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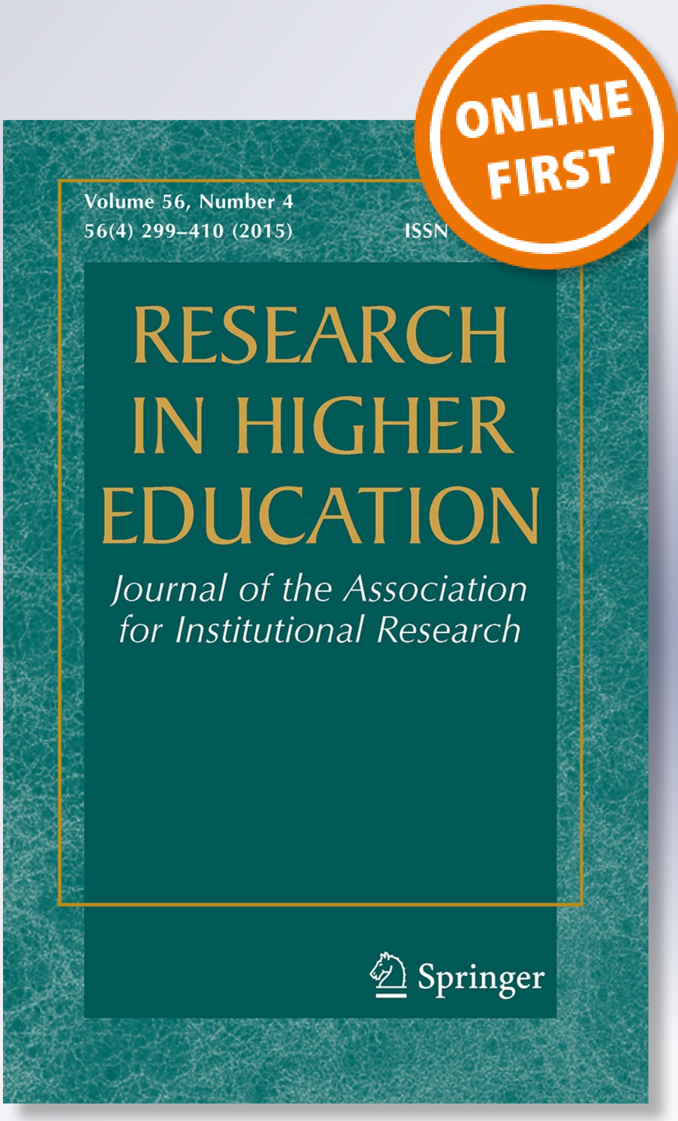

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"But I'm Not Good at Math": The Changing Salience of Mathematical Self-Concept in Shaping Women's and Men's STEM Aspirations

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Abstract Math self-concept (MSC) is considered an important predictor of the pursuit of science, technology, engineering and math (STEM) fields. Women's underrepresentation in the STEM fields is often attributed to their consistently lower ratings on MSC relative to men. Research in this area typically considers STEM in the aggregate and does not account for variations in MSC that may exist between STEM fields. Further, existing research has not explored whether MSC is an equally important predictor of STEM pursuit for women and men. This paper uses a national sample of male and female entering college students over the past four decades to address how MSC varies across STEM majors over time, and to assess the changing salience of MSC as a predictor of STEM major selection in five fields: biological sciences, computer science, engineering, math/statistics, and physical sciences. Results reveal a pervasive gender gap in MSC in nearly all fields, but also a great deal of variation in MSC among the STEM fields. In addition, the salience of MSC in predicting STEM major selection has generally become weaker over time for women (but not for men). Ultimately, this suggests that women's lower math confidence has become a less powerful explanation for their underrepresentation in STEM fields.

Keywords STEM · Mathematical self-concept · Gender · College · Major selection

Introduction

Despite an emphasis in recent decades on creating equitable classroom experiences at the K-12 level, fostering pre-college women's beliefs that science, technology, engineering and math (STEM) fields are not uniquely "male" disciplines, and recruiting young women

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into STEM, college women in the United States continue to enroll in STEM majors at lower rates than men (Hill et al. 2010; Sax 2008). The gender gap in STEM disciplines is most pronounced in the fields of computer science and engineering, where women earn 18.2 and 17.5 % of bachelor's degrees, respectively (National Center for Education Statistics 2013). Women's underrepresentation in STEM persists at a time of heightened awareness that the nation's global competitiveness may be threatened if we do not expand and fortify the U.S. STEM workforce (National Academy of Sciences 2010). Gender inequities in STEM enrollment are also troubling in light of research stressing the importance of diverse classroom and work environments, which tend to foster creativity and problem-solving skills (Carnevale et al. 2011; Blickenstaff 2005; Lewis et al. 2000). Thus, to diversify STEM is to enhance scientific output.

Since the early 1970s, a large body of research has examined women's underrepresentation STEM fields. Major reviews of this evolving literature have been contributed by Blickenstaff (2005) and Kanny et al. (2014). In a review of research spanning the 1970s through the 2000s, Kanny et al. (2014) identify five chief explanations for the gender gap in STEM fields: individual background characteristics; structural barriers in K-12 education; psychological factors; family influences and expectations; and perceptions of STEM fields. They conclude that self-confidence (an aspect of the psychological category) is "by far the most oft-cited explanation for the STEM gender gap" (Kanny et al. 2014, pp. 138–139).

Research on math self-concept, the focus of the present study, has shown that female students who exhibit lower mathematical self-concept compared to their matched-ability male peers are less likely to pursue a STEM major due to the perception that these courses of study require high-level mathematical ability (Bong and Skaalvik 2003). Moreover, female students who do pursue STEM majors, more so than their male counterparts, experience a number of factors that lead to the decline of their self-percieved math ability during college (e.g., certain interactions with faculty, a competitive environment among students) (Sax 1994a, 2008). Thus, math self-concept is linked to the STEM gender gap in various ways, spanning from the effect on women's choice to pursue a STEM major to the experiences they have after arriving at college, such as interaction with faculty or test anxiety (Aronson and Steele 2005; Sax et al. 2005).

Although there is a wealth of knowledge that connects math self-concept to women's pursuit of and persistence in STEM, significant gaps remain in the literature. Especially problematic is the fact that we know about the gender gap in math self-concept primarily for STEM students aggregated across all STEM fields, and rarely, if ever, for students in specific STEM fields. In particular, we do not know how mathematical self-concept and its associated gender differences vary between sub-fields of STEM. It is reasonable to presume that the gender gap might vary across STEM fields due to clear variations in women's representation across these fields, in addition to the fact that some STEM fields place a greater emphasis than others on math ability as a prerequisite (e.g., mathematics and engineering) (Fairweather 2008; National Science Board 2012). Further, the literature has not examined shifts over time in the nature and importance of math self-concept vis-à-vis decisions about entering STEM. As such, little is empirically known regarding how stable the gender gap in math self-concept may be or how the stability of the gender gap varies by STEM subfield over time.

An exploration into these key unknowns is important for several reasons. First, we cannot presume that the frequently cited gender gap in mathematical self-confidence is equivalent across all areas of STEM; it is possible that the gender differences in math confidence are larger in some STEM fields than others. Second, a contemporary understanding of the importance of math confidence should take into account whether the gender gap has narrowed or widened over the past several decades, a time during which significant efforts have been made to encourage women's development of quantitative skills and related self-concepts. Third, we must question how much math self-concept matters in the pursuit of specific STEM fields, and whether that has changed over time for women or men. Policy and practice should be guided by information detailing the extent that math confidence has become more or less important in shaping women's and men's STEM aspirations. In the section that follows we review extant literature related to mathematical self-concept, how it differs between men and women, and its role as a factor in women's decisions to pursue a STEM major.

Literature Review

Mathematical Self-Concept

The construct of mathematical self-concept stems from the domain of academic motivation research. Theory and literature within this area of scholarship are dedicated to understanding how psychological processes relate to various patterns of achievement behavior within academics (Bong 1996). Central to these psychological processes are self-perceptions, which have been consistently identified as predictors of achievement behavior. Academic self-concept represents a key predictor of individuals' motivation, emotion, and performance and is often used as a way of explaining the role of self within the school context.

While defined in the literature in various, complementary ways, academic self-concept might be most generally defined as one's perceived competence in a specific domain (often an academic subject) in a normative way (in comparison to peers or the average person) that includes both cognitive and affective evaluations of the self (Bong and Skaalvik 2003; Marsh 1986; Marsh and Martin 2011). Academic self-concept is also often defined as relating to subject- or course-specific perceptions of ability. Thus, applied to the mathematical domain, self-concept refers to an individual's perception of his/her own abilities related to mathematics as compared to others (Bong and Skaalvik 2003).

Having defined mathematical self-concept, it is important to review what leads to the development of such self-related perceptions of ability. Of particular importance to the present study are factors that are associated with pre-college mathematical self-concept. An individual's pre-college mathematical self-concept is initially shaped by experiences within the primary and secondary academic environments, and is reinforced by subsequent experiences within these environments and by the influences of significant others, such as teachers, family, and peers (Shavelson et al. 1976). Interestingly, research has also noted that math self-concept declines from childhood to adolescence (Eccles et al. 1993; Marsh 1989; Wigfield et al. 1997). Student-level characteristics that are positively associated with pre-college math self-concept include students' degree aspiration (Smart and Pascarella 1986), high school academic achievement, and socioeconomic status (Astin 1993; Pascarella et al. 1987). However, students' verbal achievement often negatively predicts math self-concept (Marsh 1986; Marsh et al. 1985; Sax 1994a).

Gender Differences in Mathematical Self-Concept

A great deal of research has indicated that female students tend to exhibit lower math self-concept as compared to their same-ability male peers during the pre-college years (often reflecting an under-estimation of women's math abilities), and that these gender differences tend to widen during the college years (Sax 1994a, b, 2008; Wigfield et al. 1997). In particular, the gender gap in students' perceptions of their math ability appears at the elementary school level and remains relatively consistent onward until college (Marsh 1989; Wigfield et al. 1997). Then, the gender gap in math self-concept widens at the college level, with the most prominent increases in the gap occurring among students who do not major in math or science (Sax 1994a, b).

