

When Making the Grade Isn't Enough: The Gendered Nature of Premed Science Course Attrition

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Women take qualifying exams and enter medical school at substantially lower levels than predicted by their interest in medical degrees at the end of high school. We examined how science course experiences contribute to gendered attrition in premed using a multicohort data set of 8,253 undergraduates taking the traditional premed sequence of introductory science courses at a public research university between 2008 and 2016. Gendered attrition was not based in academic performance, was specific to high-performing women, and yet was grounded in competency beliefs. The result is that high-performing women often graduate with lower paying, lower status degrees. Motivational interventions in premed science courses will be critical for retaining high-performing women in premed, an important outcome with implications for equity and women's health.

Keywords: equity; gender; longitudinal studies; medical education; motivation; premed; regression analyses; retention; STEM; structural equation modeling

Most areas of science, technology, engineering, and mathematics (STEM) are dominated by men, significantly contributing to overall gender inequality in pay and positions of influence (Beede et al., 2011; Oh & Lewis, 2011). Medicine, another domain of high pay and status, should be a countervailing force—by the end of high school, girls are much more likely than boys to express interest in medical careers (Sadler, Sonnert, Hazari, & Tai, 2012), have higher high school grades (Duckworth & Seligman, 2006; Perkins, Kleiner, Roey, & Brown, 2004), and are more likely to go to college (Lopez & Gonzalez-Barrera, 2014; Ryan & Bauman, 2016). Other fields where similar asymmetrical interests exist (i.e., teaching, social work) are now female dominant, and 30 of the 34 Organization for Economic Co-operation and Development (OECD) countries have higher rates of women physicians than men. However, the U.S. Bureau of Labor Statistics (2017) reports that only about 38% of physicians and surgeons are women, placing the United States as 31st out of 34 OECD countries in terms of percentage of women physicians (OECD, 2018).

While gender differences in medical training have also been studied internationally (Kvaerner, Aasland, & Botten, 1999; Riska, 2011), gendered attrition in the pursuit of medical careers may be particularly problematic in countries like the United States, which place medicine as a postgraduate degree. Indeed,

national data show that women are not persisting through undergraduate premed pathways (Fiorentine & Cole, 1992); women's overrepresentation in pathways to medicine in high school largely disappears by the time students finish college and apply to medical school. However, despite these recent reports of growing *equality* by gender in medical school matriculation over the past decade (Association of American Medical Colleges [AAMC], 2017a), this parity may hide that the large attrition from core premedical science courses during the undergraduate years is not *equitable* by gender; if early trends in medical interest remained constant, women should be overrepresented in the medical profession, as they are in many other OECD countries. Further, given the documented barriers for women occurring at later stages of medical training and careers, and particularly from administrative positions and male-dominated specialties where women's health issues are often relatively understudied (Bates et al., 2016; Bickel, 2005; Johnson, Fitzgerald, Salganicoff, Wood, & Goldstein, 2014; Kvaerner et al., 1999), promoting equity in these areas is likely to require encouraging high-performing women to persist at levels above 1:1 gender parity, through and beyond the point of medical school matriculation.

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Explanations are unlikely to lie in innate biological or cognitive differences related to competence in science; psychology research shows gender differences to be very small or exhibit relative strengths in both directions (Hyde, 2005; Kilminster, Downes, Gough, Murdoch-Eaton, & Roberts, 2007; Spelke, 2005). Instead, motivational mechanisms or relative academic performance may provide alternative hypotheses. There is a wealth of evidence to suggest that students' academic decision making, including course-taking behaviors, are influenced by expectations of success and valuation of academic pursuits and that these factors are related to both students' perceptions of self and abilities as well as affective responses to prior academic experiences (Watt, Eccles, & Durik, 2006). Studies show that as early as middle school, motivational factors like interest, identity, and especially competency beliefs in science are related to girls' participation in and learning of science content (Cromley, Perez, & Kaplan, 2016; Hazari, Sonnert, Sadler, & Shanahan, 2010; Vincent-Ruz & Schunn, 2017). Problematically, women may interpret academic feedback from grades more negatively than their male peers, particularly in domains that are traditionally male-dominated, and may be more likely to rate themselves lower in perceived ability despite similar levels of achievement (Beyer & Bowden, 1997; Eccles, 1994; Kugler et al., 2017).

Eccles's expectancy-value theory (EVT; Eccles, 1994; Wigfield & Eccles, 2000) provides a helpful framework through which to understand how psychological factors such as interest, identity, and competency beliefs may interact to introduce gender differences in achievement-related choices. EVT proposes that educational and career decisions are directly influenced by both students' expectations of success on a task and the subjective value of the task in terms of students' intrinsic interest or enjoyment (*interest value*), their perceived utility of the task (*utility value*), and the relationship between the task and the students' sense of self (*attainment value*; Eccles & Wang, 2016). In course enrollment decisions, for example, students might consider the subjective value of a course based on how much they will enjoy it (i.e., interest; Semsar, Knight, Birol, & Smith, 2011) and whether or not it aligns with their felt sense of self (i.e., identity; Gee, 2001) as well as whether or not they expect to be successful in the course based on beliefs about their abilities in the subject (i.e., competency beliefs; Bauer, 2005). Locating and specifying gender differences in these three indicators of student valuation and expectation of success within specific courses along the premed pathway could provide a first step to understanding the features of particular courses that influence women's decision to leave medical careers. For example, are women's decisions to leave certain required course sequences primarily a result of declining interest, perceived incompatibility between the course and their identity, a lack of belief in their ability, or some combination of these factors?

The predicted source of the effect is unclear. On the one hand, there is evidence to suggest that large differences in competency beliefs or interest would not be expected within the high-performing populations of women typically found on a premed track (Eccles, 1994). Instead, some have proposed an alternate hypothesis, that some attrition for high-performing women is a function of an increased number of viable and more desirable alternatives available (Wang, Eccles, & Kenny, 2013).

