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Disciplinary Differences in Out-of-School High School Science Experiences and Influence on Students' Engineering Choices

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Abstract

Participation from a variety of students is important to the long-term growth of the engineering field. Much of the research on engineering recruitment or career choice has focused on engineering as a whole, even though engineering disciplines are varied in student participation and focus. This work examines how students' out-of-school interests and experiences in high school predict the likelihood of choosing a career in a particular engineering discipline. Out-of-school experiences offer more unstructured ways for students to meaningfully engage with science and engineering outside of the confines of the classroom. These experiences offer opportunities to spark particular science interests not included in traditional high school science curriculum. Additionally, participation in engineering for women has been historically low. For this reason, we also examined reported differences in out-of-school experiences by gender. Our findings indicate that reported out-of-school experiences increased the odds of students choosing particular engineering disciplines. Experiences traditionally stereotyped as masculine and more often reported by men, such as tinkering, increased the odds of choosing engineering disciplines with higher representation of men. However, some experiences equally reported by men and women, such as mixing chemicals or engaging with chemistry in the kitchen or talking with friends or family about science, predicted higher odds of choosing engineering disciplines with higher representation of women (chemical, biomedical, environmental). These quantitative results are a first step in understanding how out-of-school experiences are connected to the nuanced decisions of disciplinary engineering career decisions and have implications for the way engineering faculty draw on prior experience in the classrooms and for researchers on how out-of-school activities may predict students' long-term career decisions.

Keywords: informal science, personal interest, engineering career choice, engineering disciplines, gender

Introduction

Students' participation in engineering is vitally important as calls from the U.S. President, Barack Obama, have emphasized the need for *one million* new Science, Technology, Engineering, and Mathematics (STEM) graduates in the next decade to maintain the country's global competitiveness (PCAST, 2012). Others have documented a need for not just more engineers (Kelly, Butz, Carroll, Adamson, & Bloom, 2004; Teitelbaum, 2014), but a more diverse workforce of engineers that can

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lead to greater innovation (Miller Jr., 2003). After the freshman year, routes into engineering are relatively closed due to a significant number of pre-requisite courses and time to graduation (Ohland et al., 2008). Understanding why students choose engineering in college can help identify avenues through which more students can see themselves as engineers and choose engineering as a career before routes into engineering are more difficult to pursue. Prior work has shown that developing math- and science-related identities and developing motivation to accomplish far-off goals are important attributes for students choosing and wishing to persist in engineering fields (Godwin, Potvin, Hazari, & Lock, 2016). This work is an extension of a prior study examining how students' out-of-school experiences predicted engineering identity at the beginning of college, future engineering certainty, and gender differences to further explore how interests in STEM-related activities before college can impact disciplinary engineering choice (Godwin, Sonnert, & Sadler, 2015).

Understanding how differences in students' high school experiences and interests predict students' identification with specific engineering disciplines can begin to address the need for more engineering students. Many studies treat engineering as a monolith in understanding student choices of a career path. The choice of engineering as a career is not well understood, much less *why* students choose specific engineering disciplines. Engineering disciplines are not homogeneous; significant variation exists in the number and demographics of students entering specific disciplines. For example, Black and Asian males prefer electrical engineering at higher rates than white males. On the other hand, Hispanic males choose both mechanical and electrical engineering in the same proportion (Lord, Layton, & Ohland, 2014). Women also choose engineering disciplines at different rates with biomedical and environmental engineering garnering the highest numbers. Some research on why women choose engineering careers has documented the importance of seeing engineering as a way to make a positive impact in the world (Bielefeldt, 2006; Committee on Public Understanding of Engineering Messages, 2008; Godwin & Potvin, 2015; Godwin et al., 2016; Klotz et al., 2014; Matusovich, Streveler, & Miller, 2010); however, the specific factors that impact how students choose engineering disciplines are not well understood.

Learning outside of the classroom environment offers some benefits over traditional learning. Participating in everyday experiences can support science learning, inquiry, and curiosity for a broad range of students – even those that do not excel in a school science environment (Mallya, Mensah, Contento, Koch, & Calabrese Barton, 2012; Varelas, 2012). Informal science learning is typically characterized as learner-motivated, guided by learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended (Falk & Dierking, 2000; Griffin, 2004; Rennie, Feher, Dierking, & Falk, 2003). From infancy to late adulthood, individuals learn about the natural world and develop important skills for science knowing and doing. Out-of-school experiences are rich with real-world phenomena and connect students' prior and everyday knowledge with science content and learning (Bell, Lewenstein, Shouse, & Feder, 2009). A large part of science pedagogy in schools focuses on a limited part of science education, namely received content knowledge and simplistic notions of scientific practice (Lemke, 1993; Newton, Driver, & Osborne, 1999; Rockman, Bass, & Borland, 2007; Rudolph, 2002). Out-of-school experiences offer opportunities for students to develop an interest in science, participate in science inquiry, and engage in sense-making conversations. These settings provide ways for learners to engage with science and become empowered as science learners, especially for students from underrepresented groups. These out-of-school environments have unique strengths that are complementary to the science instruction occurring in schools and can offer additional ways to connect students to science.

