Science
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Stability and Volatility of STEM Career Interest in High School: A Gender Study

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ABSTRACT: This retrospective cohort study characterizes how interest in science, technology, engineering, mathematics (STEM) careers changes during high school for more than 6,000 students in a representative national sample of 34 two- and four-year colleges taking mandatory college English courses. Overall, large gender differences in career plans were found, with males showing far more interest particularly in engineering, whereas females were more attracted to careers in health and medicine during their high school years. The key factor predicting STEM career interest at the end of high school was interest at the start of high school. There was an additional effect of gender, indicating both a lower retention of STEM career interest among females and a greater difficulty in attracting females to STEM fields during high school. During the high school years, the percentage of males interested in a STEM career remained stable (from 39.5 to 39.7), whereas for females it declined from 15.7 to 12.7. The students' initial specific (disciplinary) career interests were found to influence the stability of their interest in a STEM career, with those interested in physics careers at the start of high school having the highest retention in STEM. © 2012 Wiley Periodicals, Inc. *Sci Ed* **96:**411–427, 2012

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INTRODUCTION

Preparing students for careers in science, technology, engineering, and mathematics (STEM) is at the forefront of K-12 educational concerns in the United States. Two recently released reports, by the National Research Council (NRC) and the President's Committee of Advisors on Science and Technology (PCAST), offer guidance on how future workforce demand in these professions might be accommodated (NRC, 2010). Without an increase in the number of students pursuing careers in STEM areas, the United States may not be able to tackle the "grand challenges" that face us, which include clean energy, stewardship of natural resources, and advances in medicine (Obama, 2009). Adding urgency to this concern is the fact that some STEM fields have suffered from declining student interest. For example, bachelor's degrees in the physical sciences have proportionately declined in the past several decades (Xie & Achen, 2009).

To understand the issue of persistence to STEM careers, it is important to take into account how students' interests fluctuate prior to the college level, particularly because early science career aspirations have been found to be important for persistence (Tai, Liu, Maltese, & Fan, 2006). In addition, there continue to be significant gender differences across STEM degrees, with limited understanding of how the establishment of, and the fluctuations in, STEM interest are different for females and males. Based on a randomly chosen, nationally representative sample, this study examines how college-going students' self-reported interest in pursuing a STEM-related career develops during their high school years. Special attention is given to examining gender differences in career interests.

RESEARCH ON CAREER CHOICE

Often using the metaphor of the "leaky pipeline," the prevailing view of the STEM career progression is that young children initially have a high level of interest in science and mathematics, but that, as they move through the educational system, interest is lost at every stage, particularly among females (Blickenstaff, 2005; Kerr & Robinson Kurpius, 2004; Mitchell & Hoff, 2006; Riegle-Crumb, Moore, & Ramos-Wada, 2011). Although interest in STEM careers declines over time for students as a group, in recent years some researchers and educators have moved away from the "leaky pipeline" metaphor in favor of alternate descriptions (e.g., "pathways") that capture bidirectional flows, because there are indeed some students who are not initially interested, but are later attracted into STEM disciplines (Lewis, Menzies, Najera, & Page, 2009).

Complicating the analysis of STEM trajectories, much research has focused on students' choice of major, even though a major does not directly map onto career choice. For example, many students major in biology or chemistry as a path to becoming a doctor rather than a biologist or chemist.[1] Some students major in mathematics or science on their way to the business world, careers in finance, or as entrepreneurs. Engineering sometimes provides a background for those who want careers as patent lawyers. By not taking into account students' ultimate career goals, tracking only college major tends to inflate the number of students who are counted as planning to enter the STEM workforce. Thus, in this study, we focused on career intentions, not on college major.

Research on persistence toward a career in a STEM field has primarily examined decisions made in and after college, with less scrutiny paid to shifts in interest during the high

[1] The occupation of physician is considered a "science-related" career by the NSF and in the STEM education research.

school years (Chen, 2009; Correl, 2001; Xie & Shauman, 2003). An exclusive research focus on choices made during college neglects the influence of earlier experiences ranging from high school coursework to summer programs that may have a profound impact (Riegle-Crumb et al., 2011). Research on when scientists developed their disciplinary focus suggests that high school is the most critical time for a large proportion of future scientists and engineers (Olson, 2009). Our study examines how STEM career intentions evolve during the high school years.

FEMALES AND STEM CAREERS

We are particularly interested in how gender relates to STEM career intentions. In a review of the literature on gender and science, Brotman and Moore (2008) report that several large quantitative studies found that "girls' overall attitudes toward science are either less positive than boys' or decline more significantly with age" (p. 978). Using nationally representative data, Mau (2003) found that women were significantly less likely to persist in science and engineering career aspirations 6 years after they left the eighth grade. The ensuing gendered career choice pattern perpetuates a U.S. scientific and technical workforce that has been, in most disciplines, predominantly male (National Science Foundation [NSF], 2009). This has been a policy concern of long standing (Sonnert & Holton, 1995).

