abstract

Purpose – The term STEM often remains an undifferentiated category, especially at the graduate level. Conceptualizing STEM as a monolithic category, rather than as a combination of distinct fields, prevents researchers from understanding and documenting the full range of persistent inequality within scientific disciplines at the graduate level and throughout the lifespan. The purpose of this paper is to address two oversights prior to degree completion within the context of the USA by asking two specific questions: To what extent is gender associated with choice of discipline within STEM graduate education? In the USA, do gender differences in STEM fields depend on citizenship status?

Design/methodology/approach – Using data from the 2015 International STEM Graduate Student in the US Survey, this study employs multinomial logistic regression analyses and presents predicted probabilities to assess differences of enrollment in STEM fields by gender and citizenship status.

Findings – Results show that domestic women were less likely to enroll in computer sciences and engineering when compared to domestic men. However, in contrast to domestic students, there were no gender differences among international students' enrollment in engineering.

Research limitations/implications – This paper shows the importance and complexity of how gender intersects with citizenship status in enrollment patterns in STEM graduate fields. The survey included the top 10 universities in the USA based on the total enrollment of international students, and it is unclear if there exists differences in these selected students and schools when compared to students at colleges and universities that enroll less international graduate students.

Originality/value – The author makes the case to disaggregate STEM to better assess how specific fields can be modified to attract graduate students worldwide. This paper accentuates the significance of gender and citizenship status for understanding differences in choice of discipline among graduate students in STEM.

Keywords Gender, Higher education, STEM, Graduate education, Citizenship status

Paper type Research paper

Of the total number of awarded doctorates in 2016, the majority went to men. But, when examined by field categories within STEM – science, technology, engineering and mathematics – women appear to have earned more doctorates in the life sciences relative to men. In recent years, there has been a significant growth in international students' enrollment in American colleges and universities, generally outpacing the overall US domestic enrollment (Anelli *et al.*, 2017; Pew Research Center, 2017)[1]. At the graduate level, current surveys in the USA indicate a substantial growth in the total number of doctorates awarded to international students in science and engineering (NSF, 2015). Moreover, a majority of doctorates in fields of STEM, it is estimated, will be awarded to international students by 2020 (Han and Appelbaum, 2016).

In this growing field of research, however, the term STEM often remains an undifferentiated category, especially at the graduate level. The generalized collection of all science and technology fields under a single umbrella term precludes an understanding of student inclination for specific fields. It also hampers the examination of the educational orientation of graduate students. In other words, conceptualizing STEM as a monolithic category, rather than as a combination of distinct fields, prevents researchers from understanding and documenting the full range of persistent inequality within scientific disciplines at the graduate level and throughout the lifespan.

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Several studies document the importance of gender on the demand-side in entering the paid workforce (Quadlin, 2018), being in the paid workforce (Britton, 2017; Gascoigne *et al.*, 2015; Martin, 2004) and the persistence of segregated occupations. However, the association of gender and citizenship status with choice of a STEM field and the crucial stage prior to the job market – graduate school – remains less studied. That is, like others (Correll, 2001), the author argues that there has been less emphasis on the supply-side. To be sure, other research has focused on why women leave STEM careers (Blickenstaff, 2005; Xu, 2008) and even perhaps why women are systemically filtered out of STEM career paths (Correll, 2001, 2004). In general, there has been less empirical focus on the educational orientation of graduate students among the distinct fields within STEM, but their initial choice of a field relative to another may be shaped by their gendered experiences (Cheryan, Ziegler, Montoya and Jiang, 2016) as well as by their citizenship status. Indeed, there has not been sufficient attention to these multiple identities, which may be associated with graduate students' initial choice of a field within STEM.

This paper addresses these oversights within the context of the USA. Gender does not exist in isolation and the ways in which it intersects with other identities, such as citizenship status, may shed additional light on the complexity of enrollment within specific STEM fields at the graduate level. Although the USA tends to dominate research and development,[2] the industry is less likely to keep its competitive edge without technological breakthroughs deriving from the robustness of a sector deeply dependent on the persistent recruitment of international students. International students have become increasingly important to the US economy (Altbach, 2004), especially following the Great Recession (Pew Research Center, 2017). Within the USA, there is an increasingly high proportion of foreign-born engineers and scientists. In fact, it has been noted that immigrant entrepreneurs founded nearly double the total number of new start-ups compared to US-born adults in 2014 (Han and Appelbaum, 2016). If current educational and economic trends continue, it will become increasingly important to disaggregate STEM into its separate fields – science, technology, engineering and mathematics – in effort to better assess how the specific fields within STEM can be reworked to attract students worldwide. Similar to previous research on STEM (Cheryan *et al.*, 2016), this paper emphasizes the importance of moving beyond conceptualizing STEM as a monolithic category, and separating it into its field components. Doing so has theoretical and practical implications for not only researchers focused on gender inequality and global migration trends but also for those focused on international and domestic educational experiences.

This study asks two questions regarding graduate-level education:

RQ1. To what extent is gender associated with choice of discipline within STEM?

RQ2. In the USA, do gender differences in STEM fields depend on citizenship status?