Some prior work has examined differential choices of engineering specialties based on students' background experiences (Dee, Nauman, Livesay, & Rice, 2002; Godwin & Potvin, 2013; Johnson & Singh, 1998; Potvin et al., 2013; Shivy & Sullivan, 2005). Significant differences in career outcome expectations, math and physics identities, beliefs about the impact that STEM has on the world, high school influences on disciplinary career choice, and sustainability attitudes were found across students (Potvin et al., 2013). Additionally, some studies have explored the trajectories of students in specific engineering disciplines by both race and gender. From this work, the recruitment and retention statistics in several engineering disciplines can be understood. Women of all races in computer engineering and Hispanic women in electrical engineering are less likely to remain in their engineering discipline than their peers. Computer engineering is the most popular choice of discipline for Asian and Black students; however, Asian students graduate at high rates, but Black students are not retained in the discipline (Lord, Layton, & Ohland, 2011). These findings give weight to the need for understanding not only what experiences impact students' choice of engineering in general, but also their choice of specific engineering disciplines. Nevertheless, the data in these studies are limited to high school transcripts which include standardized scores and course taking, but not out-of-school experiences (Lord, Ohland, Layton, & Orr, 2013; Orr, Lord, Layton, & Ohland, 2014). Our work examines specifically how informal STEM experiences in high school influence differential choices with specific engineering disciplines that students choose in college. The results illustrate specific differences in students' interests in a nationally representative sample of college freshmen and provide emphasis for the claim that "engineers should not be lumped together into a single category" (Dunnette, Wernimont, & Abrahams, 1964, p. 492).

Prior research on out-of-school experiences

We focused on students' extracurricular experiences because, until college, most high school curriculum is undifferentiated for students intending on majoring in a variety of STEM fields in college (Committee on K–12 Engineering Education, 2009). Understanding how experiences outside of traditional course work may help provide opportunities for students to engage with science- and engineering-related activities and spark an interest in engineering in college; however, much of the empirical research on students' out-of-school experiences has focused on the outcomes of science interest and literacy, rather than engineering choice. Citizen science programs have been found to improve students' knowledge and attitudes about science and plans to modify behaviors based on gained scientific literacy (Crall et al., 2013). Community-based programs have also shown an impact on students' agency and ownership of science (Barton Calabrese & Tan, 2010; Mallya et al., 2012). Additionally, these experiences have been shown to improve students' success in the classroom, including additional STEM course taking and passing standardized school exams (Weinstein, Whitesell, & Schwartz, 2013). Students' views of the nature of science, specifically, the tentative nature of science and roles of observation in scientific work, also have been shown to be improved through out-of-school programs (Quigley, Pongsanon, & Akerson, 2011). While these findings are important for the development of scientifically informed citizens exiting from our public education system in the U.S., this vast body of literature does not explicitly examine students engineering career intentions, much less disciplinary engineering career intentions. Our work extends our understanding of these science outcomes in relation to engineering for students in the transition from high school to college.

Overall, there has been little research on the self-selection effects governing participation, let alone career outcomes, of out-of-school experiences (Hazari, Sonnert, Sadler, & Shanahan, 2010; Rennie, Fehrer, Dierking, & Falk, 2003). These experiences include museum visits, science groups or clubs, and science competitions, which are structured (Bell et al., 2009). Unstructured activities are less frequently studied including conversations or socializing around science, tinkering with objects, personal science hobbies, and reading non-fiction science and science fiction (Hazari et al., 2010; Maltese & Tai, 2010; Nazier, 2010). The National Research Council supports out-of-school science experiences as having a positive impact on education because they promote interest in science within the real world (Bell et al., 2009). Fostering interest in a science-related area has been shown to motivate STEM career choice and persistence (Godwin et al., 2016; Hazari et al., 2010; Lent, Brown, & Hackett, 1994; Renninger, Hidi, & Krapp, 1992). Research on informal science has begun to examine how these experiences influence students' career choice. These studies found that exposure to science at an early age (middle school or younger) has a significant impact on students' physical science/engineering career intentions, raising them by approximately 3.5 times as opposed to a non-science career (Tai, Liu, Maltese, & Fan, 2006). Additionally, students tend to develop an interest in science prior to middle school (Maltese & Tai, 2010). From this study, classroom-based activities tended to spark these interests among females, while males tended to report more self-initiated, unstructured, informal science activities.

One area in which some connection to students' interest in engineering through informal experiences has been explored is through tinkering. This activity has become a popular topic in recent years around maker spaces. "Makers are an emerging community of self-described DIY-enthusiasts, tinkers, and hobbyists," that create for enjoyment, interest, and learning (Lande, Jordan, & Nelson, 2013, p. 1). This collaborative group of technical artists works to collectively learn and share insights into developing products and interact with each other's work at gatherings called Maker Faires. These hands-on open-ended activities that involve playing with and exploring materials and making things can be a tool to foster student interest in engineering-related careers. Natural observations of children at the Lawrence Hall of Science interacting with the *Ingenuity in Action* exhibit revealed that the open-ended tinkering exhibits created explicit connections to scientific and technological knowledge as well as some engineering design process steps but did not make explicit connections to engineering as a field or the possibility of engineering as a career (Wang et al., 2013). Students did not make these connections at the time of the study; however, these interactions could have fostered interests in engineering-related topics that may manifest in career decisions later in life.