The loss of many women from the STEM sector harms the entire nation, as the demand for STEM professionals exceeds the supply. Furthermore, including the perspectives and intellectual contributions of a more diverse group of STEM professionals can serve to advance scientific and technological progress in an age rife with environmental, social, and economic challenges (Page, 2007). The occupational segregation by gender has also economic consequences for the individual. The largest factor behind the gender gap in wages is the gender difference in occupational choice, with more males pursuing financially lucrative careers, such as those in science and engineering (Correl, 2001). Furthermore, pay inequality by gender is larger in non-STEM careers than STEM careers, which gives efforts to boost female participation in STEM the added incentive that this will increase pay equality in the economy (Oh & Lewis, 2011). Clearly, studying STEM career aspirations by gender is well motivated, but there is still some ambiguity about which years are the most important to focus on to effect substantial change.

College-level statistics illustrate that gender disparities in STEM have earlier roots. While women's experiences in college certainly deter some from pursuing STEM at that stage, studies have found that more females than males enter college already determined not to study science at all (Sax & Arms, 2008). The reasons may have much to do with preferring careers that are more people oriented and conflict less with personal and family needs (Ceci & Williams, 2010). As college freshmen, males interested in STEM outnumber females by 2:1 (NSF, 2009, Table B-8).

It is also noteworthy that the genders show comparable rates of persistence in STEM interest once they have arrived in college. In the biological sciences (including agriculture), physical sciences, and engineering, the proportion of females among those with an interest in majoring in the field as freshmen is similar to the fraction that later graduates (National Science Board [NSB], 2004, Table 2-7). Among the most intellectually talented middle-school students (as identified by early administration of the SAT), high school experiences, abilities, and interests predicted the pursuit of a STEM major (Halpern et al., 2007). As engineering professor Beatrice Isaacs (2001, p. 85) of the University of Hartford states, "the problem [of the mystery of the missing women engineers] is one of enrollment rather than dropping out." This underscores the importance of what happens in the precollege phases for understanding the dearth of women in many STEM fields.

Enrolling in high school science and mathematics courses (especially calculus) is a strong predictor of persistence in engineering (Adelman 1998). U.S. high schools have been successful at achieving approximate gender parity among students taking biology (57% female), chemistry (52% female), and physics (47% female) (NSB, 2004, 2008). Calculus courses have also reached relative gender parity (NSB, 2008).

In general, females have a strong interest in higher education. Women now receive the majority of undergraduate degrees (Peter & Horn, 2005). However, these positive indicators of women's participation in and aspirations toward educational pursuits have not translated to career interests in STEM fields, especially the physical sciences and engineering. As for the cause of the persistent gender disparity in STEM career plans, the above-mentioned findings make it clear that differences in academic preparation (such as high school course taking) and *general* college aspirations/attendance are no longer viable explanations for why females are underrepresented in some STEM fields.

Critical determinants of STEM career choices appear to be the development of student engagement and interest (Bandura, 1986; Fouad & Smith, 1996; Fouad, Smith, & Zao, 2002; Lent, Brown, & Hackett, 1994, 1996; Tai et al., 2006) and of student self-perceptions and identity (Hazari, Sonnert, Sadler, & Shanahan, 2010). These determinants start exerting their influence at an early age. Investigations of the stability or development of student interests over time have explored variables that inform career choices. These include variables such as people/things and data/ideas (Su, Rounds, & Armstrong, 2009). Such interests are relatively stable over the eighth- to tenth-grade and tenth- to twelfth-grade spans (Tracey & Robbins, 2005).

Bobo, Hildreth, and Durodoye (1998) found that, in elementary school, girls show more interest in careers that require college degrees (e.g., doctor, teacher, lawyer, veterinarian) in comparison with those chosen by boys (e.g., athlete, policeman, fireman). By middle school, boys and girls are virtually identical in their universal interest and expectation in attending college (Blackhurst & Auger, 2008). There is evidence that girls consider the widest range of potential occupations during middle school and that their views become more restrictive by the start of high school and beyond (Warren, 1990).

This study is intended to improve our understanding of what happens to career interests during a particular, crucial segment of the educational pathway, the high school years. Using a nationally representative data set, it addresses two main research questions:

First, how stable or volatile are STEM career interests for males and females across the high school years? Do the genders differ in this regard?

Second, what is the nature of the fluctuations in males' and females' career choice? For instance, what career plans do those students who lose interest in STEM careers during high school switch to? Likewise, what career choices did those students who become interested in STEM during high school abandon in the process?

METHODS

We used a retrospective cohort study that examines the background of subjects as predictors of their current state. We employed a representative sample of beginning college students who reported their career interests at several educational junctures as well as on a variety of experiences and background variables. The *Persistence Research in Science and Engineering* (PRiSE) project is a large-scale study of students from 34 two- and four-year colleges and universities selected from a stratified random sample that accounted for institution size and type. Rather than survey only students in college STEM courses, we collected data in mandatory introductory college English courses, which generated a more general sampling of college students (including both those interested and those uninterested in STEM careers).