For example, girls perform at slightly higher levels than boys in non-STEM subjects in high school; this relative academic advantage may increase the variety of non-STEM career options for women, which lowers their relative likelihood of pursuing science careers. On the other hand, students' academic self-concept has been shown to be constructed through both external and internal comparisons—that is, perceptions of one's ability may be a function of both a comparison to others' ability in that subject as well as to one's own relative ability in other subjects (Marsh, 1986). Therefore, high academic achievement in other content areas compared to medicine-related courses along with a false perception of higher achievement by their male peers may result in lower competency beliefs even for high-performing women.

Gaining a better understanding and addressing the underlying causes of gendered attrition from medical careers will likely require focusing on the science coursework during the years between high school and college graduation (Cromley et al., 2016; Kugler et al., 2017; Morgan, Gelbgiser, & Weeden, 2013). Undergraduate premed typically involves four challenging two-course science sequences (Introductory Biology 1 and 2, General Chemistry 1 and 2, Organic Chemistry 1 and 2, and Introductory Physics 1 and 2). Prior studies of premed attrition indicate that students perceive chemistry, biology, and physics courses as highly indicative of medical career success; underperformance in those courses may contribute to declining interest in premed (Barr, 2010). While prior research has shown variation in gendered attrition broadly within these domains, with some (i.e., biology, chemistry) showing relative advantages for women and other domains (i.e., physics) showing relative disadvantages for women (Cheryan, Ziegler, Montoya, & Jiang, 2016), little is known about which specific premed course sequences show the largest gender differences in attrition and most importantly, what factors contribute to women leaving these courses. Therefore, our approach uses longitudinal analyses to answer the following research questions:

Research Question 1: Where do gender differences in attrition appear in the premed science sequence?

Research Question 2: What motivational factors may explain large gender gaps that may appear?

Research Question 3: Does the cumulative effect of attrition over the entire sequence result in gender differences in premed persistence?

The Current Study

In this study, we examined institutional data records from 8,253 undergraduate students at a large undergraduate research university enrolled in core premed course sequences within their first two semesters between 2008 and 2016; multiple cohorts across many sections ensures patterns that are not specific to a small number of instructors. Multiple regression analyses were used to observe whether women were less likely than men to enroll in the second course of an undergraduate premed science course sequence even when successful in the first course. Leaving mid-way through a sequence is a strong and time-specific indicator of attrition, with recent experiences (e.g., first-course performance)

offering potential explanations. By contrast, modeling factors that influence the decision to start sequences are complicated by the optional order of some courses, making attrition decisions at that timepoint somewhat ambiguous. Our primary analyses examine both whether women were more likely than men to drop from these courses and whether some sequences (either by content domain or timing) showed greater differences in within-sequence attrition by gender.

Finally, we also use graduation records to determine the proportion of degrees eventually earned by students who entered and completed these sequences of premed courses. These analyses address the critical outcomes question: If women don't persist in premed pathways, what degrees do they end up pursuing instead?

Methods

Sample

This retrospective multicohort study consisted of 8,253 undergraduate students at a large urban research university in the Northeastern United States (henceforth, “the University”). The University is broadly representative of similar institutions with a relatively selective admission rate (approximately 60%): It offers over 100 undergraduate majors, the majority (60%) of students are from in-state, with a smaller number (5%) of international students, and while there is large variability in family income ($SD = \$122,000$), students tend to come from higher income brackets (median = \$111,000).

The sample included for analyses those students enrolled in General Chemistry 1 within the first two semesters. Importantly, in the sample used here, men were not more likely than women to pass these courses (i.e., receive an A, B, or C); small differences instead favor women in introductory biology (94% vs. 92%, $p < .01$) and general chemistry (96% vs. 94%, $p < .05$). Therefore, differential failure rates would not account for women's higher levels of attrition in the overall pathway. We therefore were interested in whether observed gender differences in attrition for this group of students could be explained by relative academic strengths and weaknesses in STEM and non-STEM disciplines or by motivational factors such as competency beliefs, science identity, and science fascination.

An 8-year window was used to ensure generalizability across student cohorts and instructors. The racial and ethnic diversity of our sample roughly mirrored that of the University as a whole; students were predominantly White (71%), with Asian (15%) and Black or Hispanic (9%) students making up the next two largest ethnic groups. The primary predictor variable, gender, was coded as 1 if the student self-identified as female (57%) and 0 if the student self-identified as male (43%). In-course surveys established that overall, 63% of these students planned on going to medical school. Of those intending to go to medical school, 65% were women. All University data were provided for analysis with Institutional Review Board approval.

Measures

Course variables. Primary outcome variables included four binary measures of enrollment (1 = enrolled, 0 = not enrolled) in each of the second courses of the four pairs of courses of the

core premed sequence: Introductory Biology 2, General Chemistry 2, Organic Chemistry 2, and Introductory Physics 2. To analyze how performance in the first course of a sequence was related to students' persistence to the next course, only students also enrolled in the prior course at the University were in analyses of each course sequence. It is important to note here that while not mandatory, this series of premed science courses represents a progression that is common to premed tracks across multiple institutions (AAMC, 2017b), was highly recommended by pre-health advisors at the University, and was the most commonly observed progression in our data. Therefore, while it is possible that a student, for example, entered Organic Chemistry 1 and Physics 1 without entering Organic Chemistry 2, this occurred in less than 4% of our data set, and thus the experiences with later sequence courses would rarely influence earlier sequence courses. Further, any effects from gendered selection at earlier points would logically lead to a smaller effect in later courses as women with a propensity to leave premed would not be present in later course sequences. However, the size of the effects in organic chemistry and physics were comparable, arguing against selective attrition as the source of the observed temporal pattern regardless of the order of these courses.