Underrepresentation of women in engineering

In addition, women continue to be underrepresented in engineering as a whole, with approximately one-fifth of bachelor's degrees awarded to women each year in the United States. Substantial differences in female participation exist across engineering disciplines (Yoder, 2013). However, the reasons for these differences have not been fully investigated. For example, women are more highly represented, when compared to the average number of bachelor's degrees awarded overall in engineering (19.1%), in biomedical, civil, chemical, environmental, and industrial engineering, while continuing to have lower than average participation in mechanical, electrical, computer, and aerospace engineering (Yoder, 2013). A greater number of talented engineers is needed, and understanding how to increase diversity in engineering through how out-of-school experiences affect choices of engineering careers will contribute to improving the types and numbers of engineers entering the workforce to meet the challenges of the 21st century. Understanding how women's varied experiences outside of the high school classroom can impact engineering choices by discipline may begin to highlight ways to recruit more women into specific engineering disciplines. Engineering, although often treated as a homogenous group in many studies, shows significant variation. This paper expands work previously conducted to include these disciplinary difference comparisons and expand the discussion on the impact of out-of-school experiences on identification with engineering (Godwin et al., 2015).

Gender differences have been found in students' participation in out-of-school experiences. Females more often reported biology-related experiences (i.e., observing birds or plants), whereas males more often reported physics-related experiences (i.e., made a bow and arrow or played with electric batteries and bulbs; Jones, Howe, & Rua, 2000). In addition, the odds of reporting a STEM career interest (rather than a career interest outside of STEM) at the end of high school are approximately nine times as high for students who reported an interest in engineering or science careers at the start of high school as for students who did not report such an interest at the start of high school (Dabney et al., 2012). This finding indicates that students' interest and career intentions, which are impacted by students' out-of-school experiences, are an important part of possible engineering choice in the future.

Research Questions

In this paper, we conducted analyses to address the following research questions: (1) Are there disciplinary differences in students' prior high school extracurricular experiences and interests? and (2) Are these reported experiences different by gender?

Theoretical Framework

This study explores engineering disciplinary career interests based on out-of-school experiences. The basis of this study focuses on how students' interests may align with particular types of out-of-school experiences and impact future choices. The importance of interest in student pathways and STEM has been described in the prior section. In this work, we define interest as "person's likes, preferences, favorites, affinity toward, or attraction to a subject, topic, or activity" (Dunst & Raab, 2012, p. 1621). In other work, interest has been described by either *situational* interest or *personal* interest (Renninger et al., 1992). Situational interest is activated by the external environment based on the novelty of the context or relevant to particular task or learning goal. On the other hand, personal interest is based on a person's enduring values and is internally activated with an external context is relevant. Situational interest is important to catch students' attention, whereas personal interest is important in holding it (Durik & Harackiewicz, 2007; Mitchell, 1993). Many studies that examine the impact of out-of-school experiences including STEM outreach programs often focus on interest, in general, immediately after the intervention. We posit that these measures are typically of situational rather than personal interest. Personal interest appears to be especially important for sustaining engagement and long-term learning (Hidi & Renninger, 2006). In this paper, our work explores the connection between sustained self-reported experiences and interests as tied to long-term engineering pathways.

In fact, in prior literature, personal interest in a particular subject impacts how individuals function, produce particular ways of life, and engage with STEM (Carlone, 2012). For these reasons, interest in STEM has been an important part of behavioral research within engineering education (Geisinger & Raman, 2013; Godwin et al., 2016; Schreuders, Mannon, & Rutherford, 2009). Interest plays a key role in whether or not students want to take on the role identity of an engineer.

This interest framework has guided our study. Nevertheless, we would like to emphasize that this work is exploratory in nature and direct, causal connections between particular interests, out-of-school experiences, and career choice are not determinable in this cross-sectional study.

Methods

The data for this study came from the Outreach Programs and Science Career Intentions (OPSCI) survey given in the fall of 2013 to incoming students at U.S. institutions of higher education that participated the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) funded by National Science Foundation (NSF DUE 1161052). This program supports initiatives geared toward increasing the number of students receiving associate's or baccalaureate degrees in the STEM fields. The survey was administered in freshman English courses, typically required as a general education credit, to gain a representative sample of both STEM and non-STEM students at each participating university.

In the typical cases, personalized recruitment emails were sent to the Chairs of the English Department, specifically mentioning the STEP researcher involved at their university. Of the 150 institutions, 104 never responded to repeated inquiries. Of the 46 that responded, 27 (59%) participated with at least one professor. These responses included 23 four-year institutions and four two-year institutions. Of the 535 instructors who initially agreed to administer the survey, 414 instructors (77%) followed through, returning 15,847 completed student surveys. The surveys were administered in hardcopy during class time so that student participation was close to 100%.

The questions on the OPSCI survey were to a considerable portion identical with the questions that had already been developed and successfully used in an earlier study titled "Persistence Research in Science and Engineering" (PRiSE – NSF GSE 062444). Other questions were created specifically for the OPSCI survey by the project team. The OPSCI survey was pilot tested with students at a Southern university to ensure construct validity and the time it took for survey completion. Test-retest reliability of the survey was established by administering the survey to 57 students at that same university twice in an interval of about two weeks. For continuous variables, the Pearson correlation coefficient between the test and retest answers served as a measure of reliability; for categorical variables, Cohen's kappa was used. The overall means were 0.73 for the correlation coefficients and 0.59 for the Cohen's kappas.