To underscore the importance of these questions, the author draws from several literatures, including: gender and occupations, high-skilled labor migration and STEM education. Framed within an intersectional lens, a multinomial logistic model assesses differences in enrollment among graduate students in STEM fields. Findings show differences in choice of field associated with gender and citizenship status. Taken together, the findings add an important dimension to understanding STEM education and gender inequality and may prove useful not only to scholars but also to colleges and universities actively engaged in efforts to recruit talented students at the graduate level worldwide.

Gender inequality within STEM in the USA and intersectionality

In the USA, there has been increasing rates of women attending college, attaining degrees and doing so at rates that far outpace men (Goldin *et al.*, 2006). Reports have indicated both a growth of women receiving graduate degrees and employment in STEM occupations. Nevertheless, these trends are uneven once STEM is disaggregated into its respective components. Women tend to be less represented in engineering and computer science occupations (Corbett and Hill, 2015). The existing literature suggests that many of the factors associated with student's "choice" of major begin well before college (Riegle-Crumb and King, 2010). In fact, research shows that enrollment in mathematics and science during high school and primary years influence self-assessment and career path choices and seemingly act as a filter to careers in STEM (Correll, 2001, 2004).

But, trajectories and exposure alone do not address the representation of women across all STEM fields. Often noted as a "chilly climate," the culture of STEM tends to be a discouraging place for women granted access to traditionally "masculine" fields. They are often devalued and face power inequities in and outside of the classroom (Hall and Sandler, 1982). However, recent evidence suggests that fields within STEM may embody their own culture which may differ regarding gender and gendered experiences. That is, some fields within STEM have achieved greater parity while others have persistently shown gender gaps in enrollment. Leslie *et al.* posit that this is due to the field-specific ability beliefs hypothesis. In other words, the culture of fields within STEM differs in the extent to which they are "chilly."

These academic and scientific cultures, however, are located within the larger structure of gender and gender inequality in the USA. As others have indicated:

> […] even if the culture of a STEM field is not overtly hostile to women, women will be less likely to enter, persist, and be successful in a field when there is a mismatch between the way that they wish to be seen and are expected to behave (e.g. modest) and the norms of that culture (e.g. acting confident). Moreover, even in the absence of deterrents to women, a culture could still cause gender disparities by disproportionally attracting men. (Cheryan *et al.*, 2016 p. 2)

Given these previous findings, along with the those in the undergraduate literature on gender inequality in STEM (Su and Rounds, 2015) and gender inequality in the STEM workforce (Blickenstaff, 2005; Britton, 2017; Gascoigne *et al.*, 2015; Landivar, 2013; Martin, 2004; Quadlin, 2018; Xu, 2008) the expectation is that there will also be gender differences that emerge in the specific fields of STEM at the graduate level.

Less is known however, about the extent to which other identities may moderate these gender differences prior to degree completion. Scholars have suggested that gendered experiences in STEM vary by culture, region and ethnicity (Charleston *et al.*, 2014; O'Brien *et al.*, 2015), but it is unclear how this intersection of identities may influence initial enrollment in STEM fields at the graduate level. The intersectionality concept, for example, implies that women's experiences and choices of enrollment in STEM fields may be differentially shaped by other identities, such as citizenship status[3]. Indeed, theorists have argued that this approach gives voice to the multiply-marginalized (Cho *et al.*, 2013; Choo and Ferree, 2010). Because recent evidence shows that gender gaps in mathematics are not present in all nations (Else-Quest *et al.*, 2010), it is likely that gender differences in enrollment in STEM fields may be influenced by citizenship status. From the author's reading of the literature, this association has not been empirically tested at the graduate level and in general, there has been less emphasis on the intersection of gender and citizenship status, not to mention the extent to which they are associated with enrollment in STEM fields (e.g. Collins, 1986).

Importance of international students in the USA: high-skilled labor, human capital and the market

While several studies document the importance of high-skilled immigrants for the US economy and the general global migration patterns and trends of talented workers (e.g. Kerr, 2013; Kerr *et al.*, 2017), the association of citizenship status with choice of a STEM field and the crucial stage prior to the job market – graduate school – remains understudied. Micro-level approaches to migration such as the one offered by Lee (1966, p. 50) describe individual decisions to migrate as "push" and "pull" factors that tend to "hold and attract or repel people" from or into select nations. More rational approaches such as the human capital model suggest that workers with greater investments in education, training and skill will have greater value to potential employers (Mincer, 1974; Becker, 1964). Primarily driven by the tech boom of the 1990s however, the USA significantly increased the quotas for high-skilled workers through an expanded H-1B non-immigrant visa program, reducing barriers to residency, and letting STEM occupations account for more than half of H-1B petitions (Aneesh, 2006; Peri *et al.*, 2015). The booming IT industry of the 1990s not only brought an increasing number of foreign workers to the US labor market to overcome labor shortage in the sector through the H-1B and H-2B visa programs for high-skilled workers, but it also attracted international students and research scholars through the F and J visa programs, respectively (Lowell, 2001; Ransom and Winters, 2016). Indeed, the immigration of high-skilled labor to rich countries has been characterized as "brain drain" from developing countries (Gaillard and Gaillard, 1997) and recent patterns indicate that the USA remains the most attractive destination for international students worldwide (Docquier and Machodo, 2015).