A binary measure of students sitting the MCAT exam was also included. These analyses focused on students who completed the full combination of all four core sequences and an additional elective course (either biochemistry or chemical biology). These “premed courses” are typically taken by premed students, make up the content of the MCAT exam, and were not a required combination to earn any other degree. Enrollment in these courses was highly predictive of taking the MCAT; odds of taking the MCAT in students completing this combination were about 8.6 times higher than those not completing them, odds ratio [OR] = 8.62, 95% CI [7.10, 10.46], $z = 21.76$, $p < .001$.

Academic covariates. Academic variables consisted of students' highest SAT math, verbal, and writing scores, Advanced Placement credits and scores, and cumulative high school GPA. Two ratio variables were calculated to represent strengths in courses outside of the premed track relative to their premed science courses: *social sciences* and *arts and humanities*. Social science ratios were calculated as the mean GPA of all courses within anthropology, psychology, sociology, economics, and political science divided by the mean GPA of all premed science courses. Arts and humanities courses were calculated as the mean GPA of all courses taken within English, history, African Studies, arts, music, theater, and various languages divided by the mean GPA of all premed science courses. For attrition analyses, these discipline-specific ratios were calculated using only courses prior to the point of premed attrition (see Table 1).

Motivational covariates. Motivational data were collected from a subset of 520 students during the first 3 weeks of Organic Chemistry 1 (i.e., prior to the first summative assessment) for in-depth analysis of the largest gender effect and consisted of chemistry fascination (e.g., “I want to know everything I can about chemistry”), chemistry competency beliefs (e.g., “I can usually figure out a way to solve chemistry problems”), and science identity (e.g., “I think of myself as a ‘science person’”),

Table 1
Descriptive Statistics of All STEM, Non-STEM, and Motivational Covariates by Gender

	Female					Male				
	<i>N</i>	<i>M</i>	<i>SD</i>	Minimum	Maximum	<i>N</i>	<i>M</i>	<i>SD</i>	Minimum	Maximum
STEM AP score ^a	4,686	0.28	0.01	0	1	3,567	0.33	0.01	0	1
STEM AP credit	4,686	1.1	1.4	0	9	3,567	1.3	1.6	0	10
SAT math	4,411	642	69	410	800	3,399	665	67	440	800
Non-STEM AP score ^a	4,686	0.3	0.01	0	1	3,567	0.28	0.01	0	1
Non-STEM AP credit	4,686	1.3	1.6	0	11	3,567	1.1	1.6	0	9
SAT verbal	4,411	639	73	390	800	3,399	633	72	400	800
SAT writing	4,643	623	71	380	800	3,524	605	74	390	800
High school GPA	4,676	4.0	0.5	0	9	3,562	3.9	0.5	0	7
Arts and humanities ratio	4,494	1.5	0.6	0	9	3,399	1.4	0.6	0	10
Social sciences ratio	4,367	1.4	0.5	0	8	3,253	1.3	0.5	0	9
Fascination	322	2.9	0.6	1	4	197	3.1	0.6	2	4
Competency beliefs	321	2.8	0.5	1	4	197	3.0	0.5	2	4
Science identity	320	3.6	0.4	2	4	197	3.4	0.5	2	4
Medical career interest	322	0.59	0.03	0	1	198	0.55	0.03	0	1

^aAP score defined as proportion of AP Exams earning more than 3 out of 5, a common threshold for acceptance for university course equivalence.

adapted from the Colorado Learning Science Survey for Use in Chemistry (CLASS-Chem; Semsar et al., 2011), the Chemistry Self-Concept Inventory (CSCI; Bauer, 2005), and a science identity survey (Hazari et al., 2010). Items were rated on a 4-point Likert scale (*strongly agree, agree, disagree, strongly disagree*) and calculated as a mean score (see Table 1). Reliability for all items ranged from moderate to good. In terms of discriminability, the highest correlation was between fascination and competency beliefs, showing a moderate correlation of $r = .55$, consistent with previous reports in the literature (Bauer, 2005; Vincent-Ruz & Schunn, 2017; see Supplementary Materials, Table S1, available on the journal website). A single binary indicator of intent to pursue a medical career (yes = 1, no = 0) was also collected in General Chemistry 1 and Organic Chemistry 1.

Degrees earned. Bachelor's degrees earned by students in the sample were gathered from University historical data and coded across 498 unique degree combinations into seven general degree categories: health, social science, arts and humanities, science, math, engineering, and business (see Supplementary Materials, Table S2, available on the journal website, for a detailed coding scheme).

Procedure

For sequence completion and MCAT enrollment analyses, a multicohort longitudinal data set was analyzed using a series of multivariate logistic regressions in Stata 15. Large, multicohort data sets enable discovery of generalizable patterns unlikely to be specific to particular instructional styles, course structure, teaching assistants, or cohorts of students. However, cohorts may also differ and produce confounds in the analyses; to control for general cohort effects, we also included a model using each student's starting academic term as a single continuous cohort covariate in our analyses. Each regression model was built showing direct, uncontrolled effects of gender on each outcome variable (*uncontrolled*). Next, two groups of covariates were added one by one to determine if

different academic factors influenced gender differences: relative STEM academic strengths (*STEM*) and non-STEM relative academic strengths (*non-STEM*). For each model, covariates were only included as potential mediators of the gender effect if they were significantly correlated with gender. An alpha level of .01 was used for all exploratory analyses of the large data set.

To understand potential motivational mechanisms, we collected additional data via online surveys from multiple sections of organic chemistry, the sequence with the largest gendered attrition. Using mediation analysis, we tested whether the relationship between gender and enrolling in the second course was mediated by each attitudinal factor (i.e., fascination, science identity, competency beliefs) or all three. A generalized linear estimator was implemented using the lavaan package in R (Rosseel, 2012) to more accurately model binary outcomes. An alpha level of .05 was used for this focused analysis of the smaller survey data set.

Finally, because course attrition may be related to career pathways through the type of degree earned, logistic regressions were performed on each degree category using gender as a predictor. In addition, because students enter medical school from many undergraduate degrees but some may be more common pathways, percentages of students who took the MCAT within each degree category by gender were also examined using logistic regression, with taking the MCAT as the outcome and degree type earned as the predictor.

