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Abstract

This longitudinal study analyzes survey responses in seventh, eighth, and ninth grade from diverse public school students (n=482) to explore gender differences in engineering and science career preferences. Females were far more likely to express interest in a science career (31%) than an engineering career (13%), while the reverse was true for males (58% in engineering, 39% in science). After controlling for student and school demographic characteristics, females were as consistent as males in their science career interests during the three years of the study but less consistent in their engineering career interests. Knowing an engineer significantly predicted consistent career interest in engineering for males but not for females. Childhood interest in science and engineering was related to whether females and males expressed any interest in those subjects. Females and males both showed interest for careers where they can discover new things that help the environment or people's health; females were less interested in designing and inventing, solving problems, and using technology. These findings suggest that increasing the number of diverse students who pursue engineering careers may require introducing students from early elementary to middle school to engineering as an array of careers that can improve health, happiness, and safety, and make the world a better place.

Keywords: engineering, science, career, gender

There is consensus that engineers with diverse perspectives and experiences are needed (Huang, Taddese, & Walter, 2000; National Academy of Engineering, 2008; National Science Board, 2012). While there are efforts to recruit future engineers as early as possible, engineering is not typically part of the K-12 curriculum, and many K-12 students do not have much exposure to specific types of engineering careers (Katehi, Pearson, & Feder, 2009). This may change with the

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implementation of the science and engineering practices and engineering design core ideas that are part of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). The NGSS suggests that "the inclusion of engineering with science has major implications for non-dominant student groups" because "from a pedagogical perspective, the focus on engineering is inclusive of students who may have traditionally been marginalized in the science classroom or experienced science as not being relevant to their lives or future" (NGSS Lead States, 2013, p. A1.2). The inclusion of both science and engineering practices in the NGSS is due in part to the notion that science and engineering are "parallel and complementary" (Bybee, 2011, p. 15). For example, science and engineering practices both require asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, and designing solutions (Bybee, 2011, pp. 11–12). Yet, despite overlap between science and engineering practices, there are differences in student awareness of and interest in science and engineering careers.

Coupling science and engineering practices may not necessarily help increase the number of students interested in engineering given that there are already well-documented concerns around increasing interest in science careers, particularly for females (e.g., Archer et al., 2013; Blickenstaff, 2005; Brotman & Moore, 2008; Calabrese Barton, Tan, & Rivet, 2008; Scantlebury & Baker, 2007; Weinburgh, 1995). Archer et al. (2012) note "entrenched gender inequalities still persist" (p. 968) in terms of attitudes and participation. The authors conducted a five-year longitudinal study on science aspirations and engagement. The study included qualitative data from interviews and quantitative data from surveys from over 9,000 10- to 14-year-olds and their parents. The authors concluded that reasons for gender inequities in science participation and attitudes are "complex, multiple, and highly resistant to change" (p. 983). There is evidence that such gender disparities exist at least by the beginning of high school (Aschbacher, Li, & Roth, 2010) but that such differences are primarily in the physical sciences and engineering rather than the biological sciences, medicine or other health-related professions (Baker & Leary, 1995; Jones, Howe, & Rua, 2000; Sadler, Sonnert, Hazari, & Tai, 2012).

Students who are more aware of engineering typically have a parent, relative, or family friend who was or is an engineer (National Academy of Engineering, 2008, p. 58), which is not surprising given that engineering has not been a significant part of the K-12 curriculum. With the well-documented lack of diversity in engineering (e.g., National Academy of Engineering, 2002, 2008; National Science Board, 2012; National Science Foundation, 2013), relying on current engineers to recruit their relatives into the field has proved ineffective. For example, in 2012, females made up only 13% of the engineering workforce (National Science Board, 2012). More proportional representation is not likely to be attained unless school and extracurricular science and engineering experiences help increase awareness of engineering and invite students to pursue it. Thus, greater exposure in school to engineering and engineering design practices as defined in the NGSS might help students understand the similarities and differences between science and engineering and might increase the number of students interested in engineering as a career.

A study by the National Academy of Engineering (2008) suggested several ways to rebrand the engineering profession to entice students with diverse perspectives and experiences. The study used quantitative data collected through online surveys to test findings from qualitative data collected through interviews and focus groups. The findings were used to develop and pilot a new position statement that "emphasizes connections between engineering and ideas and possibilities, rather than engineering as a math- and science-based method of solving problems" (p. 5). In addition, the group tested taglines that might be appealing to males and females. Two of the appealing messages for females are, "Engineering makes a world of difference" and "Engineering is essential to our health, happiness, and safety." The second tagline was particularly appealing to 16- to 17-year-old African American females and all ages of Hispanic females. This research relied on survey responses and focus groups of students from a single time point and did not take into consideration other factors that relate to interest in science, technology, engineering, and mathematics (STEM) careers such as demographic characteristics (social economic status, parental education levels) or experiences with engineering or science.