More than 15 years after the tech boom and bust of the 1990s, the importance of high-skilled workers and students has not subsided. In fact, it has moved beyond technology to include, science, engineering and mathematics. STEM, both as an acronym and a set of disciplines, in the USA has gained significant attention in recent years. According to the US Bureau of Labor Statistics, there were approximately 8.6m STEM jobs in 2015, in which careers in computer sciences and engineering comprised nearly 64 percent of the total. The highest projected new jobs and openings continue to be in computer sciences and engineering. According to government estimates, the projected workforce will need approximately one million additional STEM graduates by 2022. Notably, the Obama administration took significant actions to accelerate progress from primary through secondary education, focusing on "STEM for All" and even incorporating it into competitions in programs such as Race to the Top and the White House Science Fair.

Arguably, much of these efforts were in response to the tremendous shortage of STEM educated American students. Recent predictions of the demand for employees and the total number of students pursuing STEM indicate a significant mismatch (Graham *et al.*, 2013). In other words, there is indeed an increasing market demand for STEM educated students within the USA, but the total number of domestic students is not keeping pace (Gonzalez and Kuenzi, 2012). As such, the US market demand warrants an influx of talented international students to select fields within STEM, while it remains less clear how this entry impacts gender differences in specific STEM fields, the expectation is that international students will be more likely to meet the market demand of the new country (e.g. the USA) and given the discussion above, will be more likely to enroll in computer sciences and engineering relative to other fields within STEM.

Previous STEM literature and motivation for the study

Contrary to the notion that international students crowd-out domestic students, recent findings suggest that higher levels of international graduate student enrollment increases domestic enrollment (Shih, 2017). Moreover, other scholarship has indicated that international students' mobility is often motivated by the host country's quality of education, flow of the total number of international students (Biene *et al.*, 2014) and employment opportunities (Pyvis and Chapman, 2007). Some of the current literature on STEM students focusing on the experiences of international students has noted them as members of a vulnerable population (Sherry *et al.*, 2010). For instance, Zhou (2014) explores the motivations of Chinese doctoral students in STEM fields and finds that students' who are dissatisfied with their decision to study abroad often point to their unmatched expectations and limited support from their advisors. Other findings suggest that international students experience an array of difficulties in host institutions. Lee (2010) discusses the challenges of cultural and linguistic differences and finds that international students tend to have greater difficulty in adjusting to new social environments. In these new milieus, research indicates the importance of a strong sense of belonging (Wilson *et al.*, 2015), but other findings show that international students often feel isolated from peers and faculty within STEM fields (Le and Gardner, 2010) – they have even indicated encounters with discrimination (Lee and Rice, 2007). Rientes *et al.* (2012) note that non-western students show more difficulty in social integration when compared to other students. While these studies together offer compelling evidence of why researchers should incorporate international students' experiences in STEM into empirical analyses, they are limited in answering whether these experiences differ by gender and whether they vary by fields within the monolithic category because they are unable to disaggregate the academic fields to indicate if experiences in select fields are similar or different.

In summary, two key questions remain unanswered in the context of STEM graduate education:

RQ1. To what extent is gender associated with choice of discipline within STEM?

RQ2. In the USA, do gender differences in STEM fields depend on citizenship status?

The current literature documents gender inequality within STEM at the undergraduate level and in the workforce. Alongside this literature, there is evidence of global migration patterns of high-skilled workers, but together these literatures overlook a crucial stage prior to the job market – STEM graduate education. Moreover, the existing evidence is also limited in answering the extent to which these patterns may differ by STEM field. Assessing these questions add to both the gender and migration literature in STEM education within the US context.

Method

Data

This study uses survey data from the International STEM Graduate Student in the US Survey conducted in 2015. Nearly 15,990 master's and PhD students who were enrolled in STEM disciplines were contacted via e-mail to participate in a Qualtrics survey funded by the National Science Foundation. The survey specifically asked students about their reasons for studying in the USA, their perceptions of the education system, their post-graduation aspirations and if they plan to reside in the USA following completion. "Within each institution, only departments that provided a STEM graduate degree as identified by the US Immigration and Customs Enforcement were included in [the] survey" (Han and Appelbaum, 2016). Across the total sample of universities and colleges, 114 departments met this selection criteria, 57 of them had their graduate student contact publicly available and a total of 21 departments granted access to their graduate students' contact information[4].

The total sample for these data include 2,322 graduate students. These students were selected from the top 10 US universities, as ranked by the total number of enrolled international graduate students[5]. Previously, these data have been used by other scholars to assess students' post-graduation plans (Han and Appelbaum, 2016). Because these data separate STEM by specific graduate discipline enrollment, they are especially valuable to assess the core research questions. In recent years, web-based surveys have expanded exponentially, and much of the concern with response rates rests on the notion of probability sampling relative to non-probability (Krosnick, 1999). Since this survey purposively selected universities and colleges with high proportions of international students within STEM fields, the findings presented in this study are not be generalizable to other graduate students in various institutional settings across other disciplines or those in other regional contexts. Nonetheless, these data are particularly well suited for the research question that guides this study for several reasons. Unlike other articles and reports that show completion rates of only doctoral students by gender or citizenship status and general type of discipline, these data afford the opportunity to assess current graduate students by enrollment in specific academic fields within multiple universities and colleges at both the master's and PhD level.

This paper uses measures from both domestic ($n = 1,535$) and international ($n = 787$) graduate students representing 74 different nationalities. China (29.9 percent) and India (25.7 percent) account for most of the international student population. In effort to rule out the possibility that these two countries were the main influences accounting for the associations described below, the author conducted additional analyses with and without students from China and India. Conclusions were similar to those reported below. Therefore, all countries were included in the final analyses.