Results

Overall, attrition by prior course grade showed the expected trend; both male and female students with higher grades were far more likely overall to continue to the next course, with fewer than .01% of students earning a D or F continuing on to take the second course of any sequence or the MCAT (see Supplementary Materials, Table S3, available on the journal website). Further, across all course sequences, there were no significant differences in attrition by gender for students in these

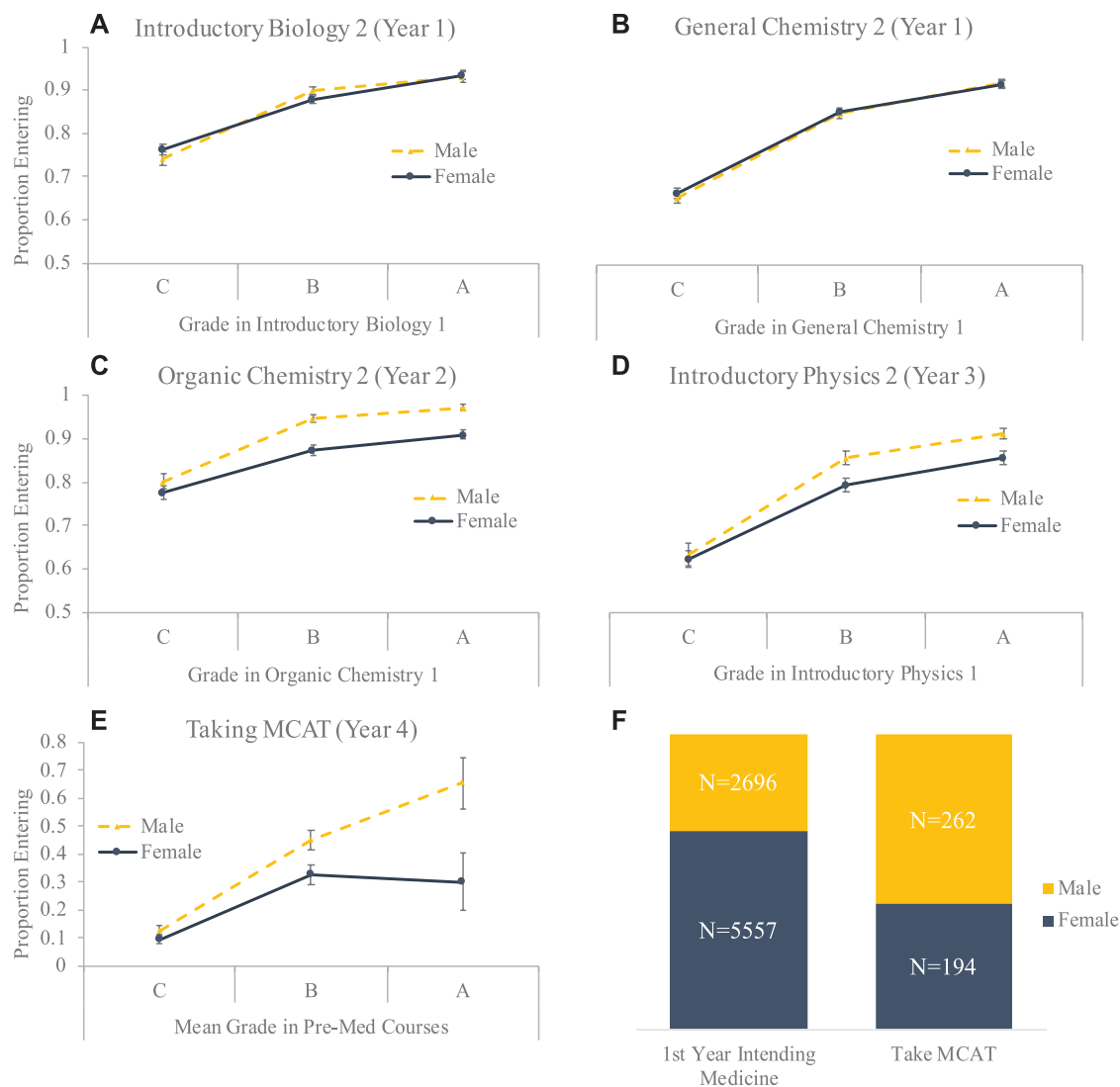


FIGURE 1. Gendered attrition on the path to medical school.

Note. (A–D) Proportion of passing students entering each second course in the four core science sequences and (E) taking the MCAT by gender and grade in prior course(s). (F) Estimated numbers of entering students intending medical school and taking the MCAT.

lowest grade ranges; therefore, the analyses focus on students earning a C or higher. No significant differences were found between female and male attrition from course sequences typically taken in the first year, intro biology (89% vs. 91%, $p = .14$; see Figure 1A) and general chemistry (88% vs. 88%, $p = .91$; see Figure 1B). However, in course sequences typically taken in the second year (organic chemistry) and third year (physics), significant differences were found between males and females. But this gendered attrition difference was only found in students who received an A or B in the prior course, with women having significantly lower odds than men of continuing to Organic Chemistry 2 (89% vs. 96%, $p < .001$) and Physics 2 (82% vs. 88%, $p < .001$). That is, women receiving an A or B in advanced courses on the premed track were approximately 2.9 times less likely than similarly performing men to continue to the next organic chemistry course (see Figure 1C) and about 1.7 times less likely to continue to the next physics course (see Figure 1D).

There was also large gendered attrition of high performers taking the MCAT after having completed all the sequences; the

odds of taking the MCAT after having received an A or B in the full set of premed courses were about two times lower for females than males (32% vs. 47%, $p < .001$; see Figure 1E). Overall, the gender proportion shifts from almost 2:1 female-to-male students intending med school at the beginning of their first semester at university to 3:4 female-to-male taking the MCAT (see Figure 1F). That is, differential losses by gender throughout the premed sequence cumulatively produce a large gender effect overall.