For methodological guidance in our retrospective study, we turned to the field of epidemiology in which great care is employed when substituting recall for longitudinal data collection. Self-report has been studied extensively in college students and is considered highly accurate when the survey addresses issues relevant to the respondents (Kuncel, Credé, & Thomas, 2005). It is difficult to imagine a concern more compelling than students' own career interests when beginning their college education. We followed recommended protocols to ensure a reasonable degree of validity and reliability, which we discuss in more detail below.

Sample

A stratified national random sample of undergraduate students was used. The distinction between four-year and two-year institutions served as the first stratification criterion. Each of the two groups thus obtained was further stratified by the size of the institution (small, medium, and large).

The National Center for Education Statistics (NCES) provided a table of degree-granting postsecondary institutions in the United States in the year 2005 (containing fall 2004 enrollment numbers), generated from the Integrated Postsecondary Education Data System (IPEDS) database. The table comprised 4,454 institutions. Of these, we excluded 457 institutions that showed zero undergraduate enrollment and 218 that showed an undergraduate enrollment of fewer than 100, leaving a total of 3,779 institutions. Both full-time undergraduates and parttime undergraduates were included in the study population.

The IPEDS data indicated that, of the undergraduate population thus defined (14.8 million), about half (44%) attended a total of 1,616 two-year institutions, and the others (56%) attended a total of 2,163 four-year institutions. Our sample was stratified to approximate this ratio of students at two-year and students at four-year institutions.

Using the institutions' undergraduate enrollment numbers, it was determined that roughly a third of the national undergraduate population attended schools that had fewer than 5,400 undergraduates (these were termed "small" institutions), another third attended schools that had between 5,400 and 14,800 undergraduates ("medium"), and the final third attended schools with more than 14,800 undergraduates ("large"). These cutoffs were similar for four- and two-year institutions. Thus, our sampling frame contained 1,732 small four-year colleges, 297 medium four-year colleges, 134 large four-year colleges, 1,227 small two-year colleges, 298 medium two-year colleges, and 91 large two-year colleges.

Each of these six lists of institutions was randomized. Schools without science majors were excluded. We then recruited institutions by going down these six lists until we had enough positive responses from institutions that, in our estimation, a sufficient number of students in the respective category could be reached. To prevent the possibility of students from any single one institution constituting a substantial fraction of the sample, we imposed a cap of 500 students per institution, which was triggered a few times.

Of 160 institutions contacted for this sampling, 43 (26.9%) initially agreed to participate. In the end, we received usable student questionnaires from 34 (i.e., from 79.1% of those who agreed to participate, or from 21.3% of all contacted institutions). To gauge the extent to which the participating institutions might be systematically different from the institutions that, when asked, did not participate, we compared the participating and nonparticipating institutions on some characteristics that were available in the IPEDS data set. In terms of public versus nonpublic institutions, of the 100 contacted public institutions, 29 (29.0%)

initially agreed to participate and 26 (26.0%) eventually did. Of the 60 contacted nonpublic institutions, 14 (23.3%) initially agreed to participate and 8 (13.3%) eventually did. The response rates were thus somewhat higher for public institutions, and public schools were consequently somewhat overrepresented among the participating institutions, but the difference in those proportions did not reach statistical significance.

In terms of the institutions' (33-level) Carnegie classification reported by IPEDS, there were no statistically significant differences between the participants and nonparticipants (neither when we compared those who initially agreed to participate with those who initially declined, nor when we compared those who actually returned filled-out surveys with those who initially declined or initially agreed but did not follow through). We also combined those 33 Carnegie categories into five larger categories: associate degree granting institutions, bachelor's degree granting institutions, master's degree granting institutions, research/doctoral institutions, and special focus institutions. Of 57 contacted associate degree granting institutions, 18 (31.6%) initially agreed to participate and 14 (24.6%) eventually did. Of 24 contacted bachelor's degree granting institutions, nine (37.5%) initially agreed to participate and seven (29.2%) eventually did. Of 36 contacted master's degree granting institutions, eight (22.2%) initially agreed to participate and six (16.7%) eventually did. Of 34 contacted research/doctoral institutions, seven (20.6%) initially agreed to participate and seven eventually did. Of eight contacted special focus institutions, one (12.5%) initially agreed to participate and none eventually did. (One contacted institution had no Carnegie classification.) The differences between these distributions were not statistically significant.