Knowing more about what aspects of science and engineering appeal to different groups of students, how aspirations may change over time, and what student characteristics are linked to such aspirations should be useful in creating more effective strategies to increase awareness of and interest in engineering and science careers, particularly among underrepresented groups. The current study addresses this need and extends prior research by comparing gender differences in career interest in science versus engineering over time, during the critical period of middle school to early high school, after which few are likely to initiate serious interest in these fields (Aschbacher et al., 2010). The study analyzes longitudinal survey data from a diverse sample of public secondary school students, while incorporating information about student and school demographics. In addition, this study compares females who expressed interest in engineering with those who did not to determine possible differences that might be used to encourage more females to pursue engineering careers. This study addresses the following research questions:

1. Are there gender differences in the consistency of engineering and science career interests over time (from seventh through ninth grade)?
2. Are the student characteristics that predict career interests similar for males and females and similar for biological science, physical science, and engineering?
3. Are there gender differences in the appeal of particular career characteristics (e.g., designing or inventing)?
4. What student characteristics differentiate females interested in engineering and/or science careers from those who are not?

The longitudinal design permits examination of "consistency" of interest in engineering and science, i.e., which ranges from interest expressed only at one survey point to more consistent interest over three annual surveys. It is possible that students who have a more consistent interest in engineering or science during K-12 might also have a greater likelihood of an eventual college major and career in engineering or science.

Method

This study used annual survey data from a larger, longitudinal research project (Aschbacher, Ing, & Tsai, 2013; Aschbacher et al., 2010; Gilmartin, Li, & Aschbacher, 2006) to investigate gender differences in the science and engineering career aspirations of a diverse cohort of public middle school students (n=482) during seventh to ninth grade.

Sample

Survey respondents were recruited in seventh grade and followed through ninth grade. The sample for this analysis, who participated in all three years, includes approximately 20% of the 2,600 seventh graders originally recruited in 2003 for the larger research study. About 1,500 students (about 60%) participated in seventh grade, 1,200 (about 45%) in eighth grade, and 800 (about 30%) in ninth grade. Attrition was primarily due to the voluntary nature of the study, requirement for written parental permission each year, ninth grade attendance at high schools outside the study, and family mobility and extended school absences among this ethnically and economically diverse population. Since participation was voluntary, participants may have been somewhat more interested in science than non-participants, although about one quarter of those surveyed expressed no strong science-related career aspirations.

The sample includes 43% males (n=205) and 57% females (n=277) who attended five pairs of public middle schools and high schools in southern California. The schools were selected for ethnic and economic diversity and similarity of science coursework. Schools included 1% to 34% African American, 16% to 64% Hispanic, 7% to 62% Asian, and 11% to 40% White (California Department of Education, 2013). The students who responded to all three years of the survey were roughly representative of the overall school population (4% African American; 18% Hispanic; 34% Asian; 16% White; 28% multiple ethnicity). The percentage of students at each school eligible for free or reduced meals ranged from 9% to 73% (California Department of Education, 2013). 49% of the students who responded to the survey in all three years were eligible for free or reduced meals. In these schools, all seventh graders took life science; all eighth graders took physical science (chemistry and physics); and most ninth graders took biology, but some took a "less demanding" course without a lab (usually environmental studies or Earth science) or no science at all.

Measure

Participants completed a 10-page "*Is Science Me*?" survey of mostly Likert-type items in fall of seventh grade, in fall of eighth grade, and in spring of ninth grade (for additional information on the survey, see Aschbacher et al., 2010; Gilmartin et al., 2006). The surveys addressed a variety of topics noted below; in this analysis we focus primarily on data related to career interest and student demographics. Other survey topics, some of which are analyzed in Aschbacher et al. (2013), included: childhood science activities; current extracurricular and school science activities; attitudes toward science, scientists, school science, and self in science; grades in science, math, and all subjects overall; perceptions of support for their science interest from teachers, family, and friends; college and career aspirations; and student demographics. The constructs included in the survey were grounded in previous research, e.g., on the role of families (e.g., Archer et al., 2012; Baker & Leary, 1995; Gilmartin et al., 2006), teacher and school experiences (e.g., Osborne, Simon, & Collins, 2003; Simpson & Oliver, 1990; Xu, Coats, & Davidson, 2012), self-perceptions (e.g., Atwater, Wiggins, & Gardner, 1995; Simpson & Oliver, 1990; Wigfield & Eccles, 2000), and pipeline participation (e.g., Hanson, 1996). An example of a theoretical framework used to create some of the items in the instrument (that were not used in this particular study) is the expectancy-value theory of achievement motivation. This framework emphasizes personal beliefs and values assigned to particular tasks in relation to the amount of effort and persistence one puts forward (e.g., Wigfield & Eccles, 2000). This theory of achievement motivation has been widely applied to work in this area as a way to understand the choices made to participate in particular tasks (such as a science project), whether they persist in those tasks, what sort of effort they put forward in those tasks, and how well they do on those tasks. The surveys drew from existing questions from the expectancy-value achievement motivation framework and scales from other related, existing surveys (e.g., McCoach &