Models testing for cohort effects showed a small overall negative linear trend (i.e., overall lower retention for later cohorts), with significant cohort effects found only in general chemistry, physics, and taking the MCAT; however, these effects were not strong enough to meaningfully change the estimates for gender differences in these courses (i.e., adjusted effects were not outside the 95% CI of the uncontrolled model), and so we proceeded without this covariate in our subsequent modeling (see Supplementary Materials, Table S4, available on the journal website, for model details).

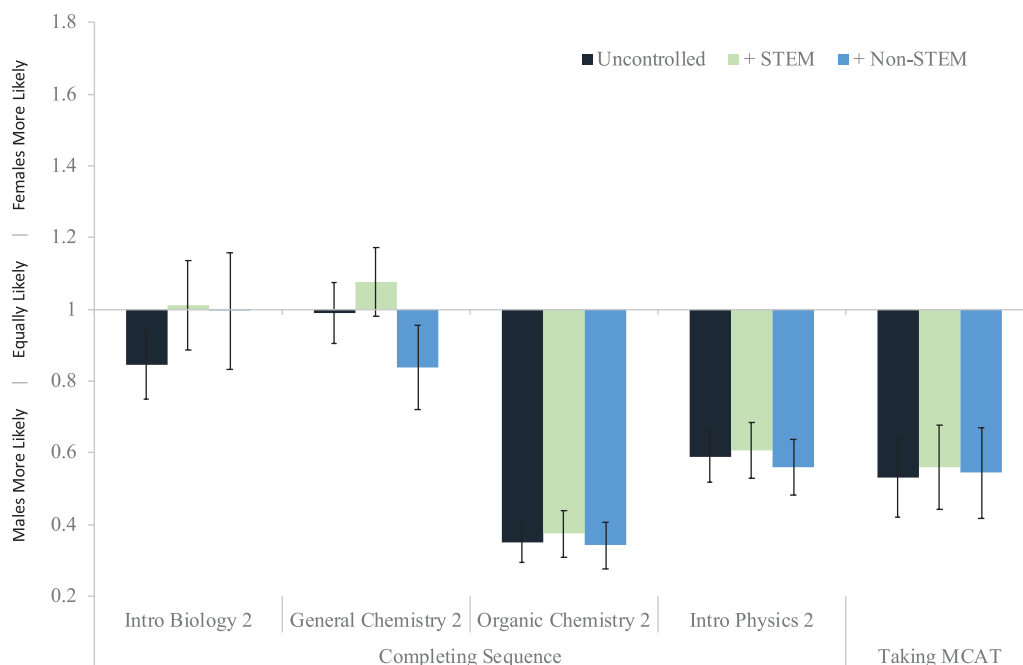


FIGURE 2. Changes in relative size of gender effect, with explanatory variables.

Note. Odds ratio of women compared to men for entering a second course in sequence after receiving an A or B in the prior course, overall, and after controlling for relative strength in STEM and non-STEM academics, with standard error bars shown.

To better understand which academic preparation and performance variables might explain persistence differences, we first tested which academic covariates generally predicted persistence in organic chemistry, the course sequence with the largest gender gap. All tested covariates were correlated with overall persistence as expected (see Supplementary Materials, Table S5, available on the journal website, for the full correlation table). Because strong correlations were shown among some of our covariates, we examined variance inflation factors (VIFs) to check for multicollinearity in those predictors; all VIFs were shown to be below 2.5, a conservative threshold for multicollinearity with such a large sample size (O'Brien, 2007; see Supplementary Materials, available on the journal website, Table S6). We also tested for gender differences in the extent to which each academic variable predicted persistence, based on prior research showing differential reactions to negative grade feedback (Beyer & Bowden, 1997)—that is, do some academic variables matter more for women than men?

Analyses showed lower odds for women than men (1:1.3) of continuing to Organic Chemistry 2 in the middle two quartiles of high school GPA range (42% vs. 49%, $p < .001$). However, women in the highest two quartiles of SAT math had slightly higher odds than men (1.2:1) of continuing to organic chemistry (61% vs. 55%, $p < .01$). Across both genders, students with a higher relative GPA in either social sciences or arts and humanities have lower odds of continuing to Organic Chemistry 2. While there were no gender differences for students with the highest and lowest range of these ratios, women in the third quartile of the social sciences ratio showed lower odds (1:1.7) of continuing than men (79% vs. 86%, $p < .01$), and women in the second quartile of the arts and humanities ratio had lower odds (1:2.2) of continuing than men (86% vs. 93%, $p < .001$). Therefore, some academic variables favor men persisting in premed, but others favor

women's persistence (see Supplementary Materials, available on the journal website, Figure S1 for a summary).

To then test the extent to which these relative academic strengths and weaknesses explained (i.e., mediated) the differential attrition by gender across all course sequences, we included academic covariates (i.e., AP scores, SAT scores, high school GPA, recent course performance) representing both STEM and non-STEM strengths in each sequence-continuation regression model (see Supplementary Materials, available on the journal website, Table S7 for model details). While overall including STEM variables slightly decreased women's relative attrition and including non-STEM variables slightly increased relative attrition as suggested in the literature (Wang et al., 2013), these effects did not differ significantly from the uncontrolled model (see Figure 2).

Resulting models still showed lower odds of women continuing to Organic Chemistry 2 when including relative strengths in both STEM (91% vs. 96%, $p < .001$) and non-STEM (90% vs. 96%, $p < .001$). Similarly, lower odds for women continuing to Physics 2 remained when including relative strengths in STEM (84% vs. 90%, $p < .001$) and non-STEM (82% vs. 89%, $p < .001$). Finally, women had lower odds relative to men of taking the MCAT exam (including only students who had completed all premed courses) both when controlling for relative strengths in STEM (35% vs. 49%, $p < .001$) and non-STEM (33% vs. 48%, $p < .001$). In sum, differential attrition effects by gender were not explained by relative academic strengths and weaknesses.