The gender gap in math self-confidence may be due to a number of factors. Shavlik and Shavlik (2004) assert that these gender differences are most commonly explained in terms of gender stereotypes and gender role socialization. That is, mathematics is frequently considered a "male" field, whereas reading, language, and other humanities are stereotyped as being "feminine" domains. Accordingly, sometime during adolescence, girls begin to internalize notions that math is not a field in which they are likely to be successful, generally through experiences within various environmental contexts, such as the home and school (Shavlik and Shavlik 2004). These gender stereotypes and processes of socialization may explain why adolescent girls tend to rate their mathematical ability lower than matched-ability male peers do (Eccles 1994; Pajares 2005; Watt 2006). The degree to which these explanations have held within the literature vary, however, with some scholars suggesting that the gender gap in math self-concept may be diminishing and that the mathematics field is becoming less perceived as a masculine enterprise (Marsh and Yeung 1998; Watt 2000). Regardless, it is important to note that employers in the STEM fields continue to rely upon these stereotypes of men and women's comparative mathematical ability when making hiring choices (Reuben et al. 2014).

Thus, the literature related to gender differences in mathematical self-concept has illustrated the existence of a significant gender gap, both in the pre-college and college years, that tends to grow larger as time goes by. Further, the cause of this gender gap has been traced to a number of factors inclusive of psychological and socialization processes as well as specific behaviors and actions. In the following section, these gender differences are considered within the context of the STEM gender gap in college majors.

Mathematical Self-Concept as a Predictor of the Gender Gap in STEM Major Aspirations

As noted earlier, a constellation of factors has been used to explain gender differentiation in choice of major, with women's lower level of self-concept emerging as a leading explanation for their underrepresentation in many STEM fields. In particular, research has consistently stressed the importance of students' self- perceptions of mathematical ability in the decision to pursue a STEM major once they arrive at college (Casey et al. 1997; Fredricks and Eccles 2002; Marra et al. 2009; McGraw et al. 2006; Meece et al. 1990; Pajares and Miller 1994).

Principally, higher math self-concept is related to an increased likelihood of majoring in a STEM discipline due to the high value placed on students' math attitudes and achievement in high school as predictors of STEM major participation (Correll 2001; Tai et al. 2006). Because math self-concept plays a key role in both of these aspects, it is situated as a critical factor in predicting both men's and women's aspirations to pursue a STEM major (Wang 2013). For example, from a national sample of high school seniors, Correll (2001) found that female students' relatively lower self-perceptions of math abilities was a particularly significant predictor of the gender gap in STEM major declaration. Additionally, math self-concept plays a key role in shaping students' aspirations to major in a STEM discipline due to its inextricable relationship with mathematical achievement. While difficult to parse due to their iterative relationship, research has indicated that high math self-concept is a positive predictor of math achievement. Research related to the STEM gender gap shows that women who rate themselves lower in math ability tend to demonstrate lower achievement in math (Ethington 1988; Marsh et al. 1985; Meece et al. 1982; Sherman 1982). Thus, the negative impact of women's comparatively lower levels of math self-concept is multiplied within these circumstances where achievement is also impacted.

Of additional note, the effect of math self-concept on STEM major choice is notable due to the potential for its long-term, cumulative impact on students' mathematical attitudes and achievement. While much of the STEM literature has focused on the role of math self-concept in predicting STEM major choice among high school students, evidence indicates that the impact of math self-concept on students' aspirations begins long before the secondary years (Eccles 1994; Eccles et al. 1998; Wigfield and Eccles 2000).Thus, it might be said that mathematical self-concept plays a longstanding and significant role in the gender gap in STEM major and career aspirations, which begin to form as early as the eighth grade year (Riegle-Crumb et al. 2011).

Objectives

The literature is clear in illustrating a pervasive gender gap favoring men in mathematical self-concept, as well as underscoring the role of math self-concept as a key predictor of STEM major choice for both women and men. However, prior research has tended to examine the role of math self-concept in predicting the choice of STEM fields in the aggregate, and little is known about how the salience of math self-concept as a predictor of major choice might vary across different STEM majors. Moreover, existing research does not reveal whether there have been changes over time in the salience of math self-concept as a predictor of STEM major selection. Accordingly, this study aims to address both of these gaps in the literature in order to achieve a more nuanced understanding of the role of mathematical self-concept and its connection to STEM decision-making at the point of college entry.

More specifically, this study utilized 40 years of national data on incoming college students to address the following research questions:

1. How do women's and men's mathematical self-concepts compare across different STEM fields?
2. How has the gender gap in mathematical self-concept changed over the past 40 years within different STEM fields?
3. To what extent has the salience of math self-concept as a predictor of STEM major selection changed for women and men in recent decades?

Conceptual Framework

In order to conceptualize the present study, we draw from the body of literature on career-development and utilize social cognitive career theory (SCCT) (Lent et al. 1994, 2002). The development of career aspirations and related goals is widely conceived of as a life-long process (Ginzberg et al. 1951; Gottfredson 1981; Super et al. 1990). As such, SCCT

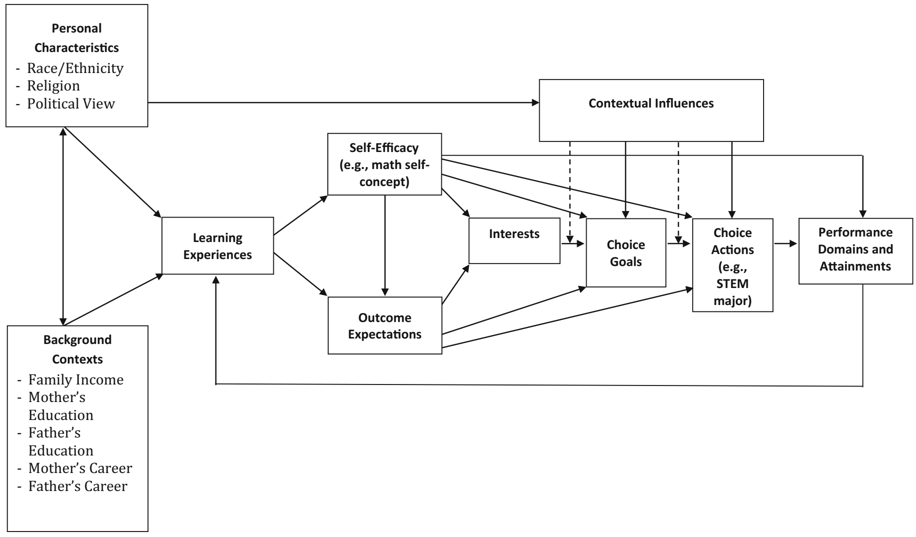

Fig. 1 Model of career-related choice behavior [adapted from Lent et al. (1994)]

describes a process by which several factors over a number of years account for individuals' decision to pursue a particular career path (represented in this study by college major selection). SCCT was deemed appropriate for this study for two primary reasons: (1) SCCT organizes both person and environment variables into a model of career choice that has been empirically tested and supported; and (2) SCCT unifies conceptually related constructs such as self-concept and self-efficacy to provide a more universal framework for studying career choice and behavior.

SCCT allows for the organization of seemingly unrelated person and environment variables into a structure that has been empirically supported and regularly applied to STEM career decisions (Lent et al. 2002). Specifically, the SCCT Model of Career Related Choice Behavior posits that personal inputs and background contexts lead to various learning experiences (see Fig. 1). As evidenced by the literature review, these socializing experiences inform the development of one's self-efficacy and expectations regarding the personal value of pursuing a given task (e.g., career outcome expectation) ultimately leading to the development of interests and the determination to undertake particular tasks (goals). Overall, these personal, contextual, and experiential factors are closely interrelated and in constant recursive processes of influence. SCCT explains how personal, contextual, and experiential factors influence an individual's perceived ability to successfully undertake the task (self-efficacy) and how that self-efficacy then influences actions toward a particular career path. Although this study focuses on the role of math self-concept—a broader concept related to self-efficacy—SCCT provides a relevant framework for this study by framing how an important social cognitive variable can develop overtime and influence career choice.

Self-concept (in this case math self-concept) is closely related to self-efficacy, and thus can be conceptualized within SCCT (Lent et al. 2002). Historically, separate bodies of literature developed around self-concept and self-efficacy; however, one of the primary goals of SCCT was to unify conceptually related constructs—notably self-concept and self-efficacy—into a more universal framework. Both constructs pertain to an individual's self-perceptions, although self-concept is a broader assessment of self in terms of the skills and abilities that one possesses whereas self-efficacy focuses on one's confidence to successfully apply their abilities to a given task (Bandura 1997; Bong and Skaalvik 2003). Both self-concept and self-efficacy are empirically correlated (Bong and Clark 1999; Lent et al. 1997, 2002; Pajares and Miller 1994) and help to explain career choice and attainments (Lent et al. 1994). Further, some scholars suggest that the two concepts might be more analogous in practice than theories suggest (Pajares and Miller 1994; Bong and Clark 1999).

Methods

Data Source and Sample

This study utilizes data from the Cooperative Institutional Research Program (CIRP), the oldest and largest longitudinal study of American higher education. The CIRP Freshman Survey (TFS), begun in 1966 and currently housed in the Higher Education Research Institute (HERI) at UCLA, asks entering college students a wide array of questions related to demographic background, high school experiences, college expectations, self-concepts, values, and life goals as well as their academic and career aspirations. Such information uniquely serves the objective of this analysis to study the role of students' mathematical self-concept and its relationship with STEM major selection.

The present study utilized nationwide TFS data from baccalaureate-granting institutions between 1971 and 2011 (trends sample), which informed analysis of the shifts over time in mathematical self-concept for STEM men and women. Among the 1305 institutions represented, the sample was comprised of 49 % private religious colleges and universities, 30 % private non-sectarian institutions, and 21 % public colleges and universities. The trends sample included approximately 1.5 million first-year students,[1] and was weighted to account for student gender as well as institutional control, type, and selectivity in order to better reflect the population of first-time, full-time college students at all four-year institutions in the United States (see Pryor et al. 2010) for a weighting scheme, in addition to validity and reliability).