Of the 13,773 surveys requested by institutions that initially agreed to participate (based on attendance estimates by the institutions prior to enrollment), 6,860 filled-out surveys were returned. This corresponds to an estimated gross response rate of 49.8%. If we discount the institutions that despite their initial agreement did not administer the survey, the estimated response rate was considerably higher. Considering only the 10,968 surveys that were requested by schools that actually administered the survey, the estimated net response rate was 62.5%. This rate is almost certainly much lower than the true response rate, because instructors generally overestimated the number of surveys that they would need so they would not run short. The surveys were administered as hardcopies during class time, and this method typically ensures a very high participation rate among the students in class.

Of the 6,860 students in our sample, 56.4% attended four-year, and 43.6% attended two-year institutions. This proportion was extremely close to the corresponding proportion in the population, as described above (56% vs. 44%). Regarding our second stratification criterion, we had aimed at a sample that contained, among both the four- and two-year students, a third of students who attended large institutions, a third of students at medium institutions, and a third who were at small institutions. Among the four-year students in our sample, 41.8% attended large, 26.0% attended medium, and 32.2% attended small institutions; among two-year students, 39.6% attended large, 24.6% attended medium, and 35.8% attended small institutions. Whereas the target proportions of 33.3% for each group were not precisely attained, the actual proportions were deemed close enough to be an adequate representation of the population. Table 1 summarizes the sample numbers by stratification.

Survey

The PRiSE survey had 50 items. Many items used were drawn from an earlier survey study of students enrolled in introductory college science courses (Factors Influencing College Science Success [FICSS]) that underwent a rigorous validation and reliability analysis (Sadler & Tai, 2007a, 2007b). To further establish validity of the PRiSE survey, multiple

TABLE 1
Sample Composition

	Small <5,400	Medium 5,400–14,800	Large >14,800	Total
Two-year colleges				
Institutions in population	1,227	298	91	1,616
Institutions in sample	6	3	5	14
Student surveys returned	1,072	735	1,185	2,992
Four-year colleges and universities				
Institutions in population	1,732	297	134	2,163
Institutions in sample	12	3	5	20
Student surveys returned	1,246	1,006	1,616	3,868

The sample is composed of both two- and four-year institutions.

methods were used. First, face and content validity of the survey were obtained through focus groups with STEM education experts (researchers and experienced practitioners) and students. In addition, open-ended free response questionnaire data from 412 science teachers and scientists served to support content validity because the PRiSE survey incorporated the breadth of views and hypotheses held by practitioners in the field that were gleaned from these questionnaires. To ensure the item choices reflected the variation in experiences of students, the survey was also pilot-tested with 49 students so that items and scales could be adjusted for the final survey to appropriately capture the natural variability in the sample. Test–retest reliability of the survey was established by administering the survey to 96 students twice, in an interval of 2–3 weeks. For continuous variables, the correlation coefficient between the test and retest answers served as a measure of reliability; for dichotomous variables, Cohen's kappa was used. The overall mean test–retest reliability of the survey of 0.70 corresponds to a 0.04% likelihood of a reversal in the direction of an effect (Thorndike, 1997). In the case of identification of career interest, test–retest agreement was 87.2% between the two administrations.

Variables

The survey asked the participants "Which of the following BEST describes what you want(ed) to be" at various points in their lives and provided them a detailed list of 19 career fields from which to choose one. For our career intention variables, we distinguished the following five broad career categories, the first two of which were considered to constitute the STEM area (Chen, 2009; Hill, Corbett, & St. Rose, 2010; Kuenzi, Matthews, & Mangan, 2006, National Governors Association, 2007)[2]:

– engineering (including computer science),
– science (physical, life, and earth sciences, mathematics, science and mathematics teaching),

[2] Quantitative analysis requires precise definitions of categories. In our analysis, we consider interest in a STEM career to include the physical and biological sciences, mathematics and statistics, computer science and engineering majors. While we include the natural sciences, we follow the convention of excluding the social sciences. Medicine and health careers are not considered STEM careers although students do typically major in a STEM field in college. The definition follows the STEM categorization used by the American Association of University Women.

TABLE 2
Breakdown of Students' Career Choices at the Beginning and End of High School

EHS: End of High School Career Interest	BHS: Beginning of High School Career Interest					
	Engineering	Science	Medicine	Health	Other	Total
Female students						
Engineering	39	25	15	9	47	135
Science	12	111	20	11	50	204
Medicine	10	35	240	36	73	394
Health	4	26	108	235	128	501
Other	29	127	150	91	1,037	1,434
Total	94	324	533	382	1,335	2,668
Male students						
Engineering	444	106	41	11	164	766
Science	38	133	16	5	69	261
Medicine	30	13	134	5	34	216
Health	20	9	20	32	25	106
Other	142	85	75	16	917	1,235
Total	674	346	286	69	1,209	2,584

We exclude students with no specific preference.

- medicine (physicians, veterinarians, all requiring advanced degrees),
- health (nursing, medical technicians), and
- Non-STEM–related fields (law, business, arts, social science, non-STEM–related teaching, etc.)