The next set of analyses tested a mediation hypothesis using a subset of A and B students ($N = 335$) surveyed in several course offerings of Organic Chemistry 1. These models included attitudinal survey variables (chemistry fascination, chemistry competency beliefs, and science identity) as possible mediators between gender and enrolling in Organic Chemistry 2 as well as a binary

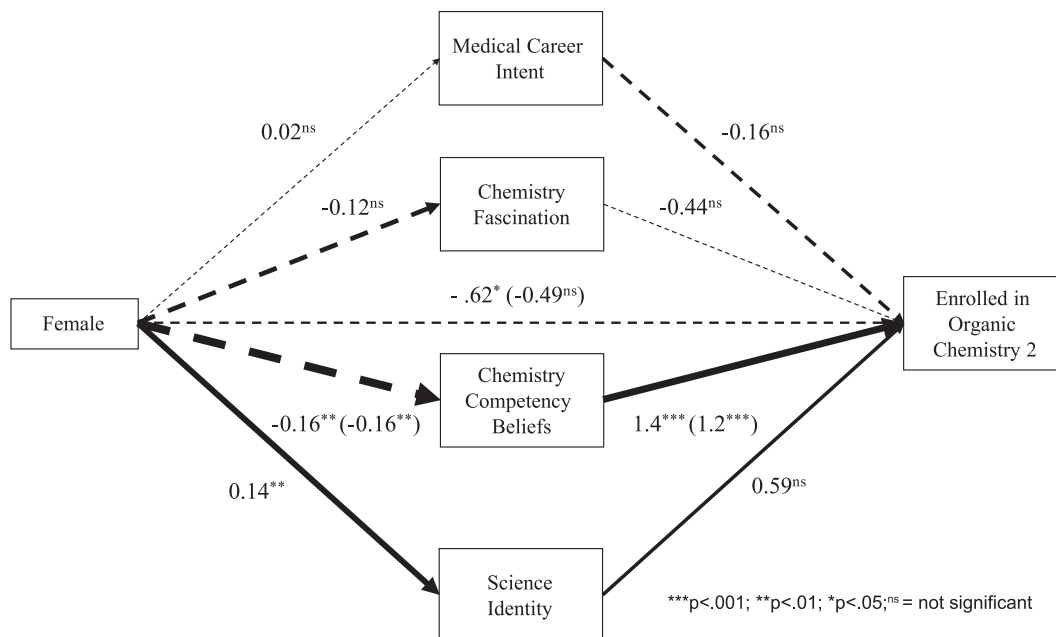


FIGURE 3. Mediating role of competency beliefs on gendered attrition in organic chemistry.

Note. Mediation analysis with logit regression coefficients shown for students earning an A or B in the first course, including all motivation variables (and with competency beliefs only).

indicator of intent to pursue a medical career for students receiving A and B grades in the prior course. Medical career intent was not significantly correlated with either gender ($p = .72$) or retention to organic chemistry 2 ($p = .58$). Overall, this sample also showed significantly lower odds of women continuing to Organic Chemistry 2 (74% vs. 84%, $p < .05$). Interestingly, mediation of this gendered attrition through chemistry fascination was not significant, while mediation through science identity was a smaller effect and in the wrong direction (i.e., predicted greater female enrollment in Organic 2); therefore, these paths were trimmed from the final model.

Mediation analyses revealed that chemistry competency beliefs, which showed the largest gender difference and the strongest connection to Organic Chemistry 2 enrollment, was the primary mediator (see Figure 3). When only chemistry competency beliefs are included in the mediation model (see Figure 3, coefficients in parentheses), the initial direct relationship between gender and enrollment is no longer significant (76% vs. 84%, $p = .10$). Further, there is a significant negative correlation between gender and chemistry competency beliefs ($p < .001$), meaning that women are more likely to respond with lower ratings of their beliefs in their chemistry ability. Also, there is a positive correlation between chemistry competency beliefs and enrollment in Organic Chemistry 2 ($p < .001$), meaning that higher ratings of chemistry competency beliefs are correlated with a higher likelihood of continuing to Organic Chemistry 2. This significant indirect pathway suggests that the initially observed direct effect of gender on enrollment in Organic Chemistry 2 is at least partially explained by women's lower competency beliefs in chemistry (Baron & Kenny, 1986).

Finally, additional logistic regressions were performed to determine whether there were gender differences in the type of undergraduate degree earned (indicative of career pathways directed

away from medicine). Similar to broader studies of undergraduate degree earning (Morgan et al., 2013), women in our sample were more likely than men to earn degrees in health, social sciences, and arts and humanities but less likely than men overall to earn degrees in science, math, engineering, or business (see Figure 4A). Results showed that even in this large sample of students intending medical school and likely taking many science courses, women's odds were 1.3 times lower than men for earning a science degree (26% vs. 32%, $p < .001$), and students earning science degrees made up 77% of MCAT-takers. Instead, women's odds of earning an undergraduate health degree were 2.4 times higher than men (21% vs. 10%, $p < .001$), one of the least likely groups to take the MCAT (see Figure 4B). Further, even women earning science degrees were less likely to take the MCAT than men (17% vs. 28%, $p < .001$). Thus, women commonly pursued a career in broader health fields but in lower paying, lower status positions relative to their initial medical school intentions. When examining subcategories of science (i.e., degrees earned in biology, chemistry, or physics), our findings follow national trends, with women equally likely to earn biology degrees as men (Cheryan, Ziegler, Montoya, & Jiang, 2016); however, those women were still less likely than their male counterparts to continue to take the MCAT (see Supplementary Materials, available on the journal website, Table S8 for model details). Similar patterns held when including only students who consistently obtained an A or B across each of the course sequences, ruling out differential attrition from poor course performance (see Supplementary Materials, available on the journal website, Table S9 for model details).