Our analysis of forty-year trends data was supplemented by a more detailed focus on data from 5 specific years: 1976, 1986, 1996, 2006, and 2011 (regression sample). This regression sample provided insight into the specific predictive power of math self-concept in men's and women's STEM major selection, and was composed of approximately 353,000 students across five STEM disciplines, and 1149,000 students from non-STEM disciplines (see Table 1). The 5 years included in the regression sample were chosen because they provide the most robust set of shared items across the 40 years of survey administration, while also capturing our chief variable of interest (self-rated mathematical ability) at each time point. Self-rated mathematical ability was only asked three times in the 1970s ('70, '74, '76). When looking at the commensurate years in the 1980s, 1990s, and 2000s, the dataset that included the most consistent variables for use as control variables in the regression analyses were the "sixes" (e.g., 1986, 1996, 2006). Finally, we endeavored to include a more recent year to capture any changes that had occurred in the

[1] Among the students included in the survey, 44 % attended public colleges and universities, 31 % were enrolled at private religious institutions, and the remaining 25 % attended private non-sectarian institutions.

Table 1 Five-year sample (1976, 1986, 1996, 2006, 2011) by major and gender

	CS		Engineering		Mathematics/statistics		Physical sciences		Biological sciences		All other majors	
	M	W	M	W	M	W	M	W	M	W	M	W
1976	2845	1853	25,298	3245	2275	1791	7533	2767	12,538	11,057	95,489	131,579
1986	5042	2706	24,778	4777	1402	1370	4009	1932	6255	7458	83,107	125,791
1996	8297	2457	22,072	5242	1296	1309	4215	3151	11,630	17,665	99,557	158,379
2006	4349	653	24,664	5780	1726	1580	4890	4052	11,587	19,203	106,751	171,123
2011	3278	618	20,514	5436	1237	1220	3866	3066	10,342	17,037	68,850	108,647

recent past (including changes that may have been influenced by national or global events). Looking a half-decade ahead, we noted that by including 2011 in the dataset we gained the use of recent data without losing any key variables from the dataset; surveys after 2011 shifted to a new categorization of college majors.

Variables

The five dependent variables were single indicator measures reflecting students' intent to major in one of the following STEM fields of study, versus all other fields: biological sciences, computer science, engineering, mathematics/statistics, or physical sciences (see Table 4 in Appendix for specific majors included in each category).[2] As noted above, our chief independent variable of interest was students' self-rating of mathematical ability, which is indicated on a five-point scale comparing the student to "the average person your age": lowest 10 %, below average, average, above average, and highest 10 %.

Additional independent variables included in this study represented student characteristics from the Freshman Survey that have been identified in prior research as predictive of choice of STEM major, or that otherwise align with SCCT. Seven of these variables were composite variables created via exploratory factor analysis in order to improve parsimony and reduce multicollinearity in the regression model (see Table 5 in Appendix). To specify the factors, we used principal axis factoring with promax rotation. This process was performed first for the entire regression dataset (5 years combined), and then the strength of the factors were further verified for each of the 5 years. The threshold for reliability was set at a Cronbach's *alpha* of .60,[3] and variables were only considered valid for inclusion in a factor if they loaded at .40 or higher (ultimately, all loadings exceeded .60). In all, seven factors were created (see Table 5 in Appendix).

The independent variables for this study were grouped into the following categories in line with SCCT:

- Personal inputs: race/ethnicity, religion, political view.
- Background characteristics: family income, mother's and father's education, mother's and father's careers.
- Learning experiences: high school GPA.
- Outcome expectations: future expectations to change major field and make at least a 'B' average.
- Interests: self-rated math ability; goals of making a theoretical contribution to science, raising a family, and developing a meaningful philosophy of life; expectations of changing major field, and making at least a B average; leader personality (factor), scholar personality (factor), social activist personality (factor), artistic personality (factor), and status striver personality (factor); educational and extrinsic reasons for going to college (factors).

[2] To categorize which majors qualified as "STEM," we took a twofold approach. First, we examined the National Center for Educational Statistics (NCES) Classification of Instructional Programs (NCES 2002), which helped us to narrow our broad list of majors into categories (noted in Appendix Table 4). Next, we examined these categories in concert with extant literature and prevailing definitions as used by the National Science Foundation (NSF) and the Department of Homeland Security (DHS) (Gonzalez and Kuenzi 2012). In doing so, we determined our list of STEM fields to include the five mentioned in the text, which are the most frequently used categories of STEM across these sources.

[3] We included some factors that fell just below this threshold due to prior usage in several major studies (e.g., Astin 1993; Sax 2008).

– Contexts proximal to choice behavior: distance of college to home, number of colleges applied to, and concerns about financing college.
– Choice goals: degree aspirations.

The variables were organized according to the Model of Career Related Choice Behavior taking into consideration the point at which the students were taking the survey (immediately prior to beginning college). Personal inputs and background characteristics included variables that would have likely influenced the development of career ideas over one's lifespan. Learning experiences (high school GPA) represented the culmination of academic performance. Self-efficacy was most closely represented by math self-concept. Outcome expectation variables represent indicators of expected success or persistence in their major field. Interest variables represent various interests that may relate to or deter individuals to pursue a particular path. The degree aspiration goals represent broad motivators that would lead directly lead individuals to select STEM or non-STEM majors. Proximal contexts influence the perceived availability of major choices or programs. They also are environments that could influence the need for some individuals to select future careers or majors based on their current economic situation or other external needs.

The remaining measures included a continuous year variable represented by: 0 = 1976, 1 = 1986, 2 = 1996, 3 = 2006, and 4 = 2011, and institutional variables (Undergraduate Enrollment; Student-Faculty Ratio; Institution Type as defined by University or College, Religious or Non-Sectarian, and HBCU; and Institutional Region). Finally, cross product interaction terms [math self-concept × (year)] were included with respect to 1986, 1996, 2006, and 2011 to indicate whether the salience of math self-confidence has changed over time (i.e., relative to 1976 levels) for men or women. See Table 6 in Appendix for descriptive statistics and coding for all variables.

Data Analysis

Research Questions 1 and 2 examined students' self-ratings on mathematical ability disaggregated by each of the five STEM sub-fields and over time (1971–2011). Specifically, frequency distributions of the 2011 math self-rating measure within each of the five STEM fields (compared to "all STEM" and "all students") were used to address Research Question 1. In turn, Research Question 2 was explored via examination of forty-year trends in the proportion of men and women in each STEM field who indicated their math ability as "highest 10 %". This category was selected because it represents those students with the highest levels of math confidence, a key trait known to predict STEM major selection.

Research Question 3 investigated the relationship between math self-concept and the selection of each of the five STEM majors using a dataset that pooled five years of data: 1976, 1986, 1996, 2006, and 2011. Binomial logistic regression analyses conducted separately by gender were used to examine the predictive power of math self-concept on the selection of each of the five STEM major fields, in light of other influential factors as suggested by SCCT.[4] In order to determine how the salience of math self-confidence changed over time, interaction terms (math self-concept * [year]) were included as a final block of predictor variables in each of the models.

[4] We opted to run binomial logistic regression because our interest was in the choice of each STEM major relative to all other STEM majors; future research may wish to use multinomial logistic regression to differentiate the choice to major in one specific STEM major versus another.

Results

Gender Gaps in Math Self-Concept Ratings Across STEM Fields

Research Question 1 compared mathematical self-concept by gender and by each of five STEM subfields: biological sciences, computer science, engineering, mathematics/statistics, and physical sciences. Frequency distributions for students' 2011 math self-ratings are shown in Table 2, with results for "all STEM" and "all Majors" included as points of reference. Looking first at the far right side of the table, it is clear that math self-ratings were higher for "all STEM" than for "all Majors," with those majoring in the STEM fields much more likely than students across all majors to view their math abilities as being in the "highest 10 %" (17.8 vs 8.7 % among women; 31.0 vs 19.0 % among men). Further, the table also reveals a great deal of variability among the STEM fields; for both women and men, the highest math self-ratings were observed among students in math/statistics, followed by engineering, physical sciences, computer science, and biological sciences. Notably, ratings of math ability for students in the biological sciences were only slightly higher than ratings of math ability for students across all majors combined. Thus, the notion of high math confidence among students in STEM is not generalizable across all STEM fields.

Table 2 also reveals a gender gap in math self-ratings within each of the five STEM subfields, reflecting that women's lower conception of their math ability is a pervasive issue across STEM, even in fields where women's beliefs about their math ability were especially strong. For example, 68.5 % of men majoring in math/statistics reported their math ability as being in the "highest 10 %," compared with 50.7 % of women in this same field.

The Changing Nature of Gender Gaps in Math Self-Concept Ratings by Field

Having established that a gender gap existed in math confidence among first-year students aspiring to the STEM fields in 2011, we now turn to our second research question, which examined how mathematical self-concept has changed over the past 40 years for women and men majoring in each of these STEM fields. Focusing on those students who indicated the highest levels of math confidence ("highest 10 %"), results over the past 40 years revealed two key facts: (1) math self-concept has varied significantly by STEM field over the entire time frame; and (2) the gender gap in math self-rating was fairly stable over time in four of the five STEM fields (see Figs. 2, 3, 4, 5, 6). The one exception is engineering; notably in the 1970s, very high math confidence among engineering majors was more common among women than among men. However, the gender gap in engineering students' math confidence reversed itself in the early 1980s, and has since favored men, similar to what was observed consistently in all other fields.