The survey responses provide specific information on graduate students' citizenship status, gender, age, parental education and degree in pursuit. Since the focus of this paper is on the extent to which gender is associated with choice of discipline and the extent to which gender differences in STEM fields depend on citizenship status, another key advantage of this data set is that it disaggregates STEM into its respective fields – "physical sciences," "life sciences," "engineering," "mathematics" and "computer sciences."

Dependent variable

In the survey, students indicated their academic field by responding to the question, "Please select the field in which you are currently pursuing your degree." The survey included six categories to self-select from: life sciences, physical sciences, engineering, mathematics, computer sciences and other. The sixth option, "other," included few students, but with various write-in fields such as, biostatistics, quantitative psychology and agronomy. Accordingly, since many of these fields do not typically fall within the traditional STEM categorizations, all participants that chose "other" were removed from subsequent analyses.

Focal independent variables

The focal independent variables for the main research questions are graduate students' gender and citizenship status. Gender was self-reported by the respondents as "male," "female," "other" or "I do not wish to respond." Due to the low responses in the latter two categories, only the binary was kept and coded as 1 for female and 0 for male.[6] To capture citizenship status, the author used the self-reported response to the question, "Please select the option that best describes your status." Respondents that selected, "I am a US citizen or permanent resident" were coded as 0 and respondents that selected, "I am an international student" were coded as 1. According to Table I, there were slightly more males included in the survey in STEM fields relative to females.

Additional independent and control variables

Estimating additional models that consider family educational background, age and level of study allows one to account for other factors that might influence choice of discipline. A total of 6.3 percent of the responses were missing data on either father's educational background, mother's educational background or gender, however. Because bivariate

Characteristics	Overall ($n=1,967$) Percent	Male domestic ($n=648$) Percent	Female domestic ($n=645$) Percent	Male international ($n=423$) Percent	Female international ($n=251$) Percent	χ^2
Gender						
Female	45.56	–	49.88	–	37.24	
Disciplines^{a,b}						*
Life sciences	30.86	27.78	46.98	10.64	31.47	
Physical sciences	23.34	26.08	28.37	16.08	15.54	
Engineering	25.11	25.15	12.56	40.43	31.47	
Mathematics	10.98	13.58	8.84	9.93	11.55	
Computer sciences	9.71	7.41	3.26	22.93	9.96	
Age^{a,b}						*
18–25	1.32	3.09	0.78	0.24	–	
26–30	0.46	0.93	0.31	–	0.40	
31–35	48.14	46.45	45.89	52.48	51.00	
36–40	40.82	39.35	44.50	38.06	39.84	
41–45	9.26	10.19	8.53	9.22	8.76	
Parent's education						
Mother, college educated^{a,b}	66.60	67.90	71.94	59.34	61.75	*
Father, college educated	71.73	74.69	69.77	71.63	69.32	
Degree^{b}						*
PhD level	75.95	79.63	81.24	68.32	65.74	

Notes: $n=1,967$. Referent for female is male; referent for mother's/father's education is no college degree; referent for PhD level is master's level. May not sum to 100 percent due to rounding. $*p<0.05$; ^{a}gender differences ($p<0.05$); ^{b}citizenship status differences ($p<0.05$)
Source: International STEM Graduate Student in the US Survey 2015

Table I. Descriptive statistics of selected demographic characteristics of graduate students in STEM fields

relations remained substantively unchanged with and without these cases, all missing cases were removed from analyses. Only cases with complete information were included providing a final sample size of 1,967.

Table I provides the summary statistics of all variables with complete responses to survey questions ($n=1,967$). Age, father's educational background and mother's educational background were measured categorically. Age ranged from less than 18 to more than 45 years old, the modal category for age range of the sample was 31–35 years old. In the original scale, parental education ranged from 1 = less than high school to 6 = PhD. Both variables for father's education and mother's education were collapsed into either, (1) college educated or (0) no college education. According to Table I, 66.6 percent of the overall sample indicated having a mother with a college education and nearly 72 percent reported having a father with a college education. Lastly, a control variable for degree was also included. This was a dichotomous variable for student's either pursing (0) master's-level education or (1) doctoral-level education.

Analysis

There are two goals of this paper. The first is to examine the relationship between gender and choice of field within STEM. The second is to assess how this relationship may depend on citizenship status. Since field choice is measured nominally, the author uses a multinomial logistic regression (Long and Freese, 1997). To interpret the regression results and to examine group differences, the author uses predicted probabilities and delta standard errors (Long, 2009). Because the bivariate relationships between the focal independent variables and the outcomes remain substantively unchanged throughout the previous models, only the final model is presented. Stepwise results are available from the author upon request.