Siegel, 2003; Simpson & Oliver, 1990), science education and pipeline literature, and input from a national advisory panel (see Aschbacher et al., 2010 for greater detail). We pilot tested the surveys in participating middle schools and used debriefing input from students to maximize item comprehensibility and sensitivity of Likert scales to the range of students' intended responses. To identify constructs underlying groups of items, principal components factor analyses were conducted using varimax rotation techniques (Gilmartin et al., 2006), and items with poor reliability were omitted. Surveys were revised each year based on the previous version's item characteristics and insights from the prior survey and interviews. Many questions were repeated year to year to trace trends over time, although the ninth grade survey had to be shorter due to high school schedules, time, and budget constraints.

Career interest

Student interest in engineering and science careers was based on student responses to the question, *How interested are you in a job like these someday?* As in prior research (Aschbacher et al., 2010), the item set listed science, engineering, and other occupations (such as lawyer, architect, psychologist). This study focuses only on student responses to the science and engineering career options. We compare all science careers and disaggregate science careers into biological science careers (e.g., biologist, zoologist) and physical science careers (e.g., physicist, chemist, and astronomer).

Response options were: *very interested*, *fairly interested*, *a little interested*, *not interested*. To capture serious interest, we coded *very interested* in each science and engineering career as 1, all others as 0. This dichotomous outcome variable for each year indicated strong interest in science or engineering careers. We then summed the number of times students indicated that they were *very interested* in a science or engineering career across all three years (maximum value of 3) to indicate consistent interest. Consistent interest in science or engineering indicates the number of years in which students were very interested in a science or engineering career across all three years. A student who indicated that they were very interested in a science career for two years translates to one of three possible scenarios: the student was very interested in a science career in 1) seventh and eighth grade, 2) seventh and ninth grade, or 3) eighth and ninth grade.

In addition to questions about student interest in specific careers, surveys in eighth and ninth grade included questions about interest in common characteristics of some science/engineering careers, such as designing/inventing, investigating ideas, solving problems, using technology, analyzing data, and being reviewed by others. These items were added because seventh grade interviews with a subset of students indicated that some students were not aware of or had misconceptions about what engineering and science careers might entail. This is similar to others' findings (e.g., National Academy of Engineering, 2008) where students understand engineering to be about mechanical or structural aspects of designing and building things but have a limited understanding of the range of possible engineering careers.

Background characteristics

To explore characteristics that might relate to gender differences in career aspirations, we included both (a) student-level background variables (ethnicity, social economic status (SES) as described below, self-reported grade point average, whether student claimed interest in science-related careers began by third grade, and whether student personally knew an engineer or a scientist); and (b) school-level background variables (percentage of students eligible for free/reduced lunch, school size, and ethnicity of student body).

About half the sample included students typically underrepresented in science and engineering careers (4% African American, 18% Hispanic, and 28% multiple ethnicity; 57% female). To estimate individual SES, we used the same method as prior work (Aschbacher et al., 2010; Gilmartin et al., 2006), creating three categories according to student survey responses (number of computers in the home, parents' education level, single mother is head of household); categories were corroborated by district data where available. Note that highly affluent families tended to send their children to private schools in the area, so "high SES" in this sample roughly corresponds to what is commonly considered high-middle SES. This sample included 28% low SES, 49% middle SES, and 22% high SES. Few students in this sample said they were first interested in a science or engineering career by third grade (28%); only 22% said they know a scientist; and about half indicated that they know an engineer (51%).

Analysis

We used ordinary least squares regression to examine gender differences in science and engineering career interest. The dependent variable was a continuous variable (number of years students were very interested in particular careers). Separate regression analyses were carried out for each field (science and engineering). In addition, we conducted logistic regression analyses to examine gender differences in particular career characteristics. The dependent variables for these analyses were dichotomous variables (whether or not student was very interested in a career with particular characteristics: design, invent, or develop new products or tools; spend a lot of time and energy on a problem until you solve it; discover new things that help the environment or people's health; use computers, lab equipment, and other technology; conduct investigations to understand how the world works; analyze data to draw conclusions; have your work reviewed and critiqued by others). All regression analyses statistically controlled for student and school demographic characteristics.