Discussion

Gender equity is currently a central problem in the United States, particularly in science, but also broadly in all high-status and

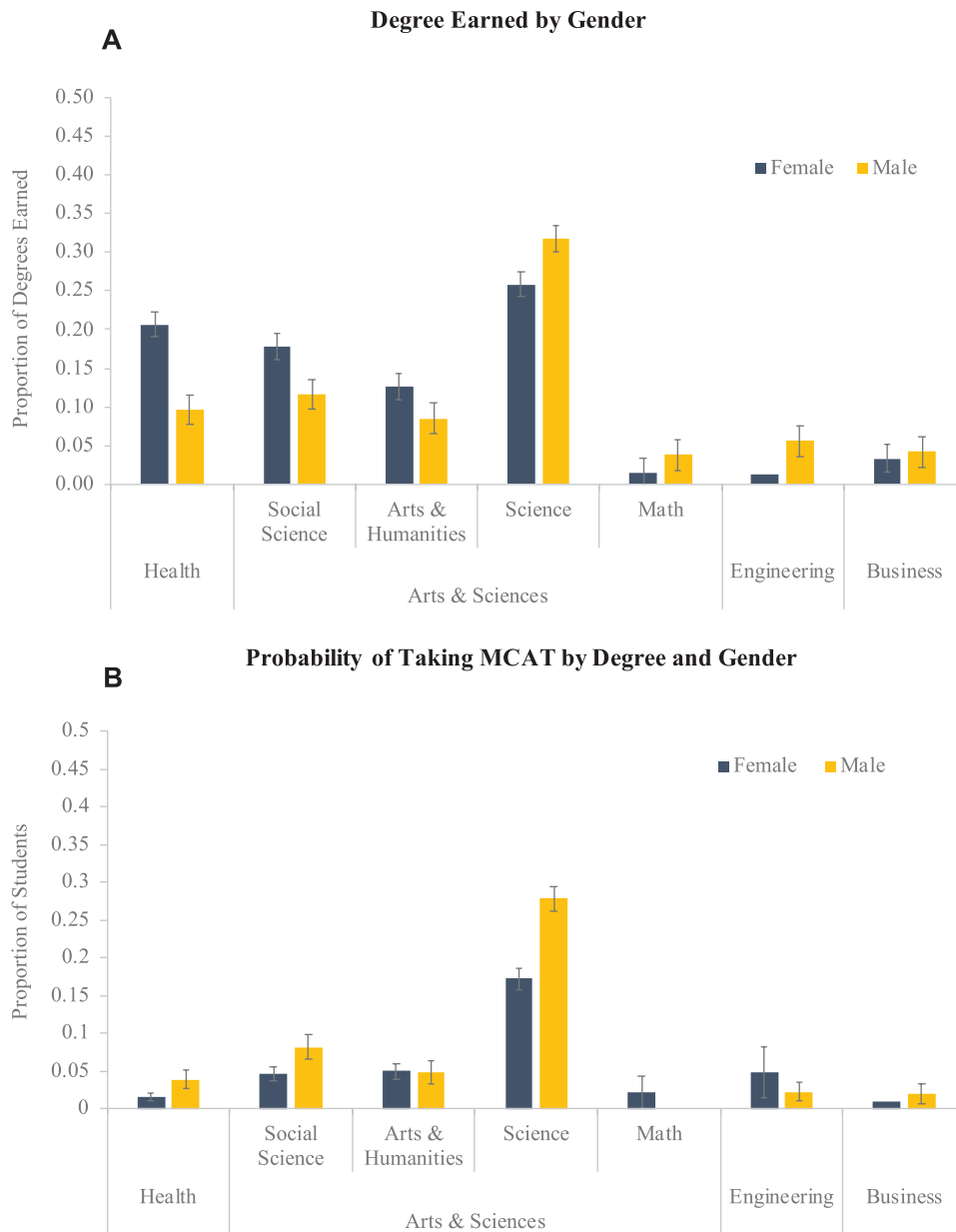


FIGURE 4. Proportions of (A) degrees types earned by gender and (B) the probability of taking the MCAT within each degree type by gender, with standard error bars shown.

high-pay positions. This study brings into focus a large contributor to this overall problem that has received relatively little prior attention: gender equity in premedicine, a pathway to one of the largest high-status, high-pay science workforce sectors in the United States. Prior work often fundamentally mischaracterizes the current situation as one of parity between men and women entering medical school—yet for a number of reasons that we have presented, medicine should be heavily dominated by women. Therefore, parity in medical schools represents an outcome that is far from ideal. Our analyses provide critical insight into the clear trend of gendered attrition that can be observed through the comparison of national career interest data for students exiting high school with national entering demographics of medical schools. We find that only later premed courses and the step of choosing to sit the MCATs after completing all required courses show large gender biases in attrition. Importantly, these effects were found primarily

for high-performing women, and these effects were partially mediated by differences in competency beliefs. While many previous studies have highlighted the importance of competency beliefs in STEM persistence, our findings uniquely locate this effect to the group of high-performing women in premed; the effect found here is therefore unlikely to be one of differential reaction to failure feedback from formal grades, a commonly offered explanation.