Results

Table I provides the descriptive statistics for all variables included in the analyses ($n = 1,967$). According to Table I, the largest portion of the final overall sample were enrolled in life sciences (30.86 percent), followed by engineering (25.11 percent), physical sciences (23.34 percent), mathematics (10.98 percent) and computer sciences (9.71 percent), respectively. Additionally, Table I shows the largest percentage of female US citizens and permanent residents, or domestic graduate students, enrolled in STEM fields were in life sciences (46.98 percent) and physical sciences (28.37 percent), whereas the largest portion of female international graduate students enrolled in STEM fields were in life sciences (31.47 percent) and engineering (31.47 percent). Moreover, the rate of female international students to female domestic students enrolling in engineering is nearly 2.5 to 1. Whereas mathematics appears most similar for each group across categories with the smallest amounts of variation, some notable differences in Table I show the highest and lowest concentrations of field enrollments. Unambiguously, the highest concentration of enrollment in computer sciences across gender and citizenship status is among male international students. Specifically, the rate of male international students being in computer sciences (22.93 percent) is more than three times higher than the enrollment of male domestic students (7.41 percent) and nearly seven times greater than female domestic students (3.26 percent).

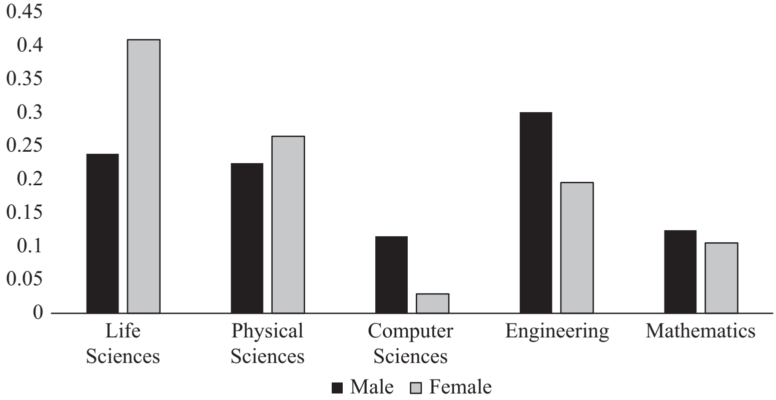
The multinomial results in Table II show significant gender differences in field choice. Overall, the effect of gender (LR $\chi^2 = 27.690$, df $= 4$, $p < 0.001$) and citizenship status citizenship status (LR $\chi^2 = 155.603$, df $= 4$, $p < 0.001$) on choice of STEM field are significant. To present a more intuitive illustration of these results, the author generated predicted probabilities of choosing a field in STEM. The first analysis (Figure 1) shows the

Table II. Model 1: odds ratios from multinomial logistic regression on graduate students in STEM fields on gender, student status, family background and controls

	Life sciences vs physical sciences	Life sciences vs engineering	Life sciences vs mathematics	Life sciences vs computer sciences
Female	0.69 (0.17)	0.38*** (0.10)	0.49* (0.17)	0.15*** (0.06)
International	1.19 (0.18)	3.63*** (0.53)	1.92*** (0.35)	7.19*** (1.43)
Mother's education	1.27 (0.28)	1.12 (0.24)	1.40 (0.38)	1.72 (0.49)
Father's education	1.02 (0.24)	1.51 (0.35)	1.16 (0.34)	1.07 (0.32)
Female X mother's education	0.79 (0.25)	0.70 (0.24)	0.72 (0.30)	0.97 (0.54)
Female X father's education	0.91 (0.29)	0.85 (0.30)	0.99 (0.43)	1.28 (0.72)
Age				
26–30	1.66 (1.92)	1.73 (1.81)	0.00 (0.00)	0.00 (0.00)
31–35	2.70 (1.90)	1.62 (1.07)	0.88 (0.57)	0.18** (0.10)
36–40	1.58 (1.11)	0.99 (0.65)	0.51 (0.34)	0.13*** (0.08)
41–45	1.03 (0.75)	0.70 (0.48)	0.26 (0.18)	0.24* (0.15)
Degree PhD level	1.76** (0.35)	0.26*** (0.04)	1.11 (0.26)	0.14*** (0.03)
Constant	0.28 (0.20)	1.51 (1.00)	0.52 (0.35)	4.32* (2.54)

Notes: $n = 1,967$. Standard errors in parentheses. Referent for student citizenship status is domestic students (US citizens and permanent residents); referent for female is male; referent for father's/mother's education is no college degree; referent for age is 18–25; referent for degree is master's level. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Source: International STEM Graduate Student in the US Survey 2015



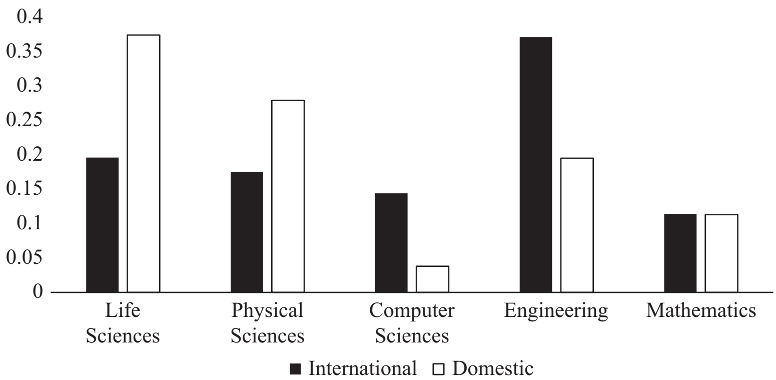
Notes: $n = 1,967$. Probabilities are based on the regression model in Table II with control variables held at their mean
Source: International STEM Graduate Student in the US Survey 2015

Figure 1. Adjusted predicted probabilities of STEM field by gender

predicted probabilities of field choice by gender. These predictions reflect the multinomial results when the additional independent and control variables are held at their mean values.