Results

Gender Differences in Engineering and Science Career Interest

Male and female students in this study had comparable student and school characteristics; however, we still incorporated background variables to determine association with other results. Approximately similar percentages of females (52%) and males (50%) indicated knowing an engineer, $\chi^2(1, N=482)=0.14$, $p=.71$. Slightly more females (24%) indicated knowing a scientist compared to males (19%) but this difference was not statistically significant, $\chi^2(1, N=482)=1.59$, $p=.21$. Females (30%) and males (25%) were similar in terms of the proportion reporting an early interest in science or engineering, $\chi^2(1, N=482)=1.43$, $p=.23$. There were gender differences, however, in terms of interest in science versus engineering careers. Females were far more likely to express any interest in a science career (31%) compared to engineering (13%) at least once during the three years of this study, while the reverse was true for males (39% interested in science; 58% interested in engineering). There were gender differences in terms of the type of science career interest. While there was a larger percentage of males (32%) who expressed interest in a physical science career compared to females (20%), there were roughly similar levels of interest in terms of biological science careers (24% males; 25% females).

Consistent interest in engineering career

Females who expressed serious interest in engineering were less consistent in their interest than males across the three years (Figure 1; $\chi^2(3, N=482)=112.61$, $p<.001$). There was only one female (<1%) who was consistently interested in an engineering career across all three years compared to 20 males (10%). There were only eight females (3%) who were interested in engineering for two of the three years of this study compared to 35 males (17%). These gender differences in engineering interest occurred each year: in seventh grade, 6% of females indicated being interested in engineering compared to 32% of males; in eighth grade, the percentage of females (5%) and males (27%) interested in engineering declined slightly, then increased again in ninth grade for males (35%) but not females (5%).

Predicting engineering career interest

Knowing an engineer was a significant predictor of the degree of consistent interest in an engineering career across all three years of this study ($b=0.21$, $t(482)=3.12$, $p<.01$), while student and school background variables were not. However, when comparing males and females, knowing an engineer significantly predicted consistent career interest for males ($b=0.41$, $t(205)=3.01$, $p<.01$) but not for females ($b=0.39$, $t(277)=0.98$, $p=.33$). Early childhood interest in science and engineering was significantly related to the degree of consistent engineering interest for both females ($b=0.14$, $t(277)=2.22$, $p<.05$) and males ($b=0.56$, $t(205)=3.56$, $p<.001$). Even after controlling for student and school characteristics, females were still less likely to be consistently interested in an engineering career compared to males (Table 1).

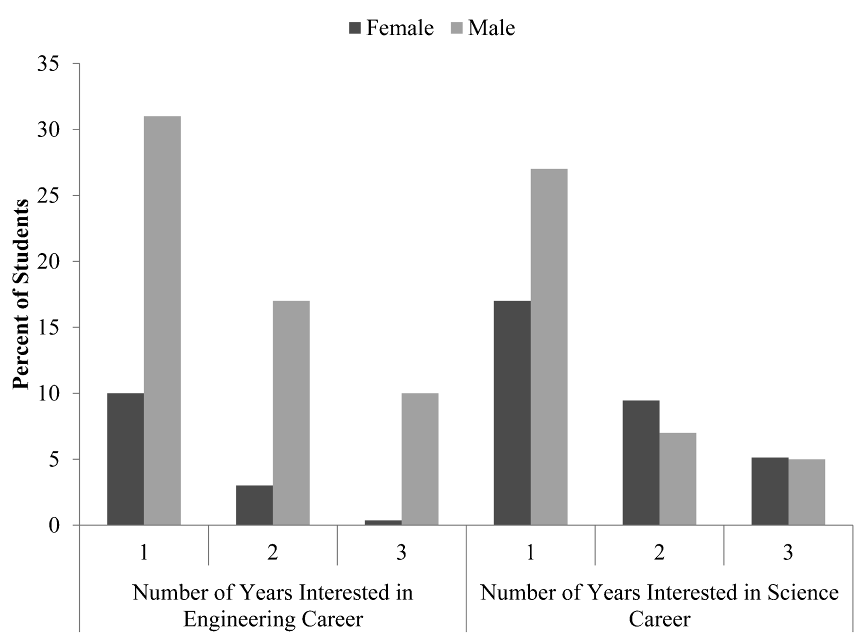

Figure 1. The total number of years that males and females expressed interest in science and engineering careers.

Table 1
Summary of regression results predicting consistent student interest in engineering and science careers (n=482).

	Engineering			Science		
	$F(13, 468)=14.14$, $p<.001$			$F(13, 468)=4.38$, $p<.001$		
	B	*SE B*	β	*B*	*SE B*	β
Gender	−0.78***	0.07	−0.46	−0.08	0.08	−0.05
R^2		0.11			0.08	

Note. These models include controls for student ethnicity, social economic status, grade point average, early interest in science, knowing an engineer/knowing a scientist, percentage of school eligible for free or reduced lunch, ethnic composition of school, and school enrollment. However, only odds ratios (standard errors in parentheses) for gender are shown here for brevity. Gender coded as 1 for female and 0 for male.
***$p<.001$.