These findings have a number of implications. First, for this population, we have shown that previously offered hypotheses of gendered attrition as a function of relative successes in non-STEM academic areas or relative weaknesses in STEM do not hold for our sample. While both men and women are influenced by relative academic performance, this effect does not disproportionately impact women. Instead, the current data support an alternative hypothesis related to motivational factors. Yet this observed mediation of competency beliefs is also not a simple

replication of past research: a general effect of competency beliefs would have predicted gendered attrition that was equally large across performance levels due to preexisting differences in competency beliefs (Vincent-Ruz, Binning, Schunn, & Grabowski, 2018) or gendered attrition only in the C and B range due to differential reaction to failure feedback based on grades (Kugler et al., 2017). One possible interpretation of the strong mediation effect of competency beliefs for women who earn an A or B in our data might be related to the perception of the relative effort required to earn those grades in these environments. Especially in science courses, where stereotype threats are often particularly noticeable for women, the level of effort required to achieve high grades in these courses may be highly salient and attributed to a lack of ability. Future work incorporating additional components of expectancy value theory could help to identify these other important factors of women's course-taking decisions. For example, understanding students' interpretation of the various costs (e.g., psychological costs, opportunity costs) associated with continuing through the premed track as well as their perception of gendered sociocultural norms associated with premedical study at their institution could further inform intervention. Indeed, some research has shown evidence that all students are likely to perceive incongruity between STEM careers and family caregiving as they get older; while no gender differences in these evaluations were found for college-aged students, structural factors such as family planning may influence women's decisions to continue in a medical career at much later points (Eccles & Wang, 2016; Weisgram & Diekmann, 2017).

Overall, regarding women's premed attrition, this study has advanced understanding of gendered attrition in this very large STEM-focused group:

- Previously offered explanations shown not to hold for our sample:
 - relative academic weakness in STEM;
 - relative academic strength in non-STEM;
 - differential changes in competency beliefs due to differential reaction to failure feedback based on grades; and
 - differences in competency beliefs prior to arriving at university.
- Alternate explanation supported:
 - differential change in competency beliefs due to factors other than success.

It now becomes important to examine the ways in which this phenomenon may be moderated by instructional and institution factors. For example, the particular institution studied was a moderately selective, large, co-ed, urban school, with a student body that was relatively homogenous by ethnicity. Looking at premed attrition at universities that are more or less selective, located in nonurban areas, more or less ethnically diverse, of a different size, or single gender may reveal interesting variation in gendered attrition along the premed pathway. A multiinstitutional approach that intentionally incorporates schools with different premed course sequences could also address a potential limitation of the current study by examining if similar attrition patterns exist in organic chemistry and physics in universities where this particular

premed course combination is less common. Additionally, as this work points to the importance of motivational factors rather than relative academic strengths and weaknesses, exploring a wider range of motivational constructs that could be related to gendered attrition might offer a deeper understanding of the underlying mechanisms that contribute to gendered attrition in premed and how these interact with particular premed science courses. For example, we hypothesize that the effects found in organic chemistry are related to the pervasive perception of this course among students and faculty as a "gatekeeper course" that is predictive of success in medical careers, making gender-based stereotypes particularly salient (Barr, Gonzalez, & Wanat, 2008). It may also be that for strong students, the particular content of Organic Chemistry 2 is much different from the content of the other chemistry courses in which they had positive experiences with up to that point, which may further lower their competency beliefs and contribute to attrition decisions. These considerations will be important in the development of targeted interventions that help support women in persisting along this trajectory, which could additionally provide opportunities to formally test causal hypotheses relating to gendered premed attrition.



Maintaining the high ratio of women showing interest in medicine is integral to improving innovation in the medical field and improving equity within health-related professions (Bates et al., 2016; Bickel, 2005; Kvaerner et al., 1999; Reed & Buddeberg-Fischer, 2001) and society more broadly. There is an increasing need for a larger and more diverse STEM workforce including more women (Page, 2007). Like gendered attrition found in other fields (i.e., engineering, computer science), losing women from highly influential and higher salaried positions in health care represents a loss in potential contributions to the field and perpetuates problematic wage and power inequities across male-dominated versus female-dominated health professions (Beede et al., 2011; Oh & Lewis, 2011). Further, medical research often fails to account for sex-based health differences, sometimes leading to misdiagnoses (Johnson et al., 2014; Mazure & Jones, 2015), and patients who see female physicians may receive higher quality care in general (Tsugawa et al., 2017) and particularly regarding women's health issues (Siriwardena et al., 2012). Maintaining early medical school interest, particularly for high-performing female students, could address these concerns by increasing the number of female physicians occupying high-level positions in various medical specialties.

However, we also acknowledge that while this study attends to a "supply-side" explanation of women's representation in the medical profession, we believe this to be an important but not sufficient condition for alleviating gender inequities in medicine, particularly in specialty fields. There are also significant structural barriers for women within medical institutions on the "demand-side," such as workplace harassment and discriminatory hiring practices, that limit women's advancement in male-dominated specialty areas (Boulis & Jacobs, 2008; Davis & Allison, 2013). Therefore, gender equity will require both increased representation and a concurrent dismantling of discriminatory practices that prevent women from reaching leadership positions in these fields and perpetuate the perception of some medical specialties as inhospitable workplaces for women.

Conclusion

Our analyses provide evidence from a large, multicohort study of undergraduate premedical students using a large institutional data set to understand where differential losses by gender occur along the undergraduate premed pathway. Further, we present a method for applying a broad range of prior and concurrent academic ability and motivation data to characterize the nature of this attrition in depth, demonstrating some common explanations of this phenomenon that fail to hold in our sample and suggesting alternate models that provide strong explanatory power and favor a hypothesis offering a greater potential for intervention. This provides a strong and simple metric for other institutions interested in identifying potential sources of gendered attrition in premed science courses, namely, focusing on continuation of students who earn an A or B within these core course sequences by gender. Important to note is that these findings also show evidence that this phenomenon has implications for the overall numbers of science undergraduate degrees for women. Further, by identifying courses in which these gaps are most problematic and providing evidence against absolute and relative academic performance explanations, this study provides a foundation for interventions focused on addressing underlying causes (e.g., gender role models, Rosenthal, Levy, London, Lobel, & Bazile, 2013; Sanfey, 2006; and negative instructor and peer messages, Archer et al., 2012; Schunk & Meece, 2006; Vincent-Ruz & Schunn, 2017; Zohar & Bronshtein, 2005) and directly targeting motivational factors that appear to be instrumental in large gender gaps found in organic chemistry, introductory physics, and taking the MCAT.

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