Compared to the unadjusted differences presented in Table I, the results shown in Figure 1 are slightly smaller after including the control variables in the model. Nonetheless, Figure 1 essentially shows the same relationship. That is, female graduate students are generally overrepresented in life sciences and physical sciences. Figure 1 also indicates that female graduate students are underrepresented in computer sciences and engineering. For example, the average female graduate student's predicted probability of being in life sciences is 0.408 compared to 0.238 for a male student. Additionally, the average female graduate student's predicted probability of being in engineering is 0.195 compared to 0.300 for a male student.

Figure 2 shows that there are significant differences in field choice based on citizenship status. For example, international graduate students are generally overrepresented in computer sciences and engineering relative to domestic students. For engineering specifically,



Notes: $n = 1,967$. Probabilities are based on the regression model in Table II with control variables held at their mean
Source: International STEM Graduate Student in the US Survey 2015

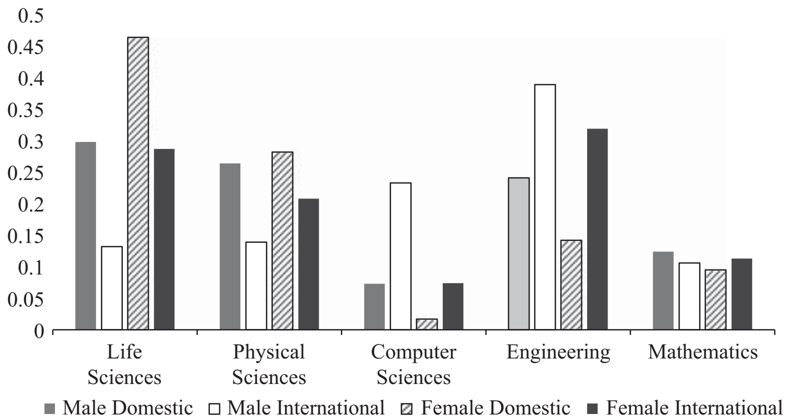
Figure 2. Adjusted predicted probabilities of STEM field by citizenship status

Figure 2 shows that an international graduate student's predicted probability of enrolling in engineering is 0.371 compared to just 0.195 for a domestic graduate student. Moreover, Figure 2 also indicates that domestic students are overrepresented in life sciences and physical sciences. For example, the average domestic graduate student's predicted probability of being in life sciences is 0.374 compared to just 0.196 for an international student.

The second part of this analysis addresses the second research question and assesses whether the gender differences observed in Table I and shown in Figure 1 are dependent on citizenship status. Table III (supplemental table) includes the intersection of gender and citizenship status and is statistically significant. Here, international women are less likely than international men to be enrolled in physical sciences relative to life sciences, holding all other variables constant. For a female international graduate student, compared to a male international graduate student, the odds of enrolling in computer sciences relative to life sciences decrease by about 67 percent ($100\times(1-0.43)$), net of other variables.

Relative to Figures 1 and 2, the results shown in Figure 3 account for the intersection of citizenship status with gender, rather than assessing each in isolation. On the one hand, Figure 3 shows that domestic women are generally overrepresented in the life sciences and underrepresented in the computer sciences. For example, the average domestic female graduate student's predicted probability of enrolling in life sciences is 0.464. On the other hand, Figure 3 indicates that the average domestic male graduate student's predicted probability of enrolling in life sciences is 0.298 and 0.264 for physical sciences. A notable finding is that for a typical domestic female student, the predicted probability of being in physical sciences is 0.282, nearly 0.018 higher than her male colleague. Among international students, Figure 3 shows that the average international male graduate student's predicted probability of enrolling in engineering is 0.389 and 0.233 for computer sciences. For the average international female graduate student however, the predicted probability of enrolling in life sciences is 0.287 and 0.319 for engineering. Additionally, the average international female graduate student's predicted probability of being in mathematics is 0.113 compared to 0.106 for an international male student.

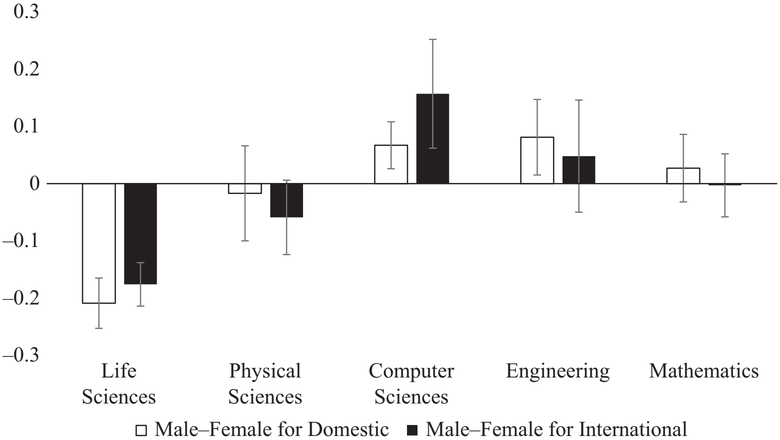
Figure 4 graphs these gender gaps by citizenship status directly while holding all other variables at their mean values. Figure 4 indicates that the 15.5-point difference shown in Figure 3 among international students by gender in life sciences is statistically significant. The same difference holds for domestic students when comparing males and females, which