Consistent interest in science career

Although females were less likely than males to express interest in engineering, females were about as likely as males to be interested in science careers (Figure 1; $\chi^2(3, N=482)=7.13$, $p=.07$). Approximately 5% of males and 5% of females were consistently interested in a science career during the three years of the study. There were no gender differences in terms of biological science career interest with approximately 2% of males and 4% of females who were consistently interested in a biological science career ($\chi^2(3, N=482)=3.16$, $p=.37$). However, there were gender differences in consistent interest in physical science careers, with 32% of males expressing any interest compared to 20% of females ($\chi^2(3, N=482)=10.94$, $p<.05$). The percentage of students who said they knew a scientist did not differ by gender ($\chi^2(1, N=482)=1.59$, $p=.21$).

Predicting science career interest

As with engineering, knowing a scientist was a significant predictor of the degree of consistent interest in a science career across all three years of this study ($b=0.27$, $t(482)=2.89$, $p<.01$), while student demographic and school background variables measured were not. As with engineering, there was no relationship between knowing a scientist and consistent interest in science for females ($b=0.10$, $t(277)=0.80$, $p=.42$), but there was a positive relationship for males ($b=0.47$, $t(205)=3.22$, $p<.01$). Also like engineering, childhood interest in science by third grade was related to the degree of consistent science career interest during the study for all students ($b=0.48$, $t(482)=5.80$, $p<.001$) and by gender (females: $b=0.45$, $t(277)=4.12$, $p<.001$; males: $b=0.51$, $t(205)=3.93$, $p<.001$). After controlling for student and school characteristics, females were as likely as males to be consistently interested in a science career, unlike the engineering results (Table 1).

When comparing the degree of consistent biological science career interest and physical science career interest, there were no gender differences for biological science career interest ($b=0.03$, $t(482)=0.45$, $p=0.65$) but there were gender differences for physical science career interest ($b=-0.14$, $t(482)=-2.48$, $p<.05$). After controlling for student and school characteristics, females were less likely than males to be consistently interested in physical science and engineering careers. Unlike physical science and engineering career interest, there are no gender differences in interest in biological science careers.

Gender Differences in Interest in Particular Career Characteristics

There were significant differences between males and females in terms of interest in particular career characteristics (Table 2). Males expressed greater interest than females in careers where they could design, invent, or develop new products or tools; spend a lot of time and energy on a problem until they solve it; use computers, lab equipment, and other technology; and conduct investigations to understand how the world works. Females and males, however, expressed similar levels of interest in careers in which they discover new things that help the environment or people's health, analyze data to draw conclusions, or have work reviewed by others.

Even after controlling for student and school characteristics, in eighth and ninth grade the same pattern of gender differences and similarities remained (Table 3).

Differences Between Females Interested in Engineering or Science Careers and Other Females

Engineering

Only two variables distinguished females in this study who expressed a strong interest in engineering in one or more surveys from those who never expressed such interest: having an early interest in science (by third grade; $\chi^2(1, N=277)=7.58$, $p<.01$), and participating before seventh grade in school science experiences such as taking enrichment science classes over the summer and participating in a science club or team (females ever interested in engineering: $M=0.36$, $SD=0.11$; other females: $M=0.19$, $SD=0.03$, $t(275)=-2.07$, $p<.05$). These two subgroups of females did not differ in whether or not they knew an engineer ($\chi^2(1, N=277)=0.67$, $p=.41$), nor on other student background characteristics, such as self-reported

Table 2
Descriptive statistics for female (n=277) and male (n=205) interest in career characteristics by grade level.

	Eighth Grade			Ninth Grade		
Career Characteristic	Female	Male	t	Female	Male	t
Design, invent, or develop new products or tools	20	40	4.89**	19	39	4.63**
Spend a lot of time and energy on a problem until you solve it	7	19	4.05**	9	15	1.76
Discover new things that help the environment or people's health	22	23	0.21	20	21	0.41
Use computers, lab equipment, and other technology	26	52	5.93**	14	39	6.18**
Conduct investigations to understand how the world works	13	21	2.31*	12	22	2.85*
Analyze data to draw conclusions	9	10	0.23	6	9	1.25
Have your work reviewed and critiqued by others	15	15	0.25	9	13	1.43

Note. Percentage of students very interested in particular career characteristic.
*$p<.05$. **$p<.01$.

grade point average in seventh grade ($t(277)=0.19$, $p=.85$), eighth grade ($t(277)=-0.02$, $p=.98$), and ninth grade ($t(277)=0.70$, $p=.49$). The two subgroups also did not differ in whether they had a family member (mother or stepmother, father or stepfather, brother or sister or other adult in family) with a science-related job (42% of females ever interested in engineering compared to 44% of other females, $\chi^2(1, N=277)=0.05$, $p=.83$). Having a family member in a science job was also not statistically related to females' consistent interest in engineering ($b=0.01$, $t(277)=0.33$, $p=.74$), or any interest in engineering ($b=0.15$, $t(277)=0.37$, $p=.71$), even after controlling for student and school demographic characteristics. Females who ever expressed interest in engineering were not more likely than non-interested females to report they participated in science- or engineering-related activities *outside* of school (such as making models; using tools to build things with wood or metal; taking things apart to see how they work; reading books about science or science fiction; writing stories about science or science fiction; visiting a science museum; spending time outside learning about nature; collecting rocks, butterflies, bugs, or other things in nature; and looking up science information in the library or on the internet) (females ever interested in engineering: $M=5.36$, $SD=0.37$; other females: $M=5.17$, $SD=0.14$; $t(275)=-0.46$, $p=.65$).