Changes in the Salience of Math Self-Concept as a Predictor of STEM Major Choice

Thus far, the results have indicated that although levels of math self-confidence vary across the STEM fields, the gender gap in math self-concept has been nearly constant across the STEM fields and over time. We now turn to research question 3, which examined whether the salience of math self-concept as a predictor of STEM major selection has changed for

Table 2 Self-rated math ability by gender and intended major, 2011

	Biology		Computer Science		Engineering		Mathematics/statistics		Physical sciences		All STEM		All majors	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Weighted N	58,189	93,320	20,271	3508	130,727	31,914	6152	6233	20,612	16,320	23,5949	151,297	681,013	809,082
Rating	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Highest 10 %	19.8	11.2	25.2	16.4	34.7	30.0	68.5	50.7	33.7	19.1	31.0	17.8	19.0	8.7
Above average	40.0	35.2	40.5	41.0	46.4	50.2	29.7	44.6	40.8	40.6	43.4	39.5	36.6	27.4
Average	30.6	37.7	26.6	34.2	16.6	17.0	1.8	4.3	19.5	29.5	20.8	31.0	30.6	38.2
Below average	8.6	13.5	7.1	7.6	2.1	2.5	0.0	0.4	5.6	9.0	4.4	10.0	11.7	20.9
Lowest 10 %	1.0	2.4	0.5	0.8	0.3	0.3	0.0	0.0	0.5	1.8	0.5	1.8	2.1	4.8

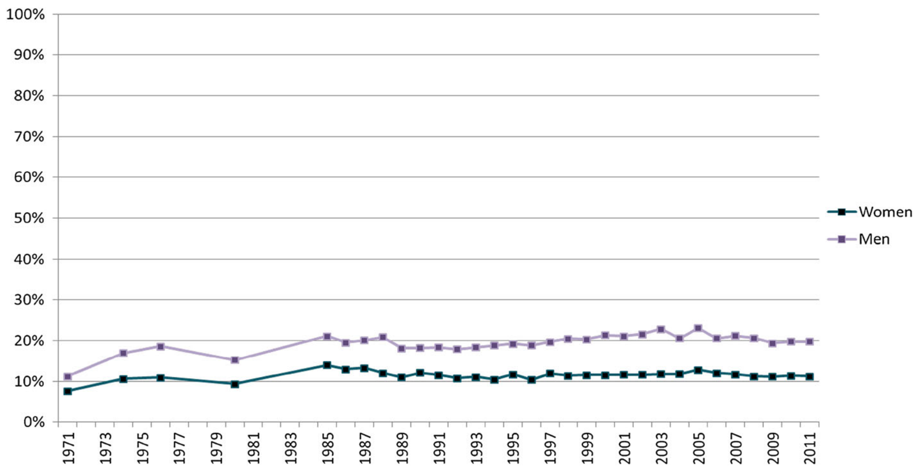

Fig. 2 Proportion of entering biology majors who rate their math ability as "highest 10 %," by gender (1971–2011)

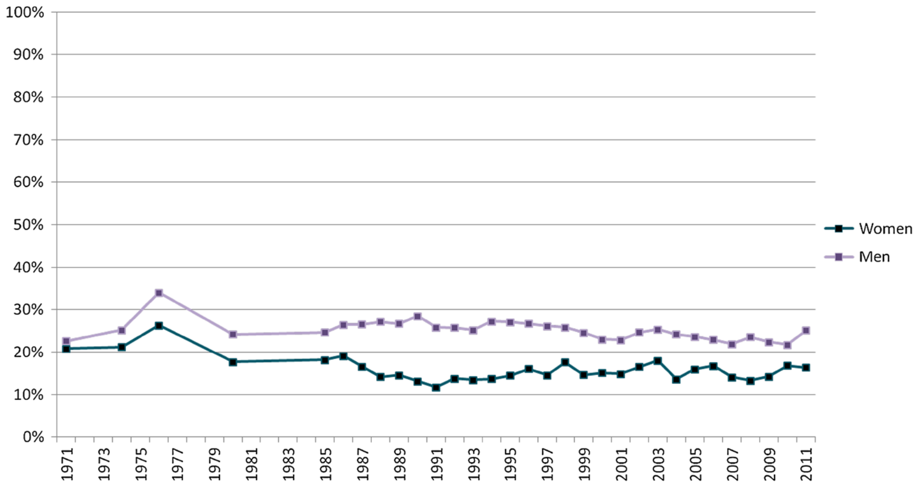

Fig. 3 Proportion of entering computer science majors who rate their math ability as "highest 10 %," by gender (1971–2011)

women and men over the past four decades, controlling for other predictors of STEM interest. While complete regression results are provided in Appendix A,[5] the following presentation of results focuses specifically on the evolving role of math self-concept in predicting STEM major selection.

Table 3 displays the logistic regression coefficients for math self-concept on the selection of each of the five STEM fields separately by year and gender, holding constant all other independent variables. The first row represents the main effect of math self-

[5] Table 7 provides logistic regression coefficients for the regression model, while Table 8 provides these data as Delta-P statistics.

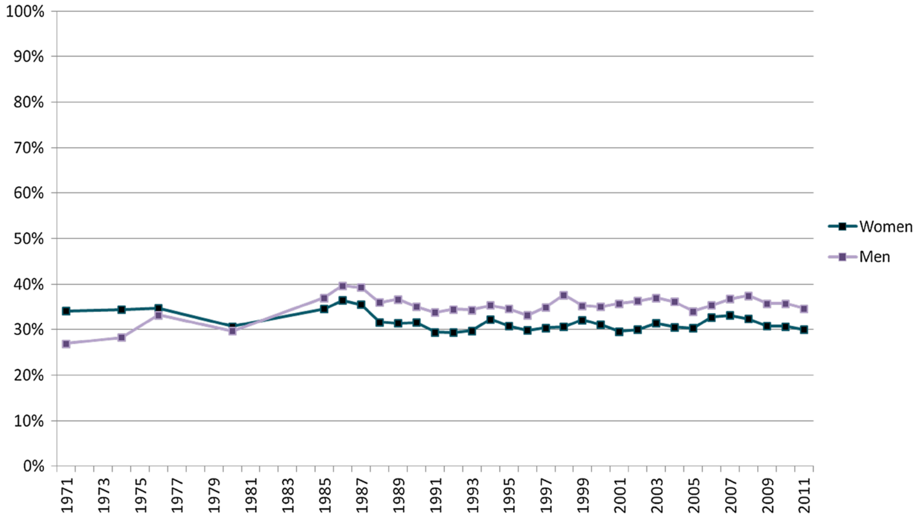

Fig. 4 Proportion of entering engineering majors who rate their math ability as "highest 10 %," by gender (1971–2011)

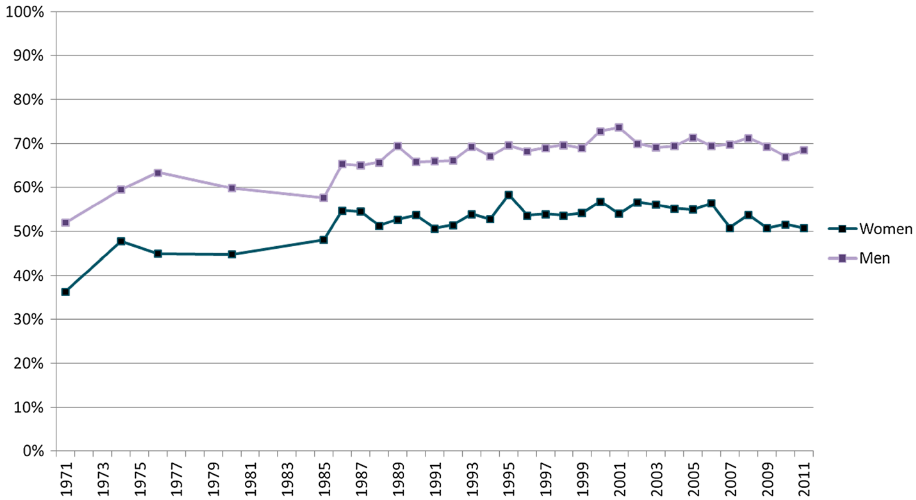

Fig. 5 Proportion of entering math/statistics majors who rate their math ability as "highest 10 %," by gender (1971–2011)

concept in 1976. The remaining rows reflect the difference between the predictive power of math self-concept in each of the subsequent years relative to that in the base year of 1976. For example, in predicting the selection of computer science major among women, the coefficient for math self-rating is .893 in 1976, but drops to .458 by 2011 (.893 minus .435).

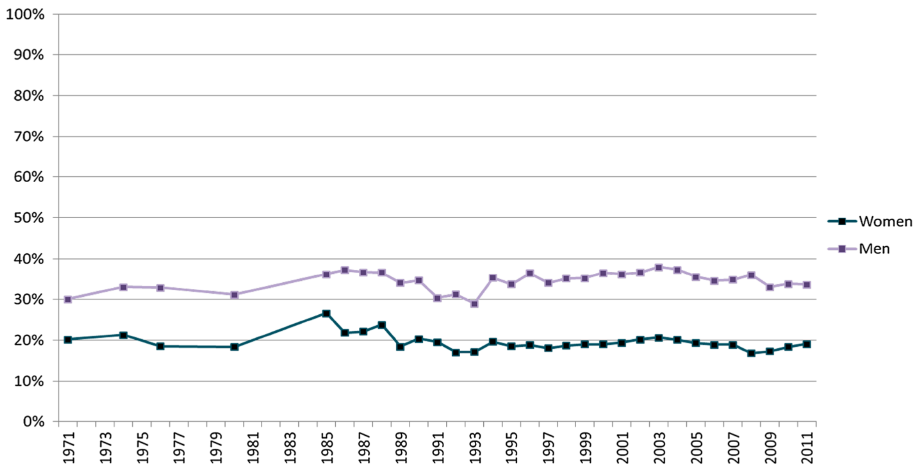

Fig. 6 Proportion of entering physical sciences majors who rate their math ability as "highest 10 %," by gender (1971–2011)

With only one exception, the table reveals that, in 1976, math self-concept was a significant and positive predictor of both men's and women's decision to major in each of the STEM fields. In other words, holding constant other predictors of major selection, including demographic factors, academic achievement, degree aspirations and personality, students who reported stronger self-assessments of their mathematical ability were more likely to major in each of the STEM fields, regardless of their gender. The one exception is that math self-rating was a significant negative predictor of majoring in the biological sciences for men.

Looking across the years, what do the results suggest about the changing salience of math self-concept in predicting choice of each STEM major? Table 3 reveals significant changes over the years in the predictive power of math self-rating. Sometimes the nature of change was similar for the two genders, such that the predictive power of math self-concept either strengthened for both women and men (as in math/statistics) or weakened for both women and men (as in computer science).

In the remaining three fields, the pattern of change over time differed for the two genders. In predicting the choice of biological science major, math self-confidence was a positive predictor for women in 1976, but became less positive (and in some years negative) over time. Nearly the opposite occurred for men, for whom math confidence was a significant negative predictor of majoring in the biological sciences initially, ultimately becoming less negative by 2011 (as indicated by the positive interaction term in 2011). In predicting the engineering major, while the predictive power of math self-concept has fluctuated over time for both genders, it has shown a net weakening over 35 years for women and a net strengthening over this time span for men. Finally, while math self-concept became a weaker predictor of majoring in the physical sciences between 1976 and 1996 for both genders, its predictive power ultimately rebounded for men, while becoming a more negative predictor over time for women. In sum, results indicate that the salience of math self-concept in predicting STEM major selections not only varies by gender and across STEM fields, but has also fluctuated over time.