The students reported career intentions at the start and at the end of high school allowing us to trace trajectories of their career interest (Table 2). Students who did not attend high school in the United States and those who did not report their gender are not included in the analysis. Furthermore, the 4% of students who showed no preference for a career at either beginning or end of high school are not part of this analysis, nor are juniors, seniors, or special students who were in these required English courses so that the time span over which recall was required was uniform. The final included sample size included 6,555 students.

For our logistic models, we collapsed the five categories of end of high school career interest into a dummy variable—STEM (comprising the engineering and science categories) versus Non-STEM (comprising the other three categories).

In addition to gender (female = 0; male = 1), we included the student's average middle school mathematics grade in our models (A+ = 4.33, A = 4, A– = 3.67, etc.). This was to serve as a rough proxy for potentially important early, i.e., pre–high school, STEM proclivities. Survey questions also collected data on activities and classes in which students participated during high school. Demographic information was collected on the level of each parents' education (i.e., less than high school, high school, some college, four-year degree, graduate degree), community affluence derived from home zipcode and U.S. Census data, and race/ethnicity (i.e., White, Black, Asian, American Indian, Pacific Islander, other, Hispanic). Multiple selections were allowed for race/ethnicity.

RESULTS AND DISCUSSION

Sankey diagrams (common in thermodynamics to show energy flow) help to visualize the flows in career interest during the high school years (Figure 1). Although there are 25 possible trajectories, just 12 of them account for more than 90% of students within each gender. Sizable overall differences can be seen between the diagrams for the 2,584 males and 2,668 females in the study. Engineering attracts the career interest of a much larger proportion of males than of females. By contrast, medicine and health attract large proportions of females. Roughly, half of both male and female students have an interest in the grouping "non-STEM–related fields."

At the start of high school, a total of 39.5% of the males and 15.7% of the females reported career interests in STEM careers, for a male–female percentage ratio of 2.5:1. At the end of high school, the percentage of those selecting STEM careers is 39.7% of the males compared with 12.7% of the females, for a ratio of 3.1:1. While the start and end percentages of males interested in STEM appear stable at the aggregate level, a large percentage of those selecting STEM careers at the beginning of high school report non-STEM–related career selections at the end of high school. This outflow is counterbalanced, however, by an inflow into engineering and science career selections by other males who earlier had not been interested in STEM. Moreover, some interchange occurs, within the broader STEM area, between engineering and science career selectors among males, with a much larger proportion changing their selection from science at the start of high school to engineering at the end than vice versa. Consequently, the proportion of males selecting science career plans shrinks during high school from 13.4% to 10.1% whereas the percentage of males who reported planning an engineering career grows from 26.1% to 29.6%.

For males, STEM fields dominate, whereas for females health and medicine are more attractive. For the few females interested in engineering, the results are starkly dissimilar to the males' results. Only a minority of females who are interested in engineering at the start of high school persist. Yet, an influx increases the percentage of females from 3.5% to 5.1%. For science careers, both the size and the aggregate trend of the female percentages are relatively similar to the males' results: The percentage of females reporting an interest in science shifted from 12.1% to 7.6% between the start and end of high school. Interesting to note are the small percentages of interchange in career selection between engineering/science and medicine/health among both male and female students. In fact, the shift of females out of science careers is primarily to non-STEM–related careers, with little movement toward careers in engineering—a pattern markedly different from that of males.

As a result of these flows, we find that, among the subset of the students interested in engineering or science careers at the end of high school, 75% are male and 25% are female. Moreover, of the males interested in a STEM career at the end of high school, nearly three quarters had been interested already at the start of high school (Table 3). Among females interested in STEM at the end of high school, about half had been interested at the start of high school. Considering all the males, 12% lose an initial STEM career interest whereas 12% are newly attracted, leaving the overall STEM percentage unchanged. Among females, 9% lose interest and 6% gain interest, a net aggregate loss of 3%.

Inferential Analysis Using Logistic Regression

Because we are dealing with a sample here, it is useful to test whether the development of STEM career plans, broadly considered, is different for males and females in a statistically significant way. A robust means of examining this issue is to construct logistic regression models that produce odds ratios for *end of high school STEM interest* (in which STEM is