Science

As in engineering, we found the same general pattern of results for females who ever expressed interest in a science career compared to those who never expressed an interest

Table 3
Summary of logistic regression results predicting student interest in career characteristics (n=482).

	Eighth Grade			Ninth Grade		
	B	$SE\ B$	e^B	B	$SE\ B$	e^B
Design, invent, or develop new products or tools						
Gender	−1.04***	0.22	0.35	−0.98***	0.22	0.38
	$\chi^2(12, N=482)=38.06$, $p<.001$			$\chi^2(12, N=482)=36.08$, $p<.001$		
Spend a lot of time and energy on a problem until you solve it						
Gender	−1.24***	0.31	0.29	−0.57	0.30	0.56
	$\chi^2(12, N=482)=22.11$, $p<.05$			$\chi^2(12, N=482)=26.66$, $p<.01$		
Discover new things that help the environment or people's health						
Gender	0.15	0.23	0.86	−0.17	0.20	0.84
	$\chi^2(12, N=482)=24.84$, $p<.05$			$\chi^2(12, N=482)=23.39$, $p<.05$		
Use computers, lab equipment, and other technology						
Gender	−1.17***	0.21	0.31	−1.44***	0.23	0.24
	$\chi^2(12, N=482)=22.11$, $p<.05$			$\chi^2(12, N=482)=64.54$, $p<.001$		
Conduct investigations to understand how the world works						
Gender	−0.64*	0.26	0.52	−0.75**	0.26	0.47
	$\chi^2(12, N=482)=56.61$, $p<.001$			$\chi^2(12, N=482)=23.71$, $p<.05$		
Analyze data to draw conclusions						
Gender	−0.20	0.32	0.82	−0.41	0.36	0.66
	$\chi^2(12, N=482)=15.46$, $p=.22$			$\chi^2(12, N=482)=23.49$, $p<.05$		
Have your work reviewed and critiqued by others						
Gender	−0.02	0.27	0.98	−0.37	0.31	0.69
	$\chi^2(12, N=482)=18.27$, $p=.11$			$\chi^2(12, N=482)=17.13$, $p=.14$		

Note. These models include controls for student ethnicity, social economic status, grade point average, early interest in science, knowing an engineer/knowing a scientist, percentage of school eligible for free or reduced lunch, ethnic composition of school, and school enrollment. However, only odds ratios (standard errors in parentheses) for gender are shown here for brevity. Gender coded as 1 for female and 0 for male.
*$p<.05$. **$p<.01$. ***$p<.001$.

in science, and the same two variables (early interest and school experiences) differentiated these two groups. Females who expressed interest during the study were more likely than non-interested females to report their interest in science had begun by third grade ($\chi^2(1, N=277)=13.32$, $p<.001$). Also, females who expressed interest in science careers were more likely to participate in school science experiences before seventh grade ($M=0.36$, $SD=0.07$) compared to females who were never interested in science ($M=0.14$, $SD=0.03$, $t(275)=-3.64$, $p<.001$). Unlike females interested in engineering, females who ever expressed interest in science were also more likely than non-interested females to participate in science-related activities outside of school (females interested in science: $M=6.23$, $SD=0.20$; other females: $M=4.74$, $SD=0.16$; $t(275)=5.46$, $p<.001$). As with engineering, these two subgroups of females did not differ in knowing a scientist ($\chi^2(1, N=277)=1.14$, $p=.29$), or other student characteristics.

Discussion

While there is much research on gender differences across STEM occupations, these regression analyses allow us to unpack gender differences within two of the STEM fields (science and engineering) after controlling for student and school demographic characteristics such as ethnicity, social economic status, and achievement, which prior research indicates is related to student interest in engineering and science careers. Our results support prior research such as quantitative studies by Sadler et al. (2012) in that not only were far fewer females than males strongly interested in engineering, but female interest in engineering was less consistent or stable over the three years of the study compared to males. Similar to previous research, we also found gender differences in terms of engineering and physical science career interests (with females being less interested than males) but not biological science career interests. However, in contrast to findings from Sadler et al. (2012), we found no gender differences in consistency of interest in *science* careers after controlling for student and school characteristics. One possible reason for this difference is that Sadler et al. (2012) surveyed a stratified national random sample of undergraduates ($n=6,860$). The survey asked undergraduates to recall their career intentions at the beginning and end of high school. Our study included a smaller sample that was not nationally representative but did not require middle school students to recall their career interests. Another possible reason is different categorizations of science careers. Sadler et al. (2012) science careers included physical, life, and Earth science, mathematics, and science and mathematics teaching whereas our categorization of science careers did not include science and mathematics teaching and differentiated between physical and life sciences career interests and overall science career interests.