The survey examined a variety of students' out-of-school experiences with the goal of increasing the use of research-based evidence in the implementation of effective practices focused on the transition from secondary to post-secondary education. The larger study examined factors that predispose students to STEM with an emphasis on under-represented minorities and young women. The questions used for this paper included two questions. The first asked students to mark a choice of a career out of a list that "BEST describes what you want to be in college." The full list of careers included engineering, science, technology, and mathematics careers as well as many non-STEM disciplines. These choices were as follows: medical professional, health professional, biologist, earth/environmental scientist, astronomer, chemist, physicist, engineer (in general), mechanical engineer, electrical engineer, civil engineer, chemical engineer, bio/biomedical engineer, environmental engineer, industrial engineer, engineering technologist, computer scientist/programmer, other scientist, mathematician/statistician, science teacher, math teacher, other teacher, social scientist, business person, lawyer, English/language arts specialist, sports-related, arts-related, other non-science related career. Students marked a single choice for their "BEST" choice. The other question used in this analysis asked students to report "Which of the following interests and experiences did you have while growing up?" Students were asked about a list of experiences (described in Table 1) in each of grades 9, 10, 11, and 12. We combined the answers to these questions across all high school years (grades 9–12) into a binary outcome if students had a particular interest or experience in high school. Because this is an exploratory study, we wanted to examine the impact of particular interests or experiences on disciplinary career choice in college. This approach is consistent with prior literature that shows that the majority of students decide on an engineering major at the end of high school (Cass, Hazari, Sadler, & Sonnert, 2011).

Students interested in the seven listed engineering disciplines (mechanical, electrical, civil, chemical, bio/biomedical, environmental, and industrial) were compared on their out-of-class high school experiences and interests using multinomial logistic regression. Of the total number of students who took the OPSCI survey, 2007 students indicated an interest in an engineering career. Logistic regression was used to quantify the relationship between engineering discipline career interest and high school out-of-school experiences. For the analysis, each out-of-school experience (binary of either had experience or did not have experience) was predicted by all seven of the disciplinary career interests. This approach allowed us to understand how each of the responses to all seven disciplines compared to one another in student interest and all estimates account for other possible disciplinary alternatives.

All students reported relationships between out-of-school experiences and disciplinary engineering interest are reported as odds ratios. Odds ratios are used to compare the relative odds of the occurrence of the outcome of interest (e.g., engineering disciplinary interest), given exposure to the variable of interest (e.g., having a particular out-of-school experience). The odds ratio can also be used to determine whether a particular exposure is a predictive factor for a particular outcome and to compare the magnitude of various factors for that outcome (Ott & Longnecker, 2008). Odds ratios greater than one indicate a higher likelihood, and odds ratios less than one indicate a lower likelihood of being interested in a particular engineering discipline.

To address the second research question, chi-square tests were utilized to understand how students differentially reported these experiences by gender. Students indicated if they had these experiences (see Table 1 for a list of interests and experiences) during high school on a binary scale (0 = "No," and 1 = "Yes"). The engineering discipline choices were determining if a student indicated that a particular engineering discipline in the survey was a desired career at the beginning of college (0 = did not check this career, 1 = checked this career – see Table 2 for numbers of participants by gender). All analyses were conducted using the statistical program R (R Core Team, 2014). The cutoff for significance was set at $\alpha < 0.01$ level to reduce the risk of Type I error.

Results and Discussion

Disciplinary differences

Significant differences were found between engineering disciplines in the types of out-of-school activities students indicated interest in or experiences with during grades 9–12 of high school (Table 3). Not surprisingly, students who indicated an experience in tinkering with either mechanical

Table 1.
Abbreviations for interests and experiences used in analyses.

Abbreviation	Reported Interest/Experience
tinkm	Tinkered with mechanical devices (e.g., rifle, bow and arrow, car jack, pulleys, wheelbarrow, sewing machine)
tinke	Tinkered with electrical devices (e.g., cars, batteries and bulbs, radio, TV)
chem	Mixed chemical/materials. Engaged with chemistry sets, kitchen chemistry
animal	Took care of or trained an animal
plant	Planted seeds, watched plants grow, watched animal behavior, collected things in nature (e.g., butterflies, rocks)
star	Observed or studied stars and other astronomical objects
group	Participated in science groups/clubs/camps
comp	Participated in science/math competition(s)
nonfic	Read/Watched non-fiction science
scifi	Read/Watched science fiction
game	Played computer/video games
prog	Wrote computer programs or designed web pages
talk	Talked with friends or family about science

Table 2.
Comparison of males and females who reported interest in a specific engineering discipline.

Engineering Discipline	Male (n)	Female (n)
Mechanical (ME)	509	74
Electrical (EE)	258	53
Civil (CE)	211	75
Chemical (ChE)	148	77
Bio/Biomedical (BME)	137	113
Environmental (EnvE)	95	64
Industrial (IE)	104	59

or electrical items were more likely to be interested in compatible engineering disciplines of mechanical, electrical, or civil engineering. Students who engaged with chemistry outside of traditional classroom experiences were more likely to enter chemical or bio/biomedical engineering. This result is consistent with previous findings that students with deep interests in chemistry more often enter chemical engineering over other engineering disciplines (Godwin & Potvin, 2013). Students who interacted with the natural world (i.e., reported plant out-of-school experiences) were more likely to go into environmental engineering over other disciplines.