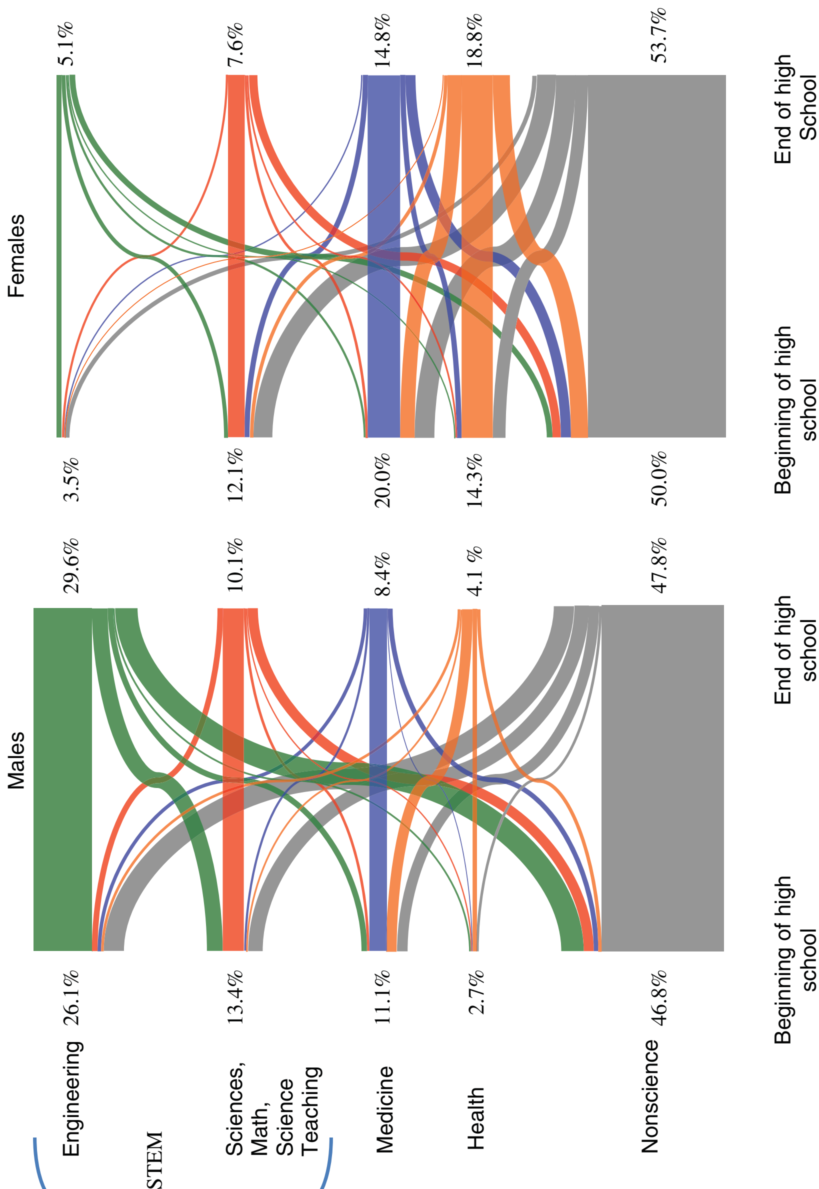

Figure 1. Student career interest at the start and end of high school.

TABLE 3
Breakdown of STEM Interest and Gender in Study Sample

	Beginning of High School Career Interest (%)					
	Male Students			Female Students		
End of High School Career Interest	Not STEM	STEM	Total	Not STEM	STEM	Total
Not STEM	49	12	60	79	9	87
STEM	12	28	40	6	7	13
Total	61	39	100	84	16	100

Four times as many males as females maintain an interest in a STEM career from the start to the end of high school.

TABLE 4
Odds Ratios for Logistic Regression Models on STEM Career Interest

	Model 1	Model 2	Model 3	Model 4
Constant	0.331***	0.462***	0.091***	0.090***
Gender (male = 1)	4.081***	2.819***	2.897***	2.911***
BHS		9.116***	8.568***	8.516***
MS Math			1.590***	1.591***
Interaction: Gender*BHS				1.048
Pseudo-R^2	0.086	0.279	0.292	0.292
N	6,555	6,151	6,130	6,130

BHS: Beginning of high school interest in STEM; MS Math: middle school mathematics grade.
***: $p < .001$.

defined as the combination of both the science and engineering categories shown in Figure 1) as the dependent variable, with gender and beginning high school STEM interest—and their interaction—as independent variables. Logistic models are appropriate when the dependent variable is binary, as in this case. We do not examine, by specific field, the career interest students have at the end of high school, only if they intend to pursue a career in the broad STEM area or not. However, their initial interest in particular careers may be predictive of a greater or lesser likelihood of pursuing a STEM career.

For our logistic regression analysis, we produce a series of nested logistic regression models and examine the behavior of the coefficients—or, rather, the odds ratios derived from them—between each of the successive models. Table 4 shows the odds ratios for the nested models used in this study. Beginning with *gender* alone (Model 1), then including *beginning of high school career interest* (Model 2), then, the last middle school mathematics grade (Model 3). Finally, we tested the interaction variable of *gender *beginning high school interest* (Model 4). The odds ratios for *gender* and *beginning of high school career interest* appear stable. Because the interaction variable lacks significance, we selected Model 3 as the appropriate model to interpret.