Table 3 Predictive power[a] of self-rated math ability and its interaction terms on STEM major selection

	Biological Sciences		Computer Science		Engineering		Math/Statistics		Physical Sciences	
	M	W	M	W	M	W	M	W	M	W
Self-rated math ability[b]	−.227***	.106***	.322***	.893***	.738***	1.197***	1.622***	1.877***	.294***	.513***
Self-rated math ability*1986	−.099***	−.153***	.092***	−.030 (NS)	.007(NS)	−.034**	.021 (NS)	−.024 (NS)	−.064***	−.103***
Self-rated math ability*1996	.004 (NS)	−.088***	.148***	−.128***	−.036***	−.147***	.075 (NS)	−.013 (NS)	−.082***	−.126***
Self-rated math ability*2006	.003(NS)	−.129***	−.084***	−.461***	−.011(NS)	−.234***	.231***	.093 (NS)	−.017 (NS)	−.115***
Self-rated math ability*2011	.062**	−.101***	−.127***	−.435***	.058***	−.245***	.343***	.193**	.029 (NS)	−.144***

* $p < .01$, ** $p < .001$, *** $p < .0001$

[a] Logistic regression coefficients controlling for all independent variables

[b] The main effect of math self-rating is reported for the model containing its interaction terms and thus represents the association between math ability and STEM major selection in 1976

Limitations

While this study contributes new knowledge about the role of math self-concept in contributing to the gender gap in STEM major selection, it is important to acknowledge several key limitations. First, mathematical self-concept is measured as a single item. It would be preferable to include a variety of indicators of students' self-conceptions of their mathematical and scientific abilities. Nevertheless, prior research has shown single-item math self-ratings to correlate with other aspects of academic self-confidence, and specifically has demonstrated the validity of single-item math self-ratings in understanding women's experiences in STEM (Sax 1994a, b).

Second, the study could not include all possible determinants of STEM major selection. The multivariate portion of this study was limited to five time points for which a consistent set of survey items was available: 1976, 1986, 1996, 2006, and 2011. Due to available data in these years, we could only focus on the role of selected measures within the SCCT framework. Specifically, we did not have data on all variables shown to be important in research on major selection in STEM fields, such as gender-role socialization, experiences in K-12 education, perceived sense of belonging in STEM, and the influence of parents and peer groups. Third, the dependent variables refer solely to intended major at the point of college entry. Considering that major choice can and does change over time, longitudinal data tracking major selection over the course of college would be ideal. Such data do exist in the HERI follow-up studies, however the longitudinal samples are much smaller and far less representative than those yielded by the Freshman Survey.

Finally, our reliance on four decade-spaced (and one half-decade) intervals for the multivariate analysis means that we could have overlooked important changes that occurred in the intervening years. Just as the popularity of a given STEM field may fluctuate over time, so might the salience of math self-concept. Thus, the results of this study may overlook the extent to which the predictive power of math self-concept ebbed and flowed in the years that are unexamined.

Summary of Results

Key findings are evident from the results of this study. First, while students' beliefs about their math ability are higher among those majoring in STEM fields relative to all majors, there is a great deal of variation in demonstrated math self-concept among the STEM fields, from a high in math/statistics to a low in the biological sciences. Second, men currently report higher math self-ratings than women, representing a gender gap that holds true across all STEM subfields. Third, trends over four decades reveal a pervasive gender gap in math self-concept within all STEM subfields (with the exception of engineering, where the gender gap favoring men did not emerge until the mid-1980s).

Finally, and of central importance to the study, though math self-concept is nearly always a significant positive predictor of students' decisions to major in STEM, its salience in predicting major choice has fluctuated over time. For women, the salience of math self-concept has grown in the prediction of selecting majors in math/statistics, but has weakened over time in explaining women's decision to major in the remaining four STEM fields. This finding is particularly important because it extends prior research that has only considered the role of female students' relatively lower math self-concept in aggregated STEM major declaration (Correll 2001). Indeed, the results of this study suggest that women's mathematical self-concept as a predictor of STEM major participation cannot and should not be generalized across all STEM fields, as it actually differs from one discipline to the next. The results also highlighted that for men, the predictive power of math confidence has become weaker in predicting major choice in only one field: computer science. Conversely, in three of the four remaining fields, math confidence has become a more important predictor of men's decision to major in STEM.

Discussion and Implications

What do these results suggest about the role of mathematical self-concept in contributing to the gender gap in STEM? On the one hand, women's relatively low math self-concept reduces their likelihood of majoring in any of the STEM fields. If women's confidence in their mathematical abilities were higher, we would expect more women to choose to major in STEM. On the other hand, over the past four decades lower math confidence has become a less prominent explanation for women's comparatively low representation in several STEM fields, including two where women are most severely underrepresented: engineering and computer science. Such results suggest at least two things: (1) that math self-concept does matter, so we need to consider how to encourage greater math confidence among young women; and (2) that we need to consider what *else* matters in predicting STEM major selection.

The former issue—the general salience of math self-concept—raises the question of what can be done to instill in young women a greater confidence in their mathematical skills. Research on college students has suggested that certain experiences promote women's self-ratings of their math ability, including taking a greater number of math and science courses, being more satisfied in those courses, having positive interactions with faculty, and reinforcing one's skills through tutoring other students (Sax 2008). In general, such findings show that continued exposure to mathematical concepts, as well as positive and supportive experiences with courses and faculty, can mitigate the decline in mathematical self-confidence that tends to occur during college. Further, based on seminal research by Sadker and Sadker (1994) showing that "girls, especially smart girls, learn to underestimate their ability" (p. 95) and more often attribute their intelligence to hard work than to innate ability, educators ought to emphasize opportunities for female students to successfully tackle difficult math-based assignments and come to recognize their mathematical abilities through their own proven success.

Even then, however, educators and researchers need to remember that achievement itself does not always promote high self-concept. Indeed, research has long-demonstrated that that women's self-rated mathematical ability is not commensurate with their demonstrated math aptitude (Marsh et al. 1985; Sax 1994b; Sherman 1983). This phenomenon also holds true for the women in this study: Of the students scoring in the top 10 % on the SAT-Math in our most recent data point (2011), women are far less likely than men to *report* their mathematical abilities as "highest 10 %". As shown in Fig. 7, this gender disparity holds true across all STEM majors (and the college population-at-large). Thus, even among top math students who presumably *know* their mathematical ranking (based on having recently received their SAT scores), in each of the STEM fields women's math ratings are lower than men's. This suggests that simply providing more opportunities for women to succeed in math (or telling them that they are talented) will not necessarily translate into higher math confidence.

The study also identified a weakening salience of women's math self-concept, which begs the question of what *else* matters in predicting STEM major selection. Results from

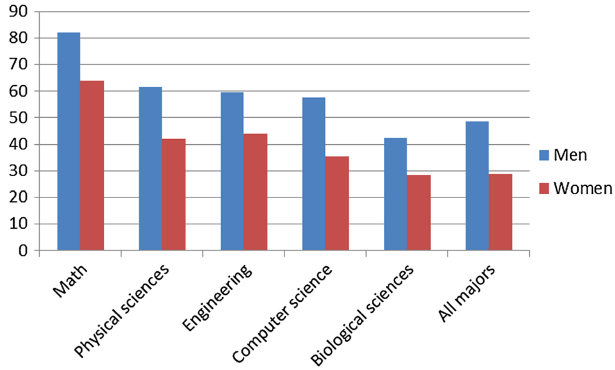

Fig. 7 Percent of students self-rating "highest 10 %" in math ability among those scoring in the top 10 % on SAT-Math, by gender and STEM major (2011). Top 10 % SAT-Math refers to scores of 680 and higher based on College Board percentiles for 2011 (College Board 2011)

see Table 7 in Appendix identify certain student attributes that predict interest in any STEM field among both women and men (e.g., stronger interest in making a theoretical contribution to science and weaker artistic orientations), but also reveal that the predictors of STEM major selection vary by gender and STEM major. For example, having a stronger social activist orientation discourages women from selecting each of the STEM majors, but discourages men from selecting all STEM majors *except* the biological sciences; biology tends to attract men who are more interested in improving the world around them than are men pursuing other fields. Similarly, status striving orientations (i.e., valuing recognition and financial success) are negatively associated with students' decision to pursue all STEM majors *except* computer science, where higher status orientations among both women and men encourage the pursuit of computing fields. Such field- and gender-based variations in the predictors of STEM major selection (and their changing salience over time) are the focus of several papers currently in preparation.

Thus, a "one-size-fits-all" approach to STEM recruitment is not supported by the results of this study. Efforts to diversify STEM—both in research and in practice—need to be approached at the field level in order to best understand what attracts women and men to a particular subfield of STEM. This also reveals a new challenge for research on the gender gap in STEM: the causes of women's comparatively low participation rates in the STEM fields appear to be moving targets. For this reason, research must endeavor to pinpoint determinants of the gender gap in STEM by taking a broader-based view of how they have changed, and will continue to change, over time. Similarly, while we were constrained to 2011 as the end-point for this study, Freshman Survey results through 2014 indicate a both a growing interest in STEM and modest increases in students' math self-concept; these trends are observed for both genders (Eagan et al. 2013, 2014; Pryor et al. 2013). It remains to be seen whether the *relationship* between math self-concept and STEM major selection has evolved since then as well.

Conclusion

This study demonstrates the value of disaggregating STEM fields and of examining the validity over time of widely held beliefs regarding the importance of math confidence. It will be important for future research on the gender gap in STEM to take into account variations across STEM fields because, as shown in this study, a key construct such as math confidence operates differently across fields by gender and over time. This paper has underscored the importance of considering, for example, students' interests in the biological sciences as distinct from computer science and other fields—a distinction which proves important when considering the characteristics that encourage women and men to select one STEM field over another. Future research also needs to examine how predictors of major selection may have evolved over time and how this differs for women and men. In fact, too often our understanding of students' major and career decision-making presumes a static constellation of predictors, when in reality new generations of college students may make their career decisions in different ways. It will be important for research to regularly re-assess longstanding assumptions about what "matters" (and for whom it matters) in predicting STEM interests.

As Tobias (1992) argued decades ago, STEM fields too often lose out on talented scientific prospects who self-select out of such fields because they do not view themselves as having the necessary traits to succeed. To the extent that students continue to view math ability as a prerequisite to STEM, women's lower math confidence will continue to deter them from these fields. However, if the trends identified in the present study were to continue, we might expect STEM fields to increasingly attract a more diverse range of women, including those whose math confidence is not commensurate with their strong math abilities.

Acknowledgments This research is supported by the National Science Foundation, HRD #1135727.

Appendix

See Tables 4, 5, 6, 7 and 8.

Table 4 Student's probable major

Aggregated item	Disaggregated item(s)
Biological Sciences	Biology (general), Biochemistry or Biophysics, Botany, Environmental Science, Marine (life) Science, Microbiology or Bacteriology, Zoology, Other Biological Sciences
Computer Science	Data Processing/Computer Programming/Computer Science
Engineering	Aeronautical or Astronautical Engineering, Civil Engineering, Chemical Engineering, Electrical or Electronic Engineering, Industrial Engineering, Mechanical Engineering, Other Engineering
Mathematics or Statistics	Mathematics, Statistics
Physical Sciences	Astronomy, Atmospheric Science (including Meteorology), Chemistry, Earth Science, Marine Science, Physics, Other Physical science

Table 5 Factor variables, loadings, and reliabilities

Factor	Factor loading	
	Men	Women
Leader personality	α = .66	α = .65
Self rating: drive to achieve	.72	.71
Self-rating: leadership ability	.83	.83
Self-rating: self-confidence (social)	.77	.75
Scholar personality	α = .64	α = .64
Self-rated: academic ability	.80	.79
Self-rated: self-confidence (intellectual)	.78	.78
Self-rated: writing ability	.72	.73
Social activist personality	α = .76	α = .72
Goal: influence social values	.77	.74
Goal: participate in a community action program	.76	.75
Goal: help others in difficulty	.65	.61
Goal: influence the political structure	.72	.69
Goal: becoming involved in programs to clean up the environment	.67	.64
Artistic personality	α = .72	α = .69
Goal: create artistic work	.83	.82
Self-rated: artistic ability	.66	.72
Goal: write original works	.75	.67
Goal: become accomplished in the performing arts	.73	.66
Status striver personality	α = .64	α = .64
Goal: obtain recognition from colleagues	.78	.78
Goal: be very well-off financially	.64	.64
Goal: become authority in my field	.75	.74
Goal: be successful in a business of my own	.62	.62
Education reasons for choosing college	α = .63	α = .60
Reason: to gain a general education and appreciation of ideas	.79	.76
Reason: to make me a more cultured person	.78	.77
Reason: learn more about things that interest me	.73	.73
Extrinsic reasons for choosing college	α = .67	α = .66
Reason: to be able to get a better job	.87	.86
Reason: to be able to make more money	.87	.86

Table 6 Descriptive statistics and coding for independent variables

Variable	Men		Women		Measurement and coding scheme
	Mean	SD	Mean	SD	
Personal inputs					
Religion					
Catholic	.30	.46	.30	.46	Dichotomous: 0 = not marked, 1 = marked
Jewish	.04	.20	.04	.19	Dichotomous: 0 = not marked, 1 = marked
Other	.08	.27	.08	.27	Dichotomous: 0 = not marked, 1 = marked
None	.18	.38	.15	.36	Dichotomous: 0 = not marked, 1 = marked
Christian[a]	.40	.49	.43	.50	Dichotomous: 0 = not marked, 1 = marked
Race/ethnicity					
Asian	.06	.24	.06	.23	Dichotomous: 0 = not marked, 1 = marked
Black	.07	.25	.09	.28	Dichotomous: 0 = not marked, 1 = marked
Latina/o	.04	.19	.04	.20	Dichotomous: 0 = not marked, 1 = marked
Other (includes Multi)	.06	.25	.07	.26	Dichotomous: 0 = not marked, 1 = marked
White[a]	.77	.42	.74	.44	Dichotomous: 0 = not marked, 1 = marked
Political orientation	3.03	.83	3.13	.76	5-pt scale: 1 = "far right" to 5 = "far left"
Background characteristics					
Father's education	5.32	2.11	5.19	2.13	8-pt scale: 1 = "grammar school or less" to 8 "graduate degree"
Mother's education	5.00	1.94	4.96	1.95	8-pt scale: 1 = "grammar school or less" to 8 "graduate degree"
Family income (quintiles specific to each survey year)	3.10	1.33	2.94	1.32	5-pt scale: 1 = "lowest income" to 5 = "highest income"
Father's career: STEM	.18	.38	.17	.38	Dichotomous: 0 = not marked, 1 = marked
Mother's career: STEM	.13	.34	.13	.34	Dichotomous: 0 = not marked, 1 = marked
Learning experience					
High school grade point average	5.73	1.69	6.15	1.53	8-pt scale: 1 = "D" to 8 = "A or A+"
Self efficacy					
Self-rated math ability	3.56	1.01	3.17	.99	5-pt scale: 1 = "lowest 10 %" to 5 = "highest 10 %"
Outcome expectations					
Future activity: change major field	2.48	.89	2.49	.93	4-pt scale: 1 = "no chance" to 4 = "very good chance"
Future activity: make at least a 'B' average	3.48	.63	3.51	.59	4-pt scale: 1 = "no chance" to 4 = "very good chance"

Table 6 continued

Variable	Men		Women		Measurement and coding scheme
	Mean	SD	Mean	SD	
Interests					
Goal: developing a meaningful philosophy of life	2.54	1.01	2.56	1.00	4-pt scale: 1 = "not important" to 4 = "essential"
Goal: making a theoretical contribution to science	1.83	.90	1.65	.85	4-pt scale: 1 = "not important" to 4 = "essential"
Goal: raising a family	2.94	.94	2.95	.97	4-pt scale: 1 = "not important" to 4 = "essential"
Leader personality factor	.07	1.01	−.06	.98	
Scholar personality factor	.10	1.02	−.08	.98	
Social activist personality factor	−.09	1.03	.08	.97	
Artistic personality factor	−.07	1.00	.06	.99	
Status striver personality factor	.10	1.00	−.09	.99	
Education reasons for choosing college factor	−.19	1.06	.16	.92	
Extrinsic reasons for choosing college factor	.04	.99	−.04	1.01	
Contexts proximal to choice behavior					
Distance from home (in miles)	3.19	1.31	3.15	1.30	5-pt scale: 1 = "10 or less" to 5 = "more than 500"
Number of colleges applied to	3.71	2.45	3.77	2.53	5-pt scale: 1 = "none" to 5 "four"
Concerns about how to finance college	1.72	.67	1.87	.67	3-pt scale: 1 = "none" to 3 = "major"
Choice goals					
Degree aspirations					
PhD	.17	.37	.16	.37	Dichotomous: 0 = not marked, 1 = marked
Law	.06	.23	.05	.22	Dichotomous: 0 = not marked, 1 = marked
Medical	.10	.29	.11	.31	Dichotomous: 0 = not marked, 1 = marked
Masters (non-medical)	.38	.49	.39	.49	Dichotomous: 0 = not marked, 1 = marked
Bachelor's[a]	.30	.46	.29	.45	Dichotomous: 0 = not marked, 1 = marked
Institutional characteristics					
Student faculty ratio	15.66	4.64	15.61	4.73	
College type					
University/College	.45	.50	.41	.49	Dichotomous: 0 = College, 1 = University
Religious/Non-Sectarian	.29	.45	.33	.47	Dichotomous: 0 = Non-Sectarian, 1 = religious
HBCU	.03	.16	.03	.18	Dichotomous: 0 = non-HBCU, 1 = HBCU
Control: public/private	.46	.50	.43	.50	Dichotomous: 0 = private, 1 = public

[a] Serves as the reference group for that set of variables

Table 7 Logistic regression results (B coefficients) for men and women who enter specific STEM sub-fields versus all other majors (N = 415,281 men; 489,044 women)

	Biology		Computer Science		Engineering		Math/Statistics		Physical Science	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Continuous year	−0.11*	0.06*	0.23*	0.17	−0.16*	0.24*	−0.53*	−0.41*	−0.21*	0.05
Religion: catholic	0.03	0.03	−0.15*	−0.01	0.08*	0.15*	0.03	0.06	−0.11*	−0.06
Religion: jewish	0.11*	−0.11*	0.13	0.12	−0.67*	−0.53*	0.18	0.04	−0.18*	−0.36*
Religion: other	0.01	0.08*	0.22*	0.34*	−0.01	0.05	0.02	−0.02	−0.10	−0.10
Religion: none	0.05	0.10*	0.10*	0.13	−0.10*	0.06	0.11	−0.01	0.05	0.04
Race: other (includes Multi)	0.06	0.11*	0.12	0.43*	0.21*	0.34*	−0.13	0.06	−0.09	0.07
Race: Asian	0.24*	0.26*	0.23*	0.81*	0.29*	0.40*	−0.21*	−0.10	−0.44*	−0.15*
Race: black	−0.08	0.05	0.50*	1.29*	0.49*	0.92*	0.05	0.07	−0.30*	−0.06
Race: latina/o	0.10	0.12*	0.01	0.66*	0.41*	0.69*	−0.16	0.11	−0.30*	−0.16
Political orientation	0.05*	0.05*	0.07*	0.04	−0.12*	−0.10*	0.02	−0.07	−0.02	−0.03
Father’s education	0.01	0.02*	0.00	−0.03	−0.01	0.01	0.00	0.00	0.01	−0.01
Mother’s education	0.00	0.00	−0.01	−0.04*	0.00	0.03*	0.01	0.00	0.01	0.02
Family income (quintiles)	0.03*	0.01	−0.11*	−0.10*	−0.05*	0.01	−0.09*	−0.05	−0.03*	−0.04*
Father’s career: STEM	0.07*	0.08*	0.24*	0.38*	0.38*	0.41*	−0.08	0.08	0.06	0.06
Mother’s career: STEM	0.08*	0.06*	0.02	−0.07	0.08*	0.07	−0.05	−0.10	−0.05	0.00
High school GPA	0.07*	0.10*	−0.03*	0.00	0.18*	0.24*	0.10*	0.19*	0.07*	0.11*
Self-rated math ability	−0.23*	0.11*	0.32*	0.89*	0.74*	1.20*	1.62*	1.88*	0.29*	0.51*
Leader personality	−0.03*	−0.07*	−0.36*	−0.23*	0.00	0.01	−0.17*	−0.18*	−0.12*	−0.08*
Scholar personality	0.02	0.02	0.11*	0.01	−0.18*	−0.09*	−0.19*	−0.31*	0.03	0.01
Future act: change major field	0.05*	0.08*	−0.23*	0.05	−0.14*	0.02	0.23*	0.24*	0.20*	0.22*
Future act: make at least a ‘B’ avg.	0.05*	0.02	0.09*	0.05	−0.13*	−0.23*	0.04	−0.02	0.00	−0.03
Goal: raising a family	−0.04*	−0.04*	−0.02	0.00	−0.04*	−0.03	0.02	0.02	0.00	−0.02
Goal: making a theoretical contribution to science	0.68*	0.95*	0.38*	0.31*	0.69*	0.76*	0.21*	0.15*	0.99*	1.07*
Goal: developing a meaningful philosophy of life	0.00	−0.05*	−0.07*	−0.10*	0.05*	−0.13*	0.02	0.03	−0.01	−0.10*

Table 7 continued

	Biology		Computer Science		Engineering		Math/Statistics		Physical Science	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Social activist personality	0.03*	−0.08*	−0.33*	−0.33*	−0.25*	−0.20*	−0.13*	−0.24*	−0.21*	−0.28*
Artistic personality	−0.18*	−0.21*	−0.07*	−0.14*	−0.18*	−0.17*	−0.17*	−0.21*	−0.16*	−0.14*
Status striver personality	−0.29*	−0.31*	0.07*	0.17*	−0.17*	−0.12*	−0.21*	−0.16*	−0.37*	−0.28*
Educational reasons for choosing college	0.01	0.03*	0.01	−0.10*	−0.06*	−0.14*	0.04	0.04	0.02	0.01
Extrinsic reasons for choosing college	0.00	0.00	0.12*	0.21*	0.23*	0.22*	−0.11*	−0.04	−0.08*	−0.05*
Distance from home	−0.03*	0.01	−0.07*	−0.04	0.11*	0.12*	−0.04*	−0.01	0.01	0.06*
Number of colleges applied to	0.03*	0.03*	−0.01	0.00	0.00	0.02*	0.01	0.05*	−0.01	0.00
Concerns about how to finance college	0.04*	−0.01	0.02	−0.04	−0.03*	0.00	−0.03	−0.03	−0.04	−0.04
Student-faculty ratio	0.02*	0.01*	0.02*	0.01	−0.02*	−0.05*	−0.03*	−0.04*	−0.04*	−0.03*
University (versus four-year college)	0.12*	0.16*	−0.29*	−0.26*	0.11*	0.31*	−0.18*	−0.12	−0.21*	−0.16*
Religious institution	0.38*	0.38*	−0.26*	−0.26*	−0.51*	−0.65*	0.10	0.14	0.05	0.04
HBCU	0.17	0.37*	0.01	0.25	0.13	−0.01	0.12	0.46	0.13	0.21
Control: public	0.08*	0.18*	−0.10	0.03	0.41*	0.32*	−0.12	0.18	0.20*	0.20*
PhD aspiration	1.06*	0.93*	−0.64*	−0.85*	−0.49*	−0.23*	0.33*	0.27*	1.03*	0.83*
Law degree aspiration	−0.94*	−0.78*	−1.82*	−1.71*	−1.76*	−1.04*	−0.29*	−0.28	−0.58*	−0.08
Medical degree aspiration	2.58*	1.96*	−2.86*	−3.10*	−2.42*	−1.64*	−1.17*	−1.31*	0.80*	0.56*
Masters/MDiv degree aspiration	0.14*	0.24*	−0.22*	−0.25*	0.15*	0.26*	−0.01	0.27*	0.27*	0.38*
Self-rated math ability*1986	−0.10*	−0.15	0.09*	−0.03	0.01	−0.03	0.02	−0.02	−0.06*	−0.10*
Self-rated math ability*1996	0.00	−0.09*	0.15*	−0.13*	−0.04*	−0.15*	0.08	−0.01	−0.08*	−0.13*
Self-rated math ability*2006	0.00	−0.13*	−0.08*	−0.46*	−0.01	−0.23*	0.23*	0.09	−0.02	−0.12*
Self-rated math ability*2011	0.06	−0.10*	−0.13*	−0.44*	0.06*	−0.25*	0.34*	0.19	0.03	−0.14*
Constant	−5.15*	−6.65*	−4.67*	−7.45*	−5.45*	−9.73*	−11.84*	−13.10*	−6.71*	−8.49*

* $p < .001$

Table 8 Delta-P statistics for men and women who enter specific STEM sub-fields versus all other majors. (N = 415,281 Men; 489,044 Women)

	Biology		Computer Science		Engineering		Math/Statistics		Physical Science	
	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)
Continuous year	−0.79	0.50	0.85	0.15	−2.21	0.90	−0.56	−0.35	−0.74	0.10
Religion: catholic	0.20	0.25	−0.48	0.00	1.21	0.53	0.04	0.06	−0.42	−1.02
Religion: jewish	0.88	−0.94	0.44	0.11	−8.20	−1.42	0.27	0.05	−0.66	−5.43
Religion: other	0.06	0.77	0.82	0.33	−0.16	0.17	0.03	−0.02	−0.39	−1.62
Religion: none	0.41	0.94	0.34	0.11	−1.41	0.21	0.15	−0.01	0.20	0.62
Race: other (includes Multi)	0.49	0.99	0.43	0.42	3.36	1.28	−0.16	0.06	−0.34	1.15
Race: Asian	2.07	2.49	0.87	0.97	4.69	1.58	−0.26	−0.10	−1.45	−2.45
Race: black	−0.59	0.44	2.08	1.97	8.28	4.52	0.07	0.08	−1.05	−0.96
Race: latina/o	0.78	1.16	0.05	0.75	6.89	3.10	−0.20	0.12	−1.04	−2.48
Political orientation	0.38	0.43	0.25	0.03	−1.69	−0.32	0.02	−0.06	−0.09	−0.06
Father’s education	0.08	0.09	0.01	−0.02	−0.10	0.04	0.00	0.00	0.03	−0.01
Mother’s education	0.01	0.01	−0.02	−0.03	0.03	0.11	0.01	0.00	0.03	0.04
Family income (quintiles)	0.20	0.23	−0.34	−0.07	−0.72	0.03	−0.11	−0.05	−0.12	−0.08
Father’s career: STEM	0.52	0.59	0.90	0.38	6.40	1.65	−0.11	0.08	0.22	0.13
Mother’s career: STEM	0.64	0.73	0.07	−0.06	1.26	0.24	−0.07	−0.10	−0.19	0.00
High school GPA	0.54	0.61	−0.09	0.00	2.81	0.89	0.14	0.21	0.28	0.23
Self-rated math ability	−1.62	−1.85	1.26	1.17	13.61	7.15	5.18	5.39	1.33	1.36
Leader personality	−0.26	−0.30	−1.04	−0.17	−0.04	0.03	−0.21	−0.17	−0.43	−0.16
Scholar personality	0.15	0.17	0.40	0.01	−2.58	−0.29	−0.24	−0.28	0.13	0.02
Future act: change major field	0.42	0.48	−0.69	0.04	−1.96	0.05	0.34	0.28	0.85	0.50
Future act: make at least a ‘B’ avg.	0.39	0.45	0.30	0.04	−1.84	−0.70	0.06	−0.02	0.00	−0.06
Goal: raising a family	−0.32	−0.37	−0.06	0.00	−0.56	−0.09	0.03	0.02	0.00	−0.03
Goal: making a theoretical contribution to science	6.98	7.85	1.51	0.30	12.62	3.68	0.31	0.17	6.24	3.77
Goal: developing a meaningful philosophy of life	−0.02	−0.03	−0.24	−0.08	0.82	−0.41	0.03	0.03	−0.04	−0.19

Table 8 continued

	Biology		Computer Science		Engineering		Math/Statistics		Physical Science	
	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)	Men ΔP (%)	Women ΔP (%)
Social activist personality	0.25	0.28	−0.96	−0.23	−3.49	−0.61	−0.17	−0.22	−0.76	−0.51
Artistic personality	−1.29	−1.47	−0.23	−0.11	−2.49	−0.53	−0.22	−0.19	−0.57	−0.27
Status striver personality	−2.02	−2.31	0.25	0.15	−2.35	−0.37	−0.26	−0.16	−1.25	−0.50
Educational reasons for choosing college	0.11	0.13	0.02	−0.08	−0.87	−0.44	0.05	0.04	0.08	0.02
Extrinsic reasons for choosing college	0.02	0.02	0.42	0.19	3.71	0.81	−0.14	−0.04	−0.30	−0.09
Distance from home	−0.20	−0.23	−0.23	−0.03	1.66	0.44	−0.06	−0.01	0.06	0.12
Number of colleges applied to	0.21	0.23	−0.05	0.00	−0.03	0.06	0.01	0.05	−0.02	0.00
Concerns about how to finance college	0.33	0.37	0.06	−0.03	−0.44	0.01	−0.03	−0.03	−0.17	−0.08
Student-faculty ratio	0.13	0.15	0.05	0.01	−0.25	−0.16	−0.04	−0.04	−0.15	−0.06
University (versus four-year college)	0.95	1.46	−0.97	−0.21	1.60	1.06	−0.24	−0.12	−0.81	−2.70
Religious institution	3.19	3.52	−0.84	−0.21	−7.21	−2.01	0.13	0.15	0.22	0.60
HBCU	1.41	3.84	0.04	0.23	1.97	−0.02	0.16	0.59	0.53	3.72
Control: public	0.63	1.65	−0.33	0.02	6.23	1.10	−0.16	0.18	0.79	3.27
PhD aspiration	11.05	10.65	−1.80	−0.55	−6.62	−0.73	0.49	0.30	5.65	15.88
Law degree aspiration	−5.32	−5.30	−3.24	−0.74	−15.88	−2.33	−0.35	−0.26	−1.82	−1.27
Medical degree aspiration	41.80	30.41	−4.38	−1.12	−19.97	−3.30	−1.06	−0.88	4.25	10.49
Masters/MDiv degree aspiration	1.14	2.16	−0.72	−0.20	2.28	0.89	−0.01	0.29	1.08	6.37
Self-rated math ability*1986	−0.74	−0.85	0.32	−0.02	0.10	−0.11	0.03	−0.02	−0.25	−0.20
Self-rated math ability*1996	0.03	0.04	0.53	−0.10	−0.53	−0.46	0.10	−0.01	−0.31	−0.24
Self-rated math ability*2006	0.02	0.03	−0.27	−0.30	−0.16	−0.70	0.35	0.10	−0.07	−0.22
Self-rated math ability*2011	0.50	0.57	−0.40	−0.29	0.88	−0.73	0.55	0.22	0.12	−0.28

References

Aronson, J., & Steele, C. M. (2005). Stereotypes and the fragility of academic competence, motivation, and self-concept. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 436–456). New York, NY: Guilford.

Astin, A. W. (1993). *What matters in college?: Four critical years revisited*. San Francisco: Jossey-Bass.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. NewYork: Free man.

Blickenstaff, J. C. (2005). Women and science careers. *Gender and Education, 17*(2), 369–386.

Bong, M. (1996). Problems in academic motivation research and advantages and disadvantages of their solutions. *Contemporary Educational Psychology, 21*(2), 149–165.

Bong, M., & Clark, R. E. (1999). Comparison between self-concept and self-efficacy in academic motivation research. *Educational Psychologist, 34*(3), 139–153.

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review, 15*(1), 1–39.

Carnevale, A. P., Smith, N., & Melton, M. (2011). STEM: Science, technology, engineering, mathematics. Center for Education and the Workforce, Georgetown University. Retrieved from http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/stem-complete.pdf.

Casey, M. B., Nuttall, R. L., & Pezaris, E. (1997). Mediators of gender differences in mathematics college entrance test scores: a comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology, 33*(4), 669.

College Board (2011). SAT Percentile Ranks 2011. College-Bound Seniors—Critical Reading, Mathematics and Writing Percentile Ranks. (n.d.). Retrieved April 6, 2015, from http://media.collegeboard.com/digitalServices/pdf/SAT-Percentile_Ranks_2011.pdf.

Correll, S. J. (2001). Gender and the career choice process: The role of biased self-assessments1. *American Journal of Sociology, 106*(6), 1691–1730.

Eagan, K., Lozano, J. B., Hurtado, S., & Case, M. H. (2013). *The American freshman: National norms fall 2013*. Los Angeles: Higher Education Research Institute, UCLA.

Eagan, K., Stolzenberg, E. B., Ramirez, J. J., Aragon, M. C., Suchard, M. R., & Hurtado, S. (2014). *The American freshman: National norms fall 2014*. Los Angeles: Higher Education Research Institute, UCLA.

Eccles, J. S. (1994). Understanding women's educational and occupational choices. *Psychology of Women Quarterly, 18*(4), 585–609.

Eccles, J. S., Midgley, C., Wigfield, A., Buchanan, C. M., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: the impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist, 48*(2), 90.

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Social, emotional, and personality development. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology* (5th ed., Vol. 3, pp. 1017–1095). Hoboken, NJ: Wiley.

Ethington, C. A. (1988). Differences among women intending to major in quantitative fields of study. *The Journal of Educational Research, 81*(6), 354–359.

Fairweather, J. (2008). Linking evidence and promising practices in science, technology, engineering, and mathematics (STEM) undergraduate education. *Board of Science Education, National Research Council*, The National Academies, Washington, DC.

Fredricks, J. A., & Eccles, J. S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two "male-typed" domains. *Developmental Psychology, 38*, 519–534.

Ginzberg, E., Ginsburg, S. W., Axelrad, S., & Herma, J. L. (1951). *Occupational choice*. New York: Columbia University Press.

Gonzalez, H.B., & Kuenzi, J. J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. Retrieved from http://fas.org/sgp/crs/misc/R42642.pdf on March 1, 2012.

Gottfredson, L. S. (1981). Circumscription and compromise: A developmental theory of occupational aspirations. *Journal of Counseling Psychology, 28*, 545–579.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: American Association of University Women.

Kanny, M. A., Sax, L. J., & Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: How explanations for the gender gap have evolved over time. *Journal of Women and Minorities in Science and Engineering, 20*(2), 127–148.

Lent, R. W., Brown, S. D., & Gore, P. A, Jr. (1997). Discriminant and predictive validity of academic self-concept, academic self-efficacy, and mathematics-specific self-efficacy. *Journal of Counseling Psychology, 44*(3), 307–315.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*, 79–122.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. In Duane Brown and Associates (Ed.), *Career choice and behavior* (pp. 255–311). San Francisco, CA: Jossey Bass.

Lewis, S., Harris, R., & Cox, B. (2000). *Engineering a better workplace: A diversity guide for the engineering profession*. Melbourne: Swinburne University of Technology.

Marra, R. M., Rodgers, K. A., Shen, D., & Bogue, B. (2009). Women engineering students and self-efficacy: A multi-year, multi-institution study of women engineering student self-efficacy. *Journal of Engineering Education, 98*(1), 27–38.

Marsh, H. W. (1986). Global self-esteem: Its relation to specific facets of self-concept and their importance. *Journal of Personality and Social Psychology, 51*(6), 1224–1236.

Marsh, H. W. (1989). Effects of single-sex and coeducational schools: A response to Lee and Bryk. *Journal of Educational Psychology, 81*(4), 651–653.

Marsh, H. W., & Martin, A. J. (2011). Academic self-concept and academic achievement: Relations and causal ordering. *British Journal of Educational Psychology, 81*(1), 59–77.

Marsh, H. W., Smith, I. D., & Barnes, J. (1985). Multidimensional self-concepts: Relations with sex and academic achievement. *Journal of Educational Psychology, 77*(5), 581.

Marsh, H. W., & Yeung, A. S. (1998). Longitudinal structural equation models of academic self-concept and achievement: Gender differences in the development of math and English constructs. *American Educational Research Journal, 35*(4), 705–738.

McGraw, R., Lubienski, S. T., & Strutchens, M. E. (2006). A closer look at gender in NAEP mathematics achievement and affect data: Intersections with achievement, race/ethnicity, and socioeconomic status. *Journal for Research in Mathematics Education, 37*, 129–150.

Meece, J. L., Parsons, J. E., Kaczala, C. M., & Goff, S. B. (1982). Sex differences in math achievement: Toward a model of academic choice. *Psychological Bulletin, 91*(2), 324.

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*(1), 60–70.

National Academy of Sciences. (2010). *Rising above the gathering storm, revisited: Rapidly approaching Category 5*. Washington, DC: National Academies Press.

National Center for Education Statistics. (2002). Classification of Instructional Programs: 2000 Edition. Retrieved from http://nces.ed.gov/pubs2002/2002165.pdf on March 1, 2012.

National Center for Education Statistics. (2013). *Digest of Education Statistics 2013*. Washington, DC: U.S. Department of Education.

National Science Board. (2012). Science and engineering indicators 2012. Arlington VA: National Science Foundation (NSB 12-01).

Pajares, F. (2005). *Gender differences in mathematics self-efficacy beliefs*. New York, NY: Cambridge University Press.

Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*, 193.

Pascarella, E. T., Smart, J. C., Ethington, C. A., & Nettles, M. T. (1987). The influence of college on self-concept: A consideration of race and gender differences. *American Educational Research Journal, 24*(1), 49–77.

Pryor, J. H., Eagan, K., Palucki Blake, L., Hurtado, S., Berdan, J., & Case, M. H. (2013). *The American freshman: National norms fall 2012*. Los Angeles: Higher Education Research Institute, UCLA.

Pryor, J. H., Hurtado, S., DeAngelo, L., Palucki Blake, L., & Tran, S. (2010). *The American freshman: National norms fall 2010*. Los Angeles: Higher Education Research Institute, UCLA.

Reuben, E., Sapienza, P., & Zingales, L. (2014). How stereotypes impair women's careers in science. *Proceedings of the National Academy of Sciences, 111*(12), 4403–4408.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458–476.

Sadker, M., & Sadker, D. (1994). *Failing at fairness: How America's schools cheat girls*. New York: Charles Scribner's Sons.

Sax, L. J. (1994a). Predicting gender and major-field differences in mathematical self-concept during college. *Journal of Women and Minorities in Science and Engineering, 1*, 291–307.

Sax, L. J. (1994b). Mathematical self-concept: How college reinforces the gender gap. *Research in Higher Education, 35*(2), 141–166.

Sax, L. J. (2008). *The gender gap in college: Maximizing the developmental potential of women and men*. San Francisco: Jossey-Bass.

Sax, L. J., Bryant, A. N., & Harper, C. E. (2005). The differential effects of student-faculty interaction on college outcomes for women and men. *Journal of College Student Development, 46*(6), 642–659.

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of educational research, 46*(3), 407–441.

Shavlik, J., & Shavlik, M. (2004). Selection, combination, and evaluation of effective software sensors for detecting abnormal computer usage. In *Proceedings of the tenth ACM SIGKDD international conference on Knowledge discovery and data mining* (pp. 276-285). ACM.

Sherman, J. (1982). Continuing in mathematics: A longitudinal study of the attitudes of high school girls. *Psychology of Women Quarterly, 7*(2), 132–140.

Sherman, J. (1983). Factors predicting girls' and boys' enrollment in college preparatory mathematics. *Psychology of Women Quarterly, 7*(3), 272–281.

Smart, J. C., & Pascarella, E. T. (1986). Self-concept development and educational degree attainment. *Higher Education, 15*(1–2), 3–15.

Super, D. E., Brown, D., & Brooks, L. (1990). *Career choice and development: Applying contemporary theories to practice*. San Francisco: Jossey-Bass.

Tai, R. T., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science, 312*(5777), 1143–1144.

Tobias, S. (1992). *Revitalizing undergraduate science: Why some things work and most don't*. Tucson, AZ: Research Corporation.

Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal, 50*(5), 1081–1121. doi:10.3102/0002831213488622.

Watt, H. M. (2000). Measuring attitudinal change in mathematics and English over the 1st year of junior high school: A multidimensional analysis. *The Journal of Experimental Education, 68*(4), 331–361.

Watt, H. M. (2006). The role of motivation in gendered educational and occupational trajectories related to maths. *Educational Research and Evaluation, 12*(4), 305–322.

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology, 25*(1), 68–81.

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J. A., & Blumenfeld, P. C. (1997). Changes in children's competence beliefs and subjective task values across the elementary school years: A three-year study. *Journal of Educational Psychology, 89*, 451–469.