Participating in science groups or competitions predicted entering a variety of engineering disciplines. Often, many of the competitions or programs involve multiple aspects of engineering and may attract a wide variety of students interested in engineering (Aschbacher, Li, & Roth, 2010; Coyle, Jamieson, & Oakes, 2005; "Engineering – Curriculum," 2014), and this response had the most associations with a variety of engineering disciplines in college including mechanical, electrical, chemical, bio/biomedical, and environmental engineering. Interestingly, no out-of-school experiences predicted a higher chance of entering industrial engineering than other disciplines. Additionally, caring for an animal did not have any relationship with engineering disciplines. Many of the reported activities were significantly related to choosing mechanical or bio/biomedical engineering in college which are the first and fourth largest engineering disciplines, respectively (Yoder, 2013). Finally, all of the reported odds ratios were slightly greater than one, indicating that students the significant impacts of these out-of-school experiences on engineering disciplinary choice were all small but positive. Participation in science-related out of school experiences fractionally increased the odds of choosing at least one engineering discipline for all experiences except, caring for an animal (which was non-significant).

Creating opportunities to connect with students' individual interests can prove to be a valuable strategy for developing students' disciplinary engineering choices in college. Individuals' interests have a rich theoretical basis as a fundamental construct in models for human learning (Renninger et al., 1992). For example, "interest in conversation, or communication; in inquiry or finding out things; in making things, or construction; and in artistic expression [are the] natural resources, the uninvested capital, upon which depends the active growth of the child" (Dewey, 1980; pp. 47, 48). By offering students opportunities to connect their interests with engineering tasks, clearer connections can be made between activities that students enjoy doing and engineering, thus combating gender stereotypes and fostering engineering career opportunities.

Gender Differences

Many of the out-of-school experiences traditionally associated with women (i.e., caring for animals, engaging in the natural world, observing stars; Jones et al., 2000) predict intended majors in engineering disciplines with traditionally higher representation of women than other engineering disciplines. These include chemical (35.4% women), bio/biomedical (40.8%), and environmental (46.0%) when compared to the overall number of bachelor's degrees in engineering awarded to women (23.9%; Yoder, 2013). Interest and involvement with these types of out-of-school experience may explain some of the variability in numbers of women in each engineering discipline. By understanding

Table 3.
Influence of out-of-school experiences on engineering discipline career interest. Significance is given as *** ($p < 0.001$) and ** ($p < 0.01$). The numbers listed are the odds ratios for these outcomes. All blank spaces represent non-significant results.

	ME	EE	CE	ChE	BME	EnvE	IE
tinkm	*** (1.40)	*** (1.19)	** (1.08)				
tinke	*** (1.20)	*** (1.23)					
chem				** (1.11)	*** (1.13)		
animal							
plant						*** (1.23)	
star					*** (1.11)		
group	*** (1.07)				*** (1.18)		
comp	*** (1.08)	** (1.07)		*** (1.14)	** (1.08)	*** (1.23)	
nonfic	*** (1.10)				*** (1.13)		
scifi			** (1.17)				
game	** (1.06)		** (1.17)		** (1.11)		
prog		*** (1.15)					
talk	*** (1.13)			*** (1.21)	*** (1.20)		

how these outcomes impact student choice, interest in these subjects may be fostered, especially by parents (Eccles & Harold, 1993; Eshach, 2007; Mau, 2003), to encourage students to choose engineering in college.

Significant differences were also found in male and female engineering students' indicated out-of-school interests or experiences during grades 9–12 of high school (Table 4). More male students reported tinkering with mechanical or electrical devices, reading or watching science fiction, playing computer/video games, and writing computer programs or designing web pages. More female students reported interacting with the natural world and participating in science groups/clubs/camps. There were no significant differences by gender in engaging with chemistry, taking care of animals, participating in science/math competitions, reading or watching non-fiction science, and talking with friends or family about science. Math and science competitions often involve multiple intersecting aspects of science and engineering that appeal to a wide-range of students including students who may enter engineering (Aschbacher et al., 2010; Coyle et al., 2005; "Engineering – Curriculum," 2014). The data reported in Table 4 not only show the significant differences and effect sizes between reported experiences of engineering students by gender but also include the averages for *all* students within the sample which are listed in parentheses. For STEM-related out-of-school experiences, all students who indicated an interest in engineering more often reported STEM-related out-of-school experiences than the average student population both male and female groups.

The gender differences found in this comparison are consistent with previous work that shows that some gender stereotypes manifested themselves in students' extracurricular interests and experiences (Godwin & Potvin, 2014; Jones, Howe, & Rua, 2000). However, many of the experiences that have been shown to foster an interest in STEM areas (Maltese & Tai, 2010; Nazier, 2010) were equally reported by male and female engineering students. These findings offer hope that out-of-school experiences that foster interest in engineering career can be centered around experiences that are of interest for both men and women. There are several out-of-school initiatives for underrepresented students to foster interest in traditionally, male out-of-school experiences. For example, "Black Girls Code" offers workshops and after school programs that teacher computer coding lessons ("Black Girls Code," 2015). Microsoft has started *DigiGirlz*, a program that gives high school girls the opportunity to learn about careers in technology (Microsoft, 2015). Also, the *FIRST* Tech Challenge offers students the chance to work with professional engineers and college students to build and program a robot (FIRST, 2015). The "Introduce a Girl to Engineering Day" has also been implemented by Women in Engineering, a co-curricular support and outreach program, at a number of campuses across the country to improve girls' understanding and exposure to engineering outside of the classroom (Purdue University, 2015; The Ohio State University, 2015; University of Texas at Austin, 2015). While many initiatives that foster female interest in more traditionally masculine out-of-school experiences such as tinkering, robotics, and coding can break down barriers to engineering, the long-term impact of these programs is less clear.