According to these statistical models, the odds of reporting a STEM career interest (rather than a career interest outside of STEM) at the end of high school are about nine times as high for students who reported an interest in engineering or science careers at the start of high school as for students who did not report such an interest at the start of high school. Controlling for this, the odds of being interested in a STEM career at the end of high school are 2.9 times as high for males as for females (Model 3). We found no significant interaction between start of high school career interest and gender (Model 4). This shows that an early STEM career interest has a similarly large effect on later STEM career interest regardless of gender or, put differently, that gender has a similarly large effect on later STEM career interest regardless of early STEM career interest. We find that, while the girls were less interested in STEM by the beginning of high school, this gender disparity was exacerbated over the high school years.

We carried out a more expansive analysis with a number of other variables and found that demographics related to race/ethnicity, parental education (as a proxy for socioeconomic status [SES]), and a composite indicator of community socioecomomic makeup combining per capita income levels and educational levels in the students' home zip codes were not significant predictors of STEM career interest at the end of high school, nor was having a parent with an engineering or science-related career. Taken together, these do not appear to be significant factors during high school, although they are predictive of *beginning high school STEM interest*. It appears that parental and SES effects bear on student interest in a STEM career before, but not during high school.

By far the most dominant factor influencing engineering or science career interest at the end of high school is student interest at the start of high school, a factor that differs greatly by gender. In addition, we found that individuals who reported higher middle school mathematics grades had 1.6 times higher odds per grade to report an interest in an engineering or science career at the end of high school than did their peers who reported lower mathematics grades in middle school.

Our models are based upon correlations and should not be interpreted as causal proof, unlike experimental studies. Model 3 has a pseudo-R^2 of 29.2%. There is certainly the possibility that unexamined variables would contribute to the prediction of STEM career interest (e.g., media exposure, encouragement by teachers) and thus could increase the variance explained. Whether conscious or not, the mathematics effect we found reaffirms that mathematics skills are important for choosing STEM careers (Hill et al., 2010). However, on average, girls earn more credits and higher grades than boys in high school mathematics and science (U.S. Department of Education, NCES, 2007). Clearly, differences in mathematics performance cannot explain the gender differences in STEM career interests that we found, particularly because gender is still significant even after controlling for mathematics achievement.

So far, we have used a dichotomous variable of STEM career interest at the beginning of high school. However, our data include the students' specific career interest, which allows us to examine how specific initial career aspirations and gender relate to end of high school STEM interest. Calculating probabilities from the odds ratios makes the data more intuitively understandable (Figure 2). To restate the general picture in probabilities: Of the females who were not interested in STEM at the start of high school, 9% become interested by the end of high school, compared with 21% of their male counterparts. Of the females who were interested in STEM careers at the start of high school, 45% are still interested at the end of high school, whereas 70% of the males maintain interest. Females thus lag males in both recruitment to, and retention in, STEM career interests.

The discipline-specific departures from these averages are informative. Among the students who were not interested in STEM careers at the start of high school, males who aspired to be lawyers still have a 30% chance of changing their mind to pursue a STEM career interest. By contrast, that chance was only 15% for the males initially interested in English and language arts. Among the students who did have an early interest in STEM, males who were interested in physics, other sciences not specified individually on the survey, and mathematics maintains an interest in STEM at a significantly higher rate than those with other initial STEM interests. By contrast, males who early on wanted to be biologists

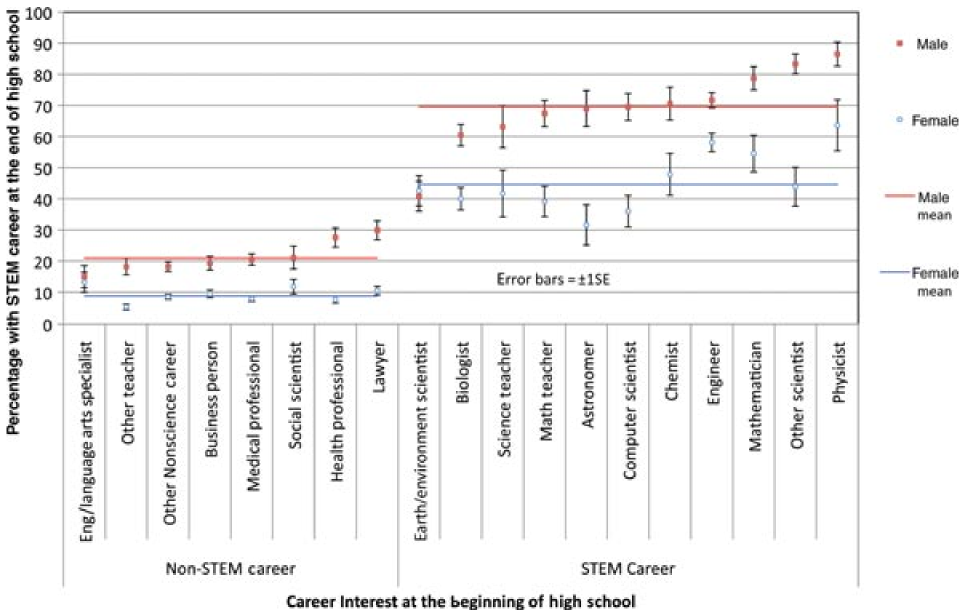

Figure 2. Probability of a STEM career interest at the end of high school based on specific career interest at the beginning of high school.

or earth/environmental scientists have a significantly lower retention than those interested in other STEM fields. Females with an interest in physics or engineering at the start of high school maintain an interest in STEM at a significantly higher level than females initially interested in other STEM fields. Noteworthy gender gaps in persistence (with particularly low female persistence rates) were found in astronomy and computer science.