Notes: $n=1{,}967$. Probabilities are based on the regression model in Table II with control variables held at their mean

Source: International STEM Graduate Student in the US Survey 2015

Figure 3. Adjusted predicted probabilities of STEM field by gender and citizenship status



Notes: $n = 1{,}967$. Probabilities are based on the regression model in Table II with control variables held at their mean. CI 95%; ME 5%. See Table AI
Source: Graduate Students in Science Survey 2015

Figure 4.
Adjusted gender and citizenship status differences of predicted probabilities in STEM fields

translates to women being more likely to enroll in life sciences compared to men for both international and domestic graduate students. Figure 4 also shows that the 5.6- point difference among domestic students by gender in computer sciences is a statistically significant difference. For international students in computer sciences, the 15.9-point difference in gender (male to female) is statistically significant. For both domestic and international students, these data show that men are more likely than women to enroll in computer sciences, net of other variables. Accordingly, Figure 4 also specifies statistically significant differences in engineering by gender, but only shows that the 9.9-point difference among male and female domestic students is statistically significant. In other words, for domestic graduate students, there is a difference in enrolling in engineering by gender, but notably, this pattern does not hold for international students by gender. This finding suggests that, within these data at least, there is no observable gender difference in enrollment in engineering among international students, whereas there is a statistically significant gender difference for domestic students. Specifically, domestic men are more likely to enroll in engineering than domestic women. Meanwhile, Figure 4 shows that there is not a statistically significant difference by gender and citizenship status for and for enrollment in mathematics or physical sciences.

In conclusion, the author finds evidence to answer the two research questions. First, the author shows that enrollment patterns by STEM discipline differ by gender. Specifically, women are overrepresented in life sciences and physical sciences and underrepresented in computer sciences and engineering (Figure 1). Using the additional evidence of enrollment patterns by citizenship status, which show that international students are overrepresented in computer sciences and engineering and underrepresented in life sciences and physical sciences (Figure 2), the findings show that gender differences depend on citizenship status (Figure 3). This is particularly evident in the field of engineering in which the results do not show observable gender enrollment differences among international students, but do show statistically significant gender differences among US-born graduate students.

Discussion

This paper contributes to the literature in important ways. First, the author contributes to the existing literature by focusing on enrollment patterns of STEM students in graduate school prior to degree completion. Existing evidence for graduate students by discipline and by gender and citizenship status is typically only available after degree completion (e.g. Surveys of Earned Doctorates). Second, the author further advances efforts to disaggregate STEM into its respective fields and contributes to this effort at the graduate level. Together, this paper contributes to the gender literature as well as the migration literature within higher education by intersecting student identities to better understand enrollment patterns. Within STEM education, there exists gender disparities in the USA at the undergraduate level, on the job market and in the workforce. Findings from this study suggest that those gender differences may not exist to the same extent for international graduate students studying certain fields within STEM in the USA during graduate school. As discussed above, this may theoretically be due to the gendered expectations young women in the US experience and this may be worse in the USA than in other countries. Taken together then, if a goal is to reach gender parity across all STEM fields in the USA, the country may be better equipped to do so by increasing international student enrollment alongside increasing its levels of encouragement toward young women in the US to enroll in all STEM graduate disciplines.

The primary strength of this paper is its focus on disaggregating STEM by field for enrollment patterns at the graduate level prior to degree completion. The findings extend previous research in higher education and gender inequality. Findings also contribute to future research on international education, and the US economy in several ways. Intersecting citizenship status with gender, however, is particularly revealing. While previous research suggests that women are less likely than men to be enrolled in quantitative majors, these findings suggest a more complicated association (Correll, 2001, 2004). Given these data, US-born women are more likely than US-born men to enroll in life sciences, which is arguably a quantitative field. At the same time, these findings show no evidence of gender differences in theoretically expected fields – mathematics and physical sciences (Blickenstaff, 2005; Correll, 2001, 2004). This result should be interpreted with caution because of this select sample, but it may suggest that the gendered filtering processes primarily occur between graduate school and the job market (e.g. Quadlin, 2018). This should be explored by future qualitative research.

By applying an intersectional approach of citizenship status with gender, these findings likely indicate the salience of gendered actions, norms and beliefs among US-born people. For instance, distinct gender differences are present in the fields of computer sciences and engineering and this is evident in graduation reports and research focused on job segregation. Notably though, these findings do not hold for international students – results suggests no gender differences in engineering. Aligned with previous literature, which shows that mathematics achievement and attitudes differ by nations (Else-Quest *et al.*, 2010), this finding may suggest that stereotype threat and gendered expectations that women experience in the USA are worse than in other countries. In other words, it may be that young women in other countries are being encouraged to major in certain academic fields, while in the USA, young women are often being discouraged to do so. Future research would benefit from assessing this speculation with in-depth interviews with graduate students in specific fields within STEM cross nationally and located within different country contexts.