The most substantial differences found in this work were in the areas of tinkering and playing computer or video games. These experiences are more stereotypically masculine (Jones et al., 2000), and research on fostering interests in engineering, especially mechanical, electrical, and computer, has focused on these interest areas as a path into engineering (Wang et al., 2013). However, the culture of engineering and emphasis on these skills and activities have created an environment and expectation of incoming students that is exclusionary. McIlwee and Robinson (1992) illustrate this point:

> As long as engineering carries with it the 'tinkering' image, young women will not be drawn to it unless they see themselves and as capable of tinkering too. Being a whiz at math is enough to compensate a

Table 4.
Reported out-of-school experiences for engineering students by gender. Percentages for experiences of all students by gender are included in parentheses for comparison.

Out-of-school Experience	Percentage Engineering Female (All Females)	Percentage Engineering Male (All Males)	Significance[a]	w^b
tinkm	38.6 (23.2)	65.5 (47.7)	***	0.61
tinke	39.5 (26.3)	66.4 (51.8)	***	0.61
chem	48.4 (37.3)	45.2 (38.5)	n/s	0.07
animal	51.8 (49.4)	49.5 (47.1)	n/s	0.05
plant	39.2 (29.9)	27.2 (26.2)	***	0.30
star	31.6 (23.6)	30.5 (27.9)	n/s	0.02
group	35.2 (20.1)	28.4 (21.2)	**	0.17
comp	33.6 (16.9)	29.5 (21.3)	n/s	0.10
nonfic	48.4 (48.5)	52.5 (45.8)	n/s	0.09
scifi	44.8 (39.0)	58.3 (52.9)	***	0.23
game	43.5 (34.6)	75.0 (69.6)	***	0.75
prog	24.0 (17.5)	32.9 (30.0)	***	0.24
talk	59.9 (40.4)	59.5 (46.7)	n/s	0.01

a. Significance calculated using chi-square test. The level of statistical significance is coded in the final column: n/s represents a non-significant result, ** represents a statistical significance less than 0.01 but greater than or equal to 0.001, and *** represents a statistical significance less than 0.001.
b. Effect size calculated using Cohen's *w*. Effect sizes are indicated as small 0.10, medium 0.30, and large 0.50.

> woman for her lack of mechanical background, at least while she is in school. But as long as this is the only kind of woman who becomes an engineer, their number will remain small. (p. 181)

From previous work, women were two times less likely to choose engineering in college than their male peers (Godwin et al., 2015). Women face significant barriers in choosing engineering in college. Often, K-12 experiences influence young girls to view physical science as masculine and not for them, while the life sciences are branded as more feminine (Clewell & Campbell, 2002). Girls typically lose interest in both science and math classes by the time they reach middle school (Miller Jr., 2003). This effect impacts Advanced Placement course taking in high school with girls earning fewer credits in mathematics and science advanced courses than boys. This difference continues the prevailing misconception that boys significantly outperform girls in these subjects (Freeman, 2004; Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Additionally, young women are often given less encouragement to choose engineering as a career and lack as many female role models in engineering as their male peers (Burke & Mattis, 2007; Seymour, 1999). The results of these other barriers are disproportionately low enrollment of women in engineering degree programs (Yoder, 2013).

Many of these barriers to enrollment in engineering occur in traditional school experiences of students as described above. Targeted out-of-school experiences that foster interest in engineering disciplines may create new opportunities to improve students' beliefs about who can be an engineer and understanding of what engineers do. Out-of-school experiences have been shown to improve students' interest ("Project Exploration," 2010), self-efficacy (McLaughlin, 2000; Richardson, 2008), and content knowledge (Wang et al., 2013), all of which impact students' motivation (Kotys-Schwartz, Besterfield-Sacre, & Shuman, 2011; Wigfield & Eccles, 2000). According to the expectancy-value theory of motivation, students' choice of a field, persistence, and enthusiasm for studying in that domain are directly related to their perceptions of the type of person that does work in that field, which can be a stereotype if students do not have direct experience with people who work in those fields (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Wigfield & Eccles, 2000). Out-of-school experiences provide ways to improve students' motivation for choosing a career in engineering through creating authentic connections to engineering, fostering students' personal interests, and combating stereotypes about the work that engineers do.

Implications

These results have several implications for faculty in engineering courses, especially early on in students' post-secondary academic careers. First, when planning engineering curriculum, it is important to know that, on average, males and females may have been engaged in different out-of-school activities before coming to college. However, instructors should be careful not to approve of, or reinforce, stereotypical gender roles, which are likely to underlie the results of this study as well. Assuming that a classroom of engineers has experiences in tinkering or using tools, in particular, may be a poor connection to students' prior knowledge, especially women's. When scaffolding students' prior knowledge and connecting engineering to real life in the classroom, referencing more male-associated out-of-school contexts may heighten the gender conflict many women experience in engineering. Second, to enhance students' motivation to remain in engineering it may be helpful to reference out-of-school experiences that are positive predictors of engineering career choices for both men and women (e.g., participating in science/math competitions, or playing computer or video games).