As a potential limitation, we note that the retrospective nature of the data might have implications for the gender findings. A qualitative STEM study by Seymour (1995) suggested that boys feel a particularly strong social pressure to persist in career interests. Hence, they might, in comparison with girls, tend to overreport stable career interests.

CONCLUSIONS

The main focus of this paper has been to gauge how stable versus volatile the reports of boys' and girls' STEM career interests are over the course of high school. Our findings show that the high school years are characterized neither by overwhelming stability nor by total volatility of career interest, but by a complex mixture of both. Students' career interest when entering high school is the strongest predictor of their career interest when leaving high school. We thus find evidence for the importance of early career interest in science for both male and female students. This result points to the relative stability of students' career plans over the high school period and demonstrates how important early (pre–high school) experiences, socialization, and characteristics are in determining young persons' career intentions. We further found that, regardless of whether an interest in STEM careers is manifest or not at the start of high school, those with high grades in middle school mathematics courses have increased odds of being attracted to STEM at the end of high school.

Regarding gender, we found that at both the beginning and the end of high school, boys with STEM career intentions vastly outnumber girls with these intentions. At the end of high school, for instance, males among college-going students had three times higher odds than females to plan STEM-related careers. This gender disparity is concentrated not in the "science" but in the "engineering" part of STEM. Our findings are tempered by the fact that in this study we have adopted the convention that medicine and health careers (which are particularly attractive to females) are held separate from engineering and science.

The findings from this study emphasize that experiences and attitudes developed prior to high school make a crucial contribution to the current disparity in interest in STEM careers exhibited by female students and the ultimate imbalances seen in the workplace. Girls with a STEM career interest are severely outnumbered by boys with such an interest by the beginning of high school. During high school, then, there is an additional gender effect resulting for both females with and without an initial STEM career interest in lower probabilities, compared with their respective male counterparts, to have a STEM career interest at the end of high school. This may be the result of the females' different experiences in high school science classes, even though overt sexism is rarer than a generation ago (Allan & Madden, 2003). Pedagogies used in science class may still favor males (Middlecamp & Subramaniam, 1999; Sandler, Silverberg, & Hall, 1996; Salter, 2003) or fail to connect science in an engaging way to young women's lives and interests (Barton, 1998). Female students may still experience fewer opportunities or feel less welcome in science-related clubs and activities. Even traditional single-sex organizations can infuse subtle social messages regarding the stereotypic gendering of subjects, i.e., what subjects are appropriate for females and males, at an early stage. For example, compared with the Boy Scouts, the Girl Scouts present girls with fewer science activities, and their badges carry more "playful" and less "career-oriented" language, such as "Sky Search" instead of "Astronomer" or "Car Care" instead of "Mechanic" (Denny, 2011, p. 37). These types of social messages have already been adopted by most students at the beginning of high school and are then reinforced during the high school years (Kessels, 2005; Potvin, Hazari, Tai, & Sadler, 2009).

Because a large gender disparity in career interests already exists at the beginning of high school, particularly good and promising chances for advancing female representation in STEM may lie in efforts to interest girls in STEM at the primary and middle school level. Nonetheless, career plans are not etched in stone once students enter high school, and it is not "game over" for STEM career interests when girls reach high school. We did find considerably more volatility in boys' and girls' career plans over the course of high school, the extent of which is only revealed through a more in-depth investigation of flows. One major lesson from this study is that comparing career interests at two points in time only at the *aggregate* level grossly overestimates stability. In particular, the amount of volatility in high school girls' career intentions suggests that there is certainly room for improving the female representation in STEM careers by measures and initiatives during the high school years that focus on reducing attrition from STEM career goals or on increasing recruitment from the ranks of the initially uninterested or on both. Engineering is an obvious candidate for these efforts. The field of engineering accounts for the largest fraction of STEM careers, but it has been found to be rather unattractive to females in high school currently. It appears that the recent growth in precollege engineering curriculum materials and afterschool programs, with professional engineering societies[3] and college engineering schools[4,5] sponsoring the development of lesson plans, teacher workshops, and competitions may be on target.

[3] http://www.asme.org/Education/PreCollege/TeacherResources/Integrated_Design_Activity.cfm.
[4] http://www.succeed.ufl.edu/icee/workshops/Richards_Presentation.pdf.
[5] http://www.newstreamz.com/2010/01/21/middle-school-engineering-contest-slated-at-texas-state/.

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