This study is not without limitations. The survey only included the top 10 universities in the USA based on the total enrollment of international students, and it remains unclear if there exists differences in these select students and schools when compared to students at colleges and universities that enroll less international graduate students. Moreover, this sample of graduate students, both international and domestic reported relatively high levels of having a parent, or both parents with a college degree. Because there was no additional measure in these data regarding family income, it is less clear how a better measure of class dynamics may also intersect with various identities and influence one's choice of field. It is likely that the findings reported here are unique to US culture and the literature would benefit from reproducing these methods in another context. Future research may also consider collecting primary data of graduate students in STEM programs within the US context and abroad. This effort should be both qualitative and quantitative. Lastly, future research may also assess the satisfaction of graduate students and the quality of teaching programs in STEM fields within a multinational context.

Nonetheless, this study offers noteworthy insights. These findings may afford US institutions the ability to maintain a dominant position in research and development if its persistent recruitment of international students focuses on the key academic fields in which these students are more likely to enroll – engineering and computer sciences. Theoretically, there appears to be support for the human capital theory. That is, within the USA the highest proportions of jobs within STEM appear to be within computer sciences and engineering, while at the same time, these two fields are also projected to have the greatest number of new jobs and openings in the near future. In this sense, the differences in choice of academic fields within STEM appear follow the expected pattern of mirroring the market demand, at least among international graduate students.

These findings should also prove useful to educational researchers focused on the experiences of graduate students. As recent findings have indicated (e.g. Lee, 2010; Le and Gardner, 2010; Lee and Rice, 2007; Zhou, 2014), international graduate students' experiences within STEM in US academies are often challenging. In which case, the findings presented in this paper can prove useful to scholars focusing on reform and improvement of STEM, as the results identify which fields are most attractive to international students. It may be the case that international students' negative experiences in STEM primarily occur within select fields.

Notable findings on the intersection of citizenship status with gender should prove useful to gender scholars and other researchers. For instance, because these results show no gender differences in mathematics and physical sciences, it may be most rewarding for future qualitative work to focus on these fields to identify how these women are experiencing these environments. Future researchers could focus on engineering to understand the dynamics and experiences of foreign-born women engineers and assess in what ways their experiences may differ from domestic women. Indeed, how are international women engineers able to "undo gender" in the US context and how can this translate into other academic fields? Unfortunately, findings from this analysis can only point to theoretical assumptions of why this may be the case, however, a more targeted in-depth understanding may prove useful to understanding the complexity of intersecting identities. Overall, the findings presented in this paper shed light on how gender dynamics intersect with citizenship status and should prove useful not only to colleges and universities actively engaged in recruitment efforts but also to social scientific researchers focused on persistent inequality within scientific disciplines and throughout the lifespan.

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Notes

1. After recent elections and appointments within the US government, this trend may change. For instance, there have been some reports that suggest the US "will consider restrictions on foreign STEM students from designated countries to ensure that intellectual property is not transferred to our competitors, while acknowledging the importance of recruiting the most advanced technical workforce to the United States" (The National Security Strategy of the USA, December 2017). Also, see Shachar for a review of the EB–5 program.
2. However, in 2014 China surpassed the USA on the total number of patent applications received (www.tprinternational.com/china-vs-us-patent-trends-giants-stack/).
3. This theory also posits that experiences and decisions may also differ along racial/ethnic, class, religion and sexual orientation identities. However, the focal intersection of this analysis is on citizenship status and gender for few reasons. This intersection tends to be less explored in the literature. Additionally, this intersection seems most timely given the general market demand for STEM educated individuals and the shortage in the USA. Additional intersecting analyses are conducted on a proxy for class status. Unfortunately, measures for other identities were not included in the survey.
4. Unfortunately, student contacts with the remaining 36 departments were not made.
5. These universities include: Columbia University, University of Illinois-Urbana Champaign, Michigan State University, Northeastern University, Purdue University, University of Southern California, Arizona State University, University of California at Los Angeles, New York University and University of Washington at Seattle.
6. Theoretically, one would hope to capture gender on more of a spectrum to attempt to understand how multiple gender identities may be associated with choice of discipline within STEM. One may also want to expand on queer identity. Unfortunately, the response rate for "Other" and "I do not wish to respond," were simply too low to draw meaningful statistical associations with this methodological approach. However, I would encourage, especially qualitative researchers to explore this question in more depth. Moreover, these survey data do not include measures for ethnic or religious differences. This intersection too should be explored by future research similar to the methodological approach taken here.

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Further reading

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Appendix

Table AI. Adjusted group differences in probabilities of STEM Field by gender and citizenship status

	Life sciences	p	Physical sciences	p	Engineering	p	Mathematics	p	Computer sciences	p
Gender and student status										
Domestic M–F	−0.209	< 0.001	−0.017	0.692	0.081	< 0.001	0.027	0.376	0.067	< 0.001
International M–F	−0.176	< 0.001	−0.059	0.076	0.048	0.334	−0.003	0.924	0.157	< 0.001

Notes: $n = 1{,}967$. M, male students; F, female students. Probabilities based on the regression model contained in Table II with control variables held at the means; p is the p-value from tests of difference between probabilities and δ-method standard errors
Source: International STEM Graduate Student in the US Survey 2015

About the author

Michael A. Miner is a PhD Student in Sociology and Distinguished Fellow at University of Wisconsin–Milwaukee. He is Quantitative Researcher who specializes in the sociology of education. His current research focuses on the relationship between school segregation and school accountability; and public trust in education. Among his award winning articles is his research on public perceptions of credentials in primary care medicine; and the experiences of first-generation students in graduate school. Michael A. Miner can be contacted at: minerm@uwm.edu