Many of the reported out-of-school experiences are low or no cost experiences that are accessible to a wide variety of students. Structuring these experiences as related to engineering careers may provide ways to open pathways for students to better understand engineering careers and choose engineering in college. Explicit connections to engineering content must be made in order for students to see their fun or interesting learning experiences as actual engineering content (Wang et al., 2013). Fostering participation in these types of out-of-school activities can connect students' personal interests with engineering. Often, students do not have clear perceptions of what engineers do in their careers (Leonardi, Jackson, & Diwan, 2009; Shivy & Sullivan, 2005), and engineering is often associated with masculine vocations (Capobioanco, French, & Diefes-Dux, 2012; Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008) like fixing or building things (Aswad, Vidican, & Samulewicz, 2011; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Powell, Dainty, & Bagilhole, 2012).

High school teachers also have an important role to play in students' learning both in and out of the classroom. Teachers influence students' understanding and attitudes about science and possible future careers in STEM-related subjects, such as engineering. Through experiences such as field trips, teachers can facilitate the interaction of in-class science learning and experiences with informal design spaces, yet studies have consistently documented that teachers play a small role in the planning and execution of excursions outside of the schoolroom and connecting these field trip experiences to classroom content (Anderson & Zhang, 2003; Griffin & Symington, 1997; Griffin, 1994; Tal, Bamberger, & Morag, 2005). In Griffin's (1994) study, half of the teachers from 13 schools reported that they planned on doing some follow-up activities after their field trip excursions, but only a half of those teachers, a quarter of the sample, actually implemented these follow-up activities. Furthermore, no students reported any expectations of participating in follow-up activities after their trips, indicating that these experiences were rare. Creating these post-activity interactions are difficult because often the experiences outside of the classroom do not directly align with the content being taught in class. Taking time to debrief from out-of-school experiences can take time away from regularly scheduled classroom time that may cover content on standardized testing, which has larger implications for teachers and schools.

Teacher professional development has been a growing topic of research and discussion over the past several decades including both in-service and pre-service teachers. One study by Anderson and colleagues (2006) documented the effects of a pre-service teacher program connected to a local aquarium and structure practicum. This intervention trained teachers in the content knowledge of ecosystems, local marine invertebrates, and the historical and economic aspects of the fishing industry. After this immersive experiences, they spent an additional ten weeks at a school and another three weeks with the aquarium staff. Teacher reflections from the semester revealed an increase in teachers' sense of what constitutes education, educational theory, classroom skills, self-efficacy, and the power of hands-on experiences for learning. Programs like this one may help teachers better connect with out-of-school experiences and provide meaningful learning and connections to science and engineering for students.

In addition, families also have a critical role to play in out-of-school experiences. Families are important in providing support for student attainment through emotional as well as financial dimensions, from fostering students' interests in STEM-careers to paying for college (Blau & Duncan, 1967; Teachman & Paasch, 1998). Parents shape children's attitudes, motivations, values, and aspirations through a socialized family culture and are a locus of control in the education of their children (Fan & Chen, 2001; Yun, Cardella, Purzer, Hsu, & Chae, 2010). Parents or guardians act as "front-line educators" in students' out-of-school experiences (Bell et al., 2009, p. 7). These front-line educators can model science learning behaviors and help their children develop their scientific understanding, explanations, and practice which can, in turn, shape how students interact with science, their peers, and educational materials inside and outside of the classroom. They can also serve as the intermediary between informal science programs and experiences and professional educators. These interactions can occur at home in discussions about observations of nature such as, experimenting with kitchen chemistry, growing plants, watching the stars, or family walks that might spark scientific discourse (Goodwin, 2007). Parents can also choose to foster student participation in structured science experiences through camps, after school programs, and trips to museums and science centers. The features of out-of-school science experiences are likely to vary a great deal depending on the cultural community and particular family. Some students grow up in environments that are rich with science experiences like regularly interacting with living animals, while others are limited in their exposure like only seeing pictures of animals or visiting the zoo on occasion. Students also vary in their exposure to new technology at home which is often closely tied to socioeconomic status. These issues have importance for the ways that different groups interact with science. Specific outreach efforts to parents of students may provide opportunities to capitalize on parent-child conversations around out-of-school experiences to foster engineering interest and expertise.

Finally, this work brings up questions about who has access to science-related experiences outside of the classroom. In this study, women and men who were interested in engineering more often reported having science-related out-of-school experiences. The direction of the relationships cannot be determined. For example, students who were interested in engineering may have sought out more opportunities to interact with science outside of the classroom or students who had those immersive experiences may have developed a stronger connection and interest with science and science-related careers. But for five of the seven experiences with significant differences between men and women, women reported fewer experiences with STEM-related out-of-school experiences.

Women may have fewer opportunities or may not be encouraged as strongly as men to participate in these types of experiences. The benefits of these experiences are well-documented. In a longitudinal study of high school girls participating in after school, summer and weekend programs offered by the Academy of Natural Sciences girls showed positive gains in interest and career intentions (Hammrich & Fadigan, 2005). Out of 152 women that participated from low-income, single-parent households, 109 enrolled in college and the majority of these students reported that their career decisions were influenced by these programs. Additionally, Eisenhart and Finkel (1998) support out-of-school experiences as a way to encourage science interest, "once outside the confines of conventional school science and engaged in more meaningful activities, women seemed to lack neither an interest in science nor the ability to learn it" (p. 239).