This research builds on prior research such as work by Jones et al. (2000) by not relying solely on the label of engineering or science as a viable career interest. We asked students about their preferences for several specific characteristics of science and engineering jobs and found important gender differences in what appeals to them. Our finding that males were more likely than females to be interested in designing, inventing, or developing things corroborates a similar result in Jones et al. (2000, p. 188) and suggests that future efforts attempt to help females see how designing, inventing, or developing things could be rewarding when applied to areas they care about. In addition, our findings suggest that females were as interested as males in jobs in which they could improve others' health or the environment, analyze data, and have their work reviewed by others. Emphasizing attractive features of potential science and engineering jobs could help future efforts be more effective in inviting female students to pursue engineering or science. Qualitative research could also explore in greater detail how female students view various aspects of the jobs they reject or to which they aspire.

Our approach also extends prior research by Baker and Leary (1995) who conducted interviews with 40 females to better understand their attitudes toward science. They found that females were interested in science careers where they perceived they could help to care for people or animals. We extended their qualitative evidence by including a larger sample and statistical controls for both student and school characteristics as well as including items about interest in careers where one could discover new things that help the environment or people's health. Our work provides additional evidence of this particularly important career characteristic that could be extended in future research to better ascertain the nature of what invites young people to consider various careers regardless of the job title, particularly in engineering, a field few students know much about. Males and females were about equally interested in careers where one discovers new things that help the environment or people's health. However, males were more likely than females to favor career characteristics that are typically associated with engineering careers, including designing, inventing, and developing new products or tools. While this is certainly part of what engineers do, students may not realize that they also help to design, invent, and develop new products or tools that help the environment or people's health. Our findings are consistent with recommendations from the National Academy of Engineering (2008), which indicate that students do not know the range of possible ways engineers help others. Since both males and females expressed interest in careers that help people or the environment, it may be productive to better inform young people about this aspect of many engineering careers. For example, engineers "constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward-thinking ways" (National Academy of Engineering, 2008, p. 5), help address important societal and community concerns (such as working to cool overheated fuel from Japan's damaged nuclear power station), and can immediately and directly contribute to our welfare and quality of life on a large scale.

This research is also consistent in terms of the important influence of early science interest and experiences on future interest in science and engineering careers. However, there are differences with prior research in terms of the influence of family members with science-related jobs on student interest in science or engineering careers. Either our sample was more likely to have extended rather than immediate family members with science-related jobs, diluting their potential influence, or it was older than samples included in other research. Another difference is the influence of knowing a scientist or engineer. This was related to interest in science or engineering careers but was significantly related to *consistent* interest in science or engineering for males and not females. Future research could explore why this gender difference may exist. For example, sustained female interest may be a function of certain aspects of the relationship between female students and the engineers or scientists they know. Does the engineer work closely and in a positive manner with the student on a design project or does s/he intimidate the student, overemphasize competitive actions, or not bother to share his/her engineering enthusiasm? The gender difference may also reflect gendered views of many families about what engineering entails and who can/should become an engineer. Also notable was the lack of association between engineering career interest and early engineering-related experiences such as taking things apart or building things, while for *science* there was an association between early extracurricular activities and career interest. One possible explanation is that the association depends on adults in some way. For example, students have been more likely to have experiences in science but not in engineering during those early years. Extracurricular experiences in science may not need additional adult involvement beyond what exists in school, whereas extracurricular experiences in engineering up to now have typically had no school counterpart to back them up. Thus, the effect of early experience on career interest may be related to certain types of adult involvement, modeling, and/or career awareness, which may be more likely in school-based programs than in free-play activities or family settings, where some parents may not share much about science or engineering with their children, particularly girls.

In this sample, in addition to the importance of early interest in science, was the importance of early school science experiences. This research included only structural issues such as school demographic characteristics related to school science experiences; but with the inclusion of engineering in science classes by the NGSS, there are a number of process issues that future research should continue to explore, such as teacher characteristics (Donna, 2012; Druva & Anderson, 1983; Hsu, Purzer, & Cardella, 2011; Wang, Moore, Roehrig, & Park, 2011) and instructional opportunities in schools (Brotman & Moore, 2008; Furtak, Hardy, Beinbrech, Shavelson, & Shemwell, 2010; Price & McNeill, 2013; Schnittka, 2012; Stohlmann, Moore, & Roehrig, 2012) and outside of school (Demetry et al., 2009; Fadigan & Hammrich, 2004; Hughes, Nzekwe, & Molyneaux, 2013; Virnoche, 2008). There is still much to understand about the kinds of experiences in families, classrooms, after-school, and summer programs that spark and sustain student interest in engineering and science (e.g., Hutchinson, Bodner, & Bryan, 2011). Future research could also explore how students perceive various career options in relation to their developing values and perceived abilities in their everyday lives.

References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). "Balancing acts": Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, *96*(6), 967–989.

Aschbacher, P. R., Ing, M., & Tsai, S. (2013). Boosting student interest in science. *Phi Delta Kappan*, *95*(2), 47–51.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*(5), 564–582.

Atwater, M. M., Wiggins, J., & Gardner, C. M. (1995). A study of urban middle school students with high and low attitudes toward science. *Journal of Research in Science Teaching*, *32*(6), 665–677.

Baker, D., & Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Teaching*, *32*, 3–27.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, *17*(4), 369–386.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, *45*(9), 971–1002.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms: Understanding "A Framework for K-12 Science Education." *Science Teacher*, *78*(9), 34–40.

Calabrese Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal*, *45*(1), 68–103.

California Department of Education. (2013). Data and statistics [Data file]. Retrieved from http://www.cde.ca.gov/ds/

Demetry, C., Hubelbank, J., Blaisdell, S. L., Sontgerath, S., Nicholson, M. E., Rosenthal, E., & Quinn, P. (2009). Supporting young women to enter engineering: Long-term effects of a middle school engineering outreach program for girls. *Journal of Women and Minorities in Science and Engineering*, *15*(2), 119–142.

Donna, J. D. (2012). A model for professional development to promote engineering design as an integrative pedagogy within STEM education. *Journal of Pre-College Engineering Education Research*, *2*(2), 1–8.

Druva, C. A., & Anderson, R. D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching*, *20*(5), 467–479.

Fadigan, K. A., & Hammrich, P. L. (2004). A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program. *Journal of Research in Science Teaching*, *41*(8), 835–860.

Furtak, E. M., Hardy, I., Beinbrech, C., Shavelson, R. J., & Shemwell, J. T. (2010). A framework for analyzing evidence-based reasoning in science classroom discourse. *Educational Assessment*, *15*(3–4), 175–196.

Gilmartin, S. K., Li, E., & Aschbacher, P. (2006). The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students. *Journal of Women and Minorities in Science and Engineering*, *12*(2–3), 179–207.

Hanson, S. L. (1996). *Lost talent: Women in the sciences*. Philadelphia, PA: Temple University Press.

Hsu, M., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research*, *1*(2), 31–39.

Huang, G., Taddese, N., & Walter, E. (2000). *Entry and persistence of women and minorities in college science and engineering education* (NCES 2000601). Washington, DC: National Center for Education Statistics.

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The single sex debate for girls in science: A comparison between two informal science programs on middle school students' STEM identity formation. *Research in Science Education*, *43*(5), 1979–2007.

Hutchinson, K., Bodner, G. M., & Bryan, L. (2011). Middle- and high-school students' interest in nanoscale science and engineering topics and phenomena. *Journal of Pre-College Engineering Education Research*, *1*(1), 30–39.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84*(2), 180–192.

Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

McCoach, D. B., & Siegle, D. (2003). The school attitude assessment survey—revised: A new instrument to identify academically able students who underachieve. *Educational and Psychological Measurement*, *63*(3), 414–429.

National Academy of Engineering. (2002). *Diversity in engineering: Managing the workforce of the future*. Washington, DC: National Academies Press.

National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: National Academies Press.

National Science Board. (2012). *Science and engineering indicators 2012*. Arlington, VA: National Science Foundation. Available online at: http://www.nsf.gov/statistics/seind12/

National Science Foundation. (2013). *Women, minorities, and persons with disabilities in science and engineering*. Washington, DC: National Science Foundation.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049–1079.

Price, J. F., & McNeill, K. L. (2013). Toward a lived science curriculum in intersecting figured worlds: An exploration of individual meanings in science education. *Journal of Research in Science Teaching*, *50*(5), 501–529.

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, *96*(3), 411–427.

Scantlebury, K., & Baker, D. (2007). Gender issues in science education research: Remembering where the difference lies. In, S. Abell & N. Lederman(Eds.), *Handbook of research on science education* (pp., 257–286). Mahwah, NJ: Lawrence Erlbaum.

Schnittka, C. G. (2012). Engineering education in the science classroom: A case study of one teacher's disparate approach with ability-tracked classrooms. *Journal of Pre-College Engineering Education Research*, *2*(1), 35–48.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74*, 1–18.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrating STEM education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34.

Virnoche, M. E. (2008). Expanding girls' horizons: Strengthening persistence in the early math and science education pipeline. *Journal of Women and Minorities in Science and Engineering*, *14*(1), 29–48.

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, *1*(2), 1–13.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching*, *32*(4), 387–398.

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

Xu, J., Coats, L. T., & Davidson, M. L. (2012). Promoting student interest in science: The perspective of exemplary African American teachers. *American Educational Research Journal*, *49*(1), 124–154.