More recent research also supports these calls for higher participation of women in science experiences outside of the traditional classroom (Banks et al., 2007; Basu & Barton, 2007; Carlone & Johnson, 2007; Dotterer, McHale, & Crouter, 2009; Falk & Dierking, 2010; McCreedy & Dierking, 2013; Munley & Rossiter, 2013; Schwartz & Noam, 2007). On average, girls hold less positive attitudes toward science than do boys (Brotman & Moore, 2008), and women exhibit less interest and higher attrition rates in pursuing science-related careers (Freeman, 2004; Hill, Corbett, & St Rose, 2010; Xie, Shauman, & Shauman, 2003). Trends in bachelor's degrees awarded to women in STEM show that fewer are awarded to women, specifically in engineering (Hill et al., 2010; Huang, Taddese, & Walter, 2000; Landivar, 2013; Rosser & Taylor, 2009; Yoder, 2013). These numbers are in spite of the fact that women typically have higher GPAs in high school and college and enroll in college, overall, at higher rates than men (Conger & Long, 2010; Nord et al., 2011). Thus, it is vital to understand how experiences outside of the classroom can influence young women to enjoy and pursue science, as well as the affordances that these experiences give students that may be disempowered in their science classrooms based on traditional gender norms (Carlone, Johnson, & Scott, 2015). These less structured activities that can be tied to students' personal interests are one way to combat the ways that gendered messages about science are reproduced. Overall, inequities exist in science participation by gender and race. Students at the intersection of these social identities face a double challenge in overcoming the stereotypes of science as being for the majority, white men (Ong, Wright, Espinosa, & Orfield, 2011). Out-of-school experiences can begin a positive trend toward reducing these disparities in degree-seeking students from non-dominate backgrounds by providing new access to science content, discourse, and agency. The short-term benefits of out-of-school experiences are more extensively research than the impact on more long-term and significant impact like science identity, motivation, and agency. Our work is a first step to connect specific experiences with engineering disciplinary choices, but continued work in understanding and improving these alternative access points to science and engineering is a crucial step in broadening participation in STEM. We have shown that specific out-of-school experiences predict differences in students' interest in engineering disciplines. Understanding the variation of student interest and background even with the same high school preparation can affect interest in general engineering coursework may offer opportunities to expand traditional engineering contexts to areas that may be of interest to a broader community of all engineering students.

Limitations and Future Work

The findings from this work begin to highlight how important out-of-school experiences can be for fostering students' personal interests in specific engineering fields. A strength of the cross-sectional methodology used in this paper is the ability to draw conclusions from a national sample of college students. Also, we were able to test hypotheses related to factors and events that occurred naturally in students' experiences, rather than being restricted to student variables that could be manipulated in an intervention setting. A notable weakness of this methodology is that it can draw only correlational, not causal, conclusions. For example, students may have chosen mechanical engineering partially because of an interest in tinkering with objects, or students may tinker with objects because of an established interest in mechanical engineering or related career interests. The directionality of these experiences cannot be inferred from these correlational data. In many cases, the correlational results reported here are strong, but further work is necessary to investigate the causal relationships underlying the results reported here. While the causation of out-of-school experiences may not be inferred from these results, the findings are still valuable in understanding how students' experiences outside of the classroom can impact career choices.

It is important to foster science interactions that allow students to engage with science in personally meaningful ways. Identification with science has been shown to be a strong predictor of physics and engineering career choice (Godwin et al., 2016; Hazari et al., 2010). Seeing oneself as the kind of person who can participate in science through connections to one's personal interests is an important step in understanding how students make engineering career decisions. Science education should empower students to think and act, give students new ideas, and develop skills that contribute to future success, personal fulfillment, and social responsibility. Calabrese Barton (1998) captured this purpose in her comment, "Pedagogy involves the production of values and beliefs about how scientific knowledge is created and validated, as well as who we must be to engage in that process … The way teachers choose to represent science to students leaves room for particular kinds of engagements, particular kinds of activities, and particular kinds of identities" (p. 380). Studies on the impact of out-of-school experiences must move beyond measuring knowledge gains and engagement to understanding how students can reimagine who they see themselves to be and how their interests fit within the science and engineering disciplinary communities. This shift may help educators, families, and researchers find new access points for non-dominant groups to engage in science and contribute their rich human resources to the complex, global problems that engineering faces.

Conclusions

The findings from this work have implications for pedagogy in high school classrooms, outreach efforts, and introductory engineering courses. Understanding how informal learning experiences and interest in high school can affect students' disciplinary engineering choices may create opportunities to create more connections to students' prior knowledge, interests, and relatable everyday experiences. This work also shows that engineering is not homogenous in the types of students and backgrounds that it attracts.

In the future, it would be useful to understand *how* out-of-school experiences, prior to college, impact the student choices reported here. This future work would give a clearer explanation for how students become directed towards engineering, a critical piece of information in the improvement of the recruitment and retention of the next generation of engineers. Another future application of this work is to incorporate some of these findings into the curricula of engineering programs and make these findings practical for engineering